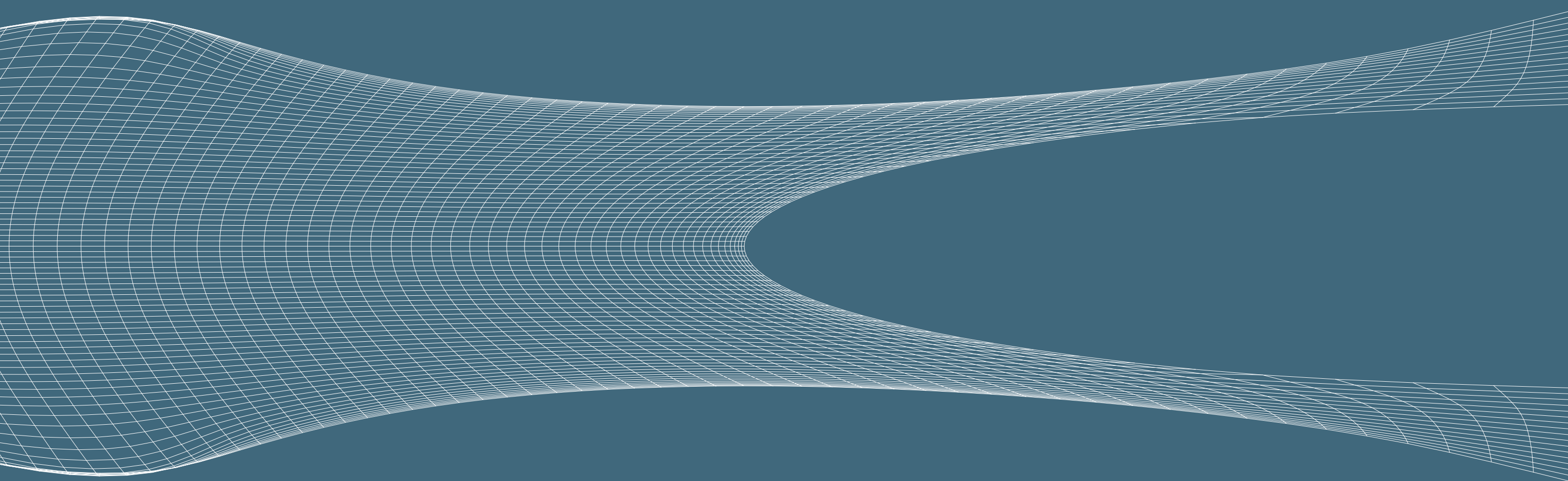
POLITECNICO DI TORINO
MSc In Architecture Construction City
LM-4 Architecture and Building Engineering

A BRIDGE SON OF TURIN

STRUCTURAL PARAMETRIC APPROACH FOR A NEW BRIDGE OVER THE PO



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STRUCTURAL PARAMETRIC APPROACH FOR A NEW BRIDGE OVER THE PO

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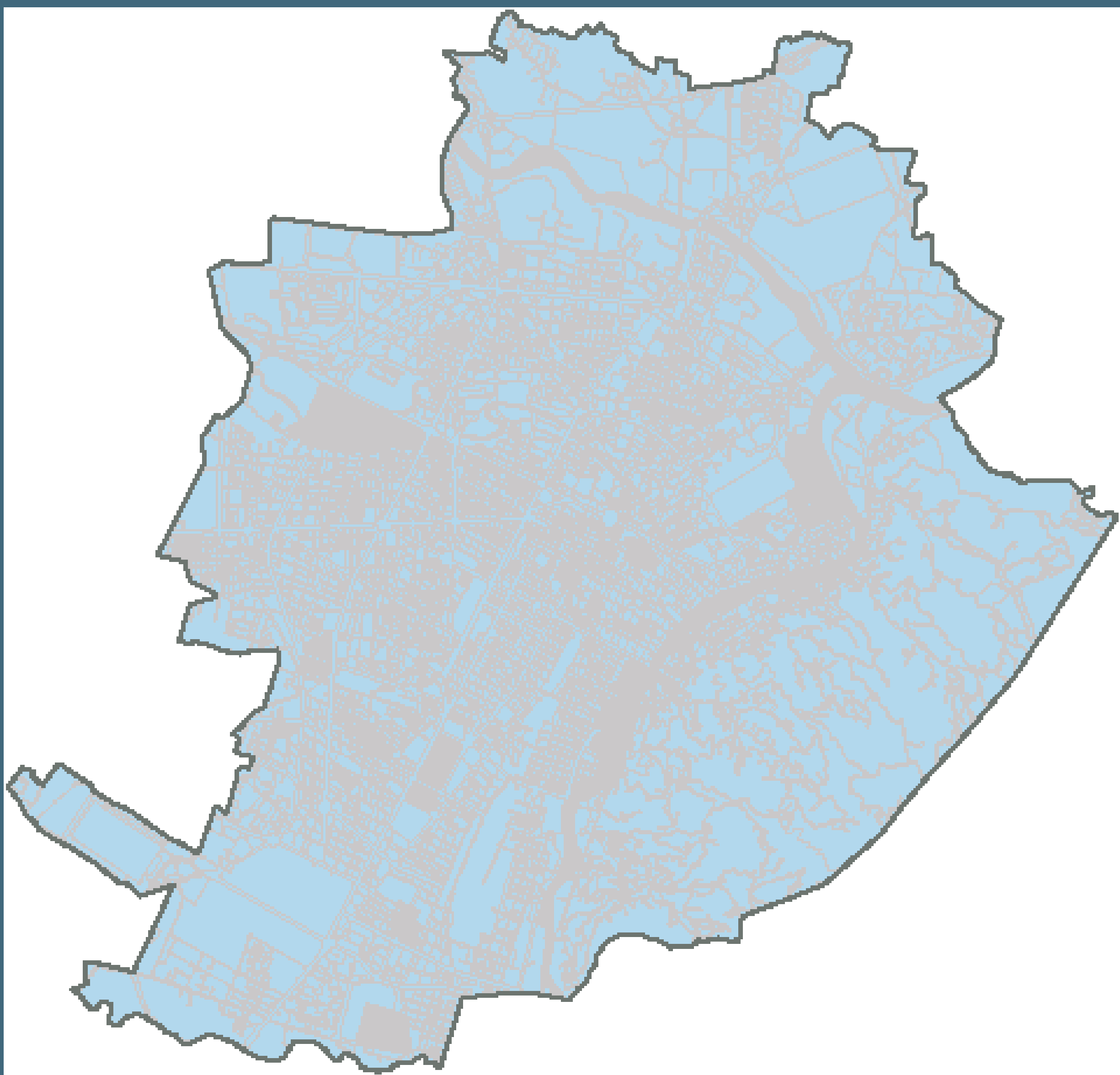
CONTENT

ABSTRACT
ENGLISH/ITALIANO

Non c'è passione nel vivere in piccolo, nel progettare una vita che è inferiore alla vita che potresti vivere.

Nelson Mandela *(Un ideale per cui sono pronto a morire, 2014)*

There isn't passion in living small, in designing a life that is less than the life you could live



ENGLISH VERSION

Consciously aware on my interest concerning the structures and the link between them and the architectural shape, the structural shape and the digital approach in architecture. I have decided to investigate in depth the language of the structures and to develop methodology and theory though the use of the Parametricism. To learn how to generate architectural objects using structural principles.

The thesis's subject will be the Parametricism: to study how it is possible to think and design an architectural object investigating the structural aspects, they give shape to the object and render it parametric, mathematical explicit and structural verifiable. The Parametricism is an application tool for the concept of the "form finding": design process that determines shapes though the study of the minimum structural mass, maintaining a direct connection between structure and architectural shape. This relation is possible thank to the parametric approach, this approach has to carry out form's demands though statics principles and not an aesthetics style. To define that concept, we start from semiotics and structuralism: the study of the language is important to understand the theoretical perception of the shape. The last step of the research is the Parametricism, current result of the structural design.

Parametric theory and methodology, explained in the research part, are applied on a project of urban regeneration. The design process of a new vehicle accessible bridge under the structural point of view with the parametric approach solving an unsolved urban situation in Turin. Parametric structures and parametric urbanism are two possible ways that researchers and professionals can adopt to develop a complex architectural project.

The project "The Bridge The Square The Park" takes place in the area of Turin circumscribed between Piazza Vittorio Veneto, Piazza Gran Madre di Dio and Parco Michelotti: the intervention has its central point in the project of a new bridge that connects Corso San Maurizio with the east bank of Po, this new bridge diverts the flux of traffic and allows to have Ponte Vittorio Emanuele I relieved of urban flows, where the direct consequence is the pedestrianization of Gran Madre Square. To lead the regeneration of the area the new bridge is useful also like a starting point in the renovation of Parco Michelotti inserted inside a new system of spaces. The values that drive the project are the defense of the historic value of the place, the reorganization of the chaotic mobility of the area and the resolution of the abandonment of Michelotti Park.

The conformation of the new bridge from Corso San Maurizio will be determined by a generative algorithm which, based on different structural parameters, will generate a parametric architectural form, this will then be statically verified. Static verification is necessary to verify the efficiency of the algorithm. The algorithm is based from the theoretical point of view on structural parameters and, then, in practical application it is adapted to the context in which the project is inserted, becoming the architecture of the place.

VERSIONE ITALIANA

Fortemente conscio del mio interesse per le strutture e il legame tra loro e la forma architettonica, la forma strutturale e l'approccio digitale in architettura. Ho deciso di approfondire nel dettaglio il linguaggio delle strutture e applicare metodologia e teoria mediante l'uso del Parametricismo. Per impare come generare oggetti architettonici usando princici strutturali.

Il soggetto della tesi sarà il Parametricismo: studiare come sia possibile pensare e progettare un elemento architettonico indagandone gli aspetti strutturali, i quali danno forma all'oggetto e lo rendono parametrico, matematicamente esplicito e strutturalmente verificabile. Il Parametricismo è strumento di applicazione del concetto di "form finding": processo progettuale che determina forme attraverso lo studio del minimo strutturale, mantenendo una rapporto diretto fra struttura e forma architettonica. Questo rapporto avviene grazie all'approccio parametrico, quest'approcio deve adempiere a esigenze di forma mediante la statica e non in quanto stile estetico. Per definire questi concetti si parte dalla semiotica e dallo strutturalismo: lo studio del linguaggio è importante per capire la determinazione teorica della forma. L'ultimo passo della ricerca è il Parametricismo, risultato odierno progettazione strutturale.

Teoria e metodologia parametriche, spiegate nella parte di ricerca, sono applicate a un progetto di rigenerazione urbana. Il processo di progettazione di un nuovo ponte carrabile dal punto di vista strutturale mediante l'approccio parametrico risolve una situazione urbana irrisolta a Torino. Le strutture parametriche e l'urbanistica parametrica sono due modi possibili che ricercatori e professionisti possono adottare per sviluppare un progetto architettonico complesso.

Il progetto "The Bridge The Square The Park" si svolge nell'area di Torino circoscritta tra Piazza Vittorio Veneto, Piazza Gran Madre di Dio e Parco Michelotti: l'intervento ha il suo punto centrale nel progetto di un nuovo ponte che collega Corso San Maurizio con la sponda orientale del Po, questo nuovo ponte devia il flusso del traffico e permette di avere il ponte Vittorio Emanuele I alleggerito dai flussi urbani, dove la conseguenza diretta è la pedonalizzazione di Piazza Gran Madre. Per guidare la rigenerazione dell'area il nuovo ponte è utile anche come punto di partenza per la riqualificazione di Parco Michelotti inserito all'interno di un nuovo sistema di spazi. I valori che guidano il progetto sono la difesa del valore storico del luogo, la riorganizzazione della mobilità caotica dell'area e la risoluzione dell'abbandono di Parco Michelotti.

La forma del nuovo ponte da Corso San Maurizio sarà determinata da un algoritmo generativo che, sulla base di diversi parametri strutturali, genererà una forma architettonica parametrica, questa sarà poi staticamente verificata. La verifica statica è necessaria per verificare l'efficienza dell'algoritmo. L'algoritmo si basa dal punto di vista teorico su parametri strutturali e, poi, nell'applicazione pratica si adatta al contesto in cui si inserisce il progetto, diventando l'architettura del luogo.

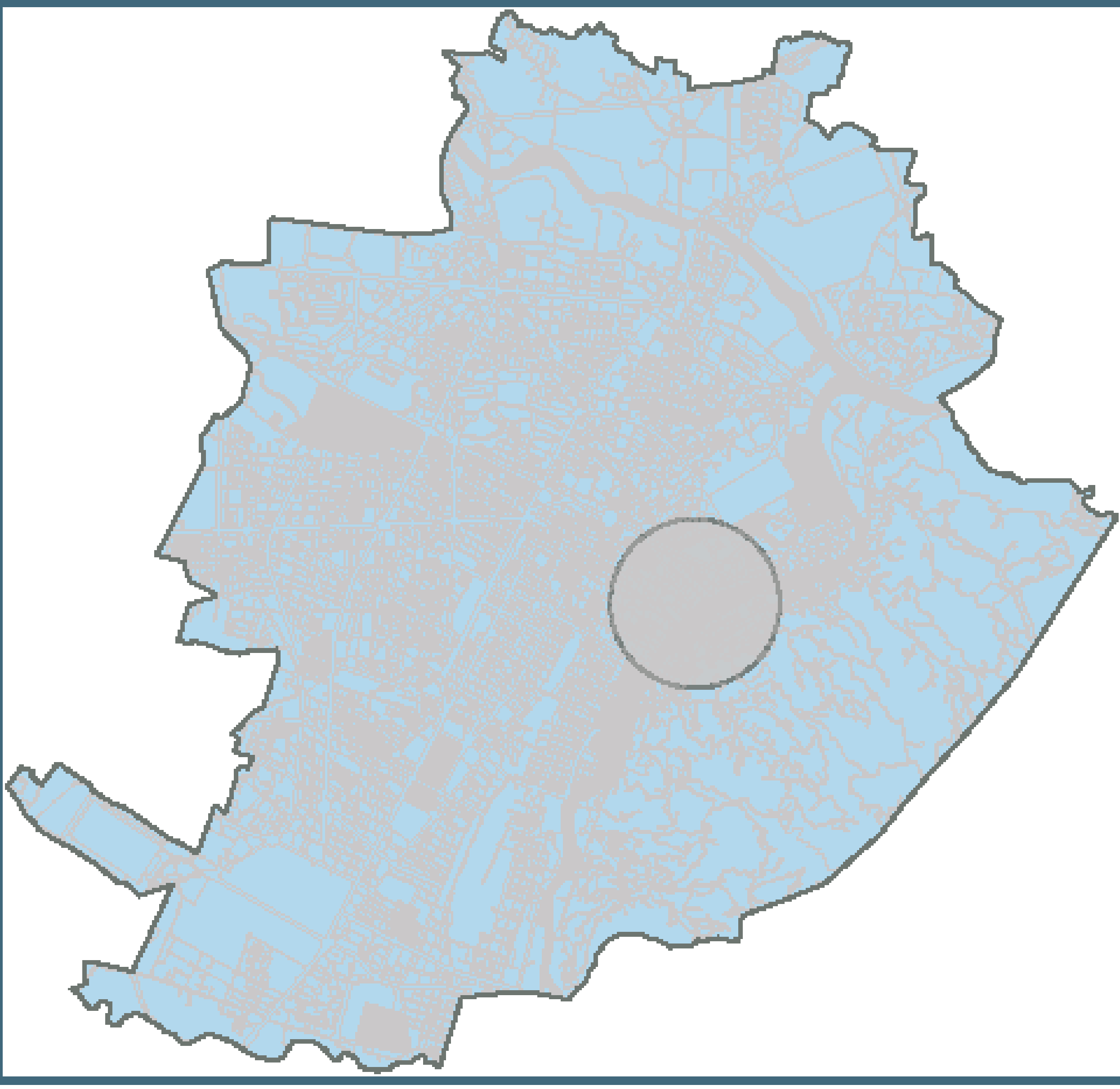
INTRODUCTION

GOALS FOR TURIN

La bellezza di Torino è difficile a scorgere; talmente difficile che fuori di Nietzsche e di me stesso non conosco nessuno che se ne sia preoccupato finora.

Giorgio De Chirico *(Il Meccanismo del Pensiero, 1985)*

The beauty of Turin is difficult to see; so difficult that except Nietzsche and myself, nobody is still afraid by it.



There is a magic place in Turin where everyone should go. The river and the hills have preserved the natural environment blocking the urban development of the built city. The big square allows to walk along its perimeter without getting wet every day of the year. The wood gives the opportunity to be in an open air space remaining in the historical city center. The church, in the axis with the square, posed like a focal point, leads the perception of the space and enables to enjoy everything around itself. The stone bridge connects all the spaces overpassing the river and giving opportunity of different views. The uniqueness of this place could be seen like an autonomous entity in a city and it could be place in every city but the awareness that it is in Turin is visible looking the sky behind the straight line of the roofs: the Mole Antonelliana is always present, its top is a reference point and nobody feels itself alone. The magic place described is the area circumscribed between Piazza Vittorio Veneto, Gran Madre di Dio and Parco Michelotti, here Turin boasts some of the most exceptional Italian architectures but has a huge problem: the traffic.

Coming back to the quote at the beginning of this introduction, Giorgio De Chirico gives a comment of Turin: city full of meanings with a complexity that comes from its history, its urban shapes and the culture of the people. In the work “Il Meccanismo del Pensiero” De Chirico describes Turin like the most deep, enigmatic and disquieting city of the world, his thinking is shared with Nietzsche that first understood the poetry of an orderly city built on a level ground and surrounded by hills, parks, castles and monumental buildings. Its extension is along the banks of its river, the Po. Turin is composed by straight streets, square plots and 18 kilometers of porches. The area of the thesis’ projects is a perfect summary of the idea of De Chirico: its historical position, its urban shapes, its long porches, the river and the hills. This place is in a focal point of the city. Starting from a fast overview of the city it is possible to understand generally the complexity under some points of view with the final goal linked with the urgency of solving the noise and the discomfort produced by the complexity of the mobility.

Some impressive data show that the city of Turin has 896˙773 inhabitants and the metropolitan area has 1,7 million in habitants; the city covers 130 km² and 6˙846 inhabitants/km². The population is quite equally distributed in terms of ages and the use of the services in city is distributed in the same way. Everyday there are 1˙890˙715 daily transport movements where 43,40% are made by private cars and only the 20,70% are made with the public transport trips.

Noticing that the Po is crossed three times, between the city center and the eastern part, Ponte Vittorio Emanuele I is the most congested bridge with six lines of the public transport system. The traffic is massive and out of capacity for a bridge that was built in the early nineteenth.

The Gran Madre is stuck between a congested street and a sad car parking.

Parco Michelotti is open just in one limited part, the rest is in abandonment conditions and Piazza Vittorio Veneto is not yet secure for pedestrians crossing the streets that in some moments of the day are full of cars.

Back to the data the main reasons to move inside the city are for working (30,80%) and for shopping (30,30%), the city center is the focal point of the city for economical move-

OVERVIEW GOALS

ments both connected to the tourism and the local life.

Looking at the summerized data in the following pages it is clear the necessity to intervene with a systematic project that has to modify the mobility:

- a new bridge gives the possibility to minimize the traffic that cross the Po though Ponte Vittorio Emanuele I, to reorganize the entire organization of urban flows in the area and be the engine of redevelopment

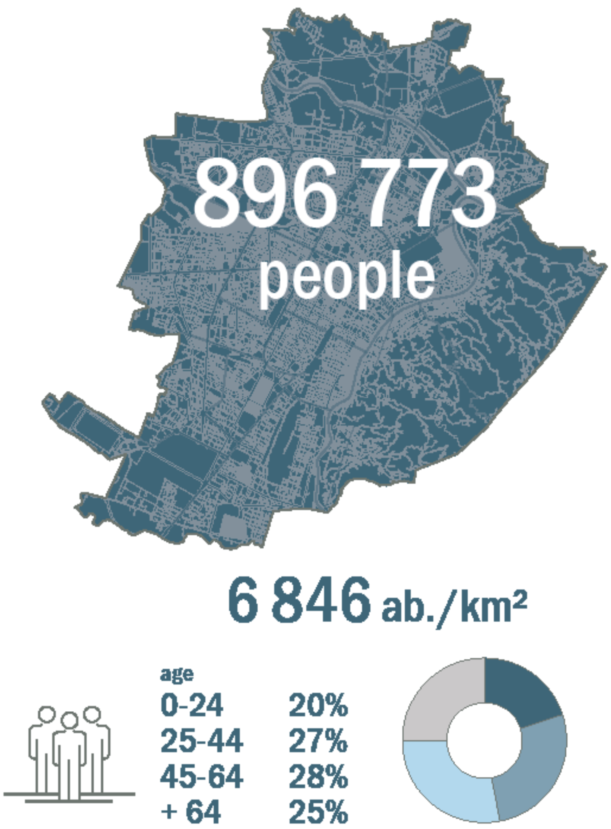
- the Gran Madre has to be insert in context more available by the people

- Piazza Vittorio Veneto needs to be more secure in its crossing parts and in proximity of the bridge

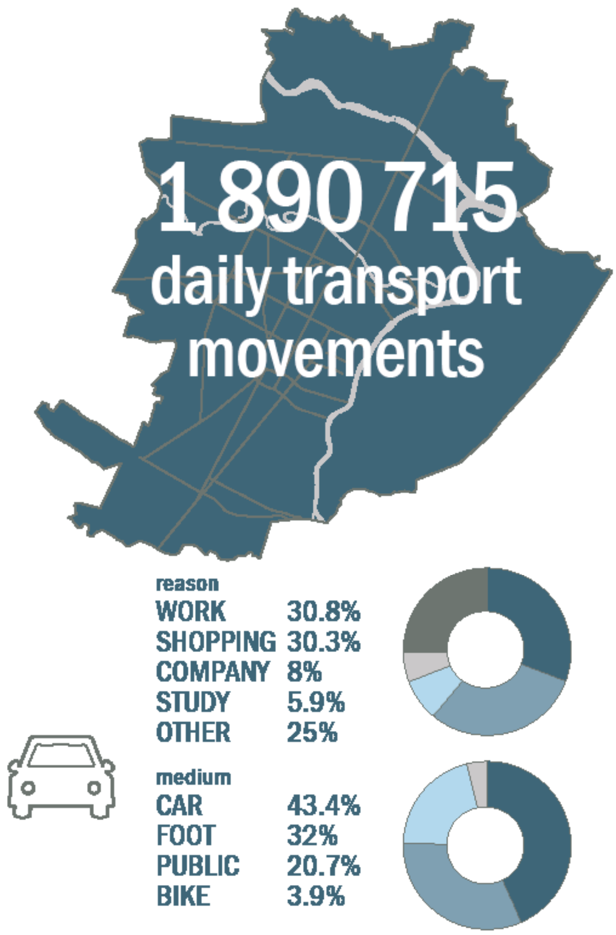
- the conditions of the Michelotti Park must improve, starting from the pre-existing structures the value of the park must also be renewed through conservation and architectural restoration, then, it must be a mainly public and open park where the population can have a meeting point, the park must be a green manifesto against land consumption through the use of the existing one and, finally, the park must be strengthened with the construction of new infrastructures that make it possible to expand the functions and services of the area.

This last point is connected firstly with the

POPULATION DATA



MOBILITY DATA



OVERVIEW GOALS

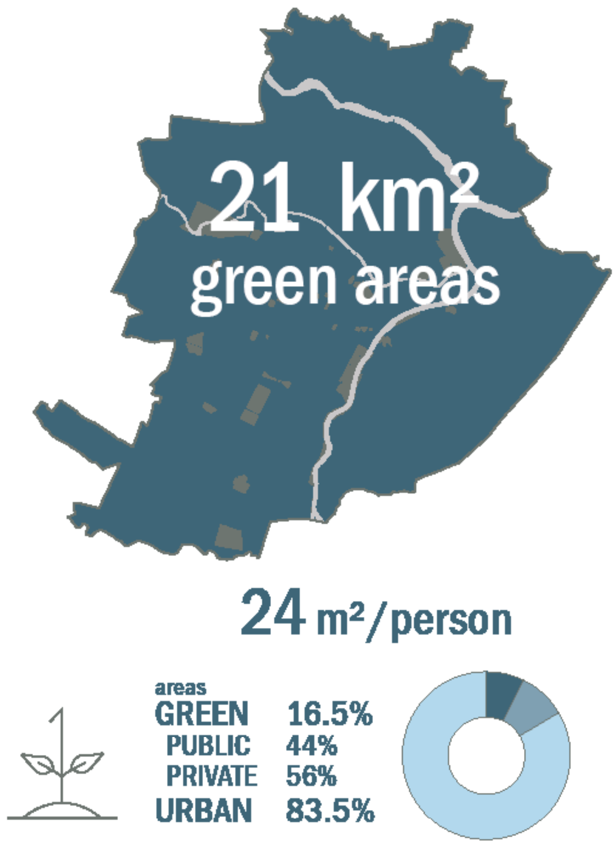
necessity to delete an abandoned place in this area, its current presence is harming for different economical aspects; on the second hand Turin needs in that area a portion of public greenery, this aspect of the city is going to decrease and right now is fixed to 21 square kilometers rappresenting the 16,50% of the total urban area covered by the city, where the public is around the 7%.

The project sets the goal to reach two main objectives:

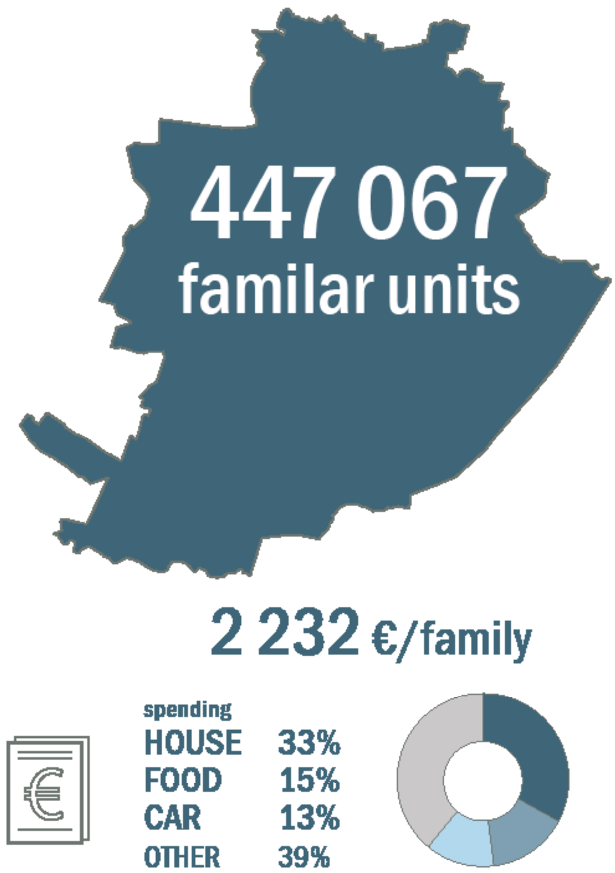
- investigate how it is possible to think and design an architectural object investigating the structural aspects using the Parametricism, and, at the same time, to use parametric concepts in the construction of the new bridge that from Corso San Maurizio will connect the east part of the river; the project requires the parameterization because the bridges are structured in all their mass and because the area, object of project, in continuous evolution and susceptible to different institutions and laws, must have a dynamic project ready to be modified at any moment of its life, even the construction site if necessary

- design a potential solution to regenerate an unsolved mobility in a specific part of the city thought the project of a new bridge on the Po, the bridge itself, and its need to be built, is a precondition that would lead to improvements in the use of the area by people who today only use it as a passage area, which is not even guaranteed in a capillary way, the new bridge must guide

GREENERY DATA



ECONOMIC DATA



OVERVIEW

the construction of a new place which, as the fulcrum will have Parco Michelotti, and will no longer be just a mandatory passage.

This thesis represents an attempt to solve an untenable mobility with a new project: looking the last set of data the wealthess of the families is spent for the 15% for personal cars, evident sign of the popular culture of the city. The historical fame of Turin industrial city and a common walk through the streets of the city are witnesses of the high use of personal cars like cultural aspect.

GOALS

Three goals in terms of project design and the two goals in terms of research way are the bases to understand the macro systems of this master thesis where the structural level of the Architecture considers different aspects like artistic value and static opportunities in the same time. The final outcome can be read as a possible solution for future of Turin considering the project also as a possible new approach in structural Architecture design.

CHAPTER ONE

CURRENT PATHS

Torino è una città che invita al rigore, alla linearità, allo stile. Invita alla logica, e attraverso la logica apre alla follia.

Italo Calvino *(Eremita a Parigi, 1974)*

Turin is a city that inspires rigor, linearity and style. It inspires logic, and towards the logic Turin shows insanity.

Starting from the quote at the beginning of this chapter, Italo Calvino gives a fast definition of Turin and the mind goes directly to his work “Le Città Invisibili” where the description of the cities is a complex mix of emotions that sometimes are easy to understand and other times not. It depends by the experiences that the reader has about the cities that had have the occasion to go and visit them walking.

There is an interesting research book written by Francesco Careri, the title is “Walkscapes: Walking as an Aesthetic Practice”. Here the author proposes walking as a new approach to understanding the architecture, an invitation to walk as a tool to read the city, a common practice that can be an opportunity.

The concept presents walking as a way not only of seeing but also a way to create landscapes. The walker is the protagonist and his movements are inside the landscape, all visible features of the space, living the architecture, art of design and construction, guided by the sculptures, shapes and point of view in a complex radius of movement. Sculpture, architecture and landscape are artform and physical presence: firstly, result of a process, conscious or unconscious, and then reference and evidence. The author pushes the reader to be aware of the personal presence in the city because the continuous use of it produces more livable spaces.

The point of view of Careri is a pratical approach of what a bridge has to be. A bridge can be approximated with a line, a path of passage, the walkng produces architecture and for this reason to design a new bridge means to design a new opportunity to walk. Then, created a new walk, it is possible to improve the conditions with new paths, sons

To have a personal experience in the places gives the opportunity to discover what is important and how it is possible to read the physical presences. Walking has to be a positive practice of aesthetics not for beauty but as a continuous discovery of the new, that was there also before but was difficult to see and it is inside a continuous process of modelling that is always changing.

The beauty and the opportunities, that Parco MIchelotti represents, are not exploited nowadays, its abandonment is an unsolved situation that at the current conditions is not possible to exploit. The awareness and, at the same time, the hope of Careri live in places like this park: the park itself is a reason to design new routes that produce more living spaces. The direct consequence is the improvement of the macrourban conditions

In the following paragraphs are described four paths, they are results of four personal experiences in the places presented. The area of the project, already seen in the introduction, extends widely in various environments that are in different level and present different points of view. The experiences are important before the knowledge of the final project for the reader of this work to understand the potential of the project itself and for the designer to try to image solutions with his personal physical experience. Coming back to the Careri’s book walking itself has to see like a way to design: people are part of the project also before the process of design.

Then, considering the design process of this thesis a not conventional process, as we will see, it may have like a first step the physical experience. An experience done without the observation of fixed notionsof the plot but living the spaces and walking. Walking itselfis

OVERVIEW PATHS

the final goal of the entire master thesis, the creation of the bridgeand the new blood system of the park are in realty the creation of paths, of movements.

The four paths are two in eastern bank of the river and two in the other. The Po, in the middle, gives the opportunity to perceive the focal position and the feelings that the life in the city is strongly connected with its river.

Then the presence of the river shows the necessity to have a new bridge, and the diversities between the experience in one bank compared with the other. The four paths are a part of a set of possible paths that can visually describe the places but the main to understand the purposes that the project wants to satisfy:

- to improve the usability of no-motor transport vehicles in the river's banks with a direct view in the Po itself, the change in the trend in favor to a greener mobility is a possible solution to improve the data explained in the introduction

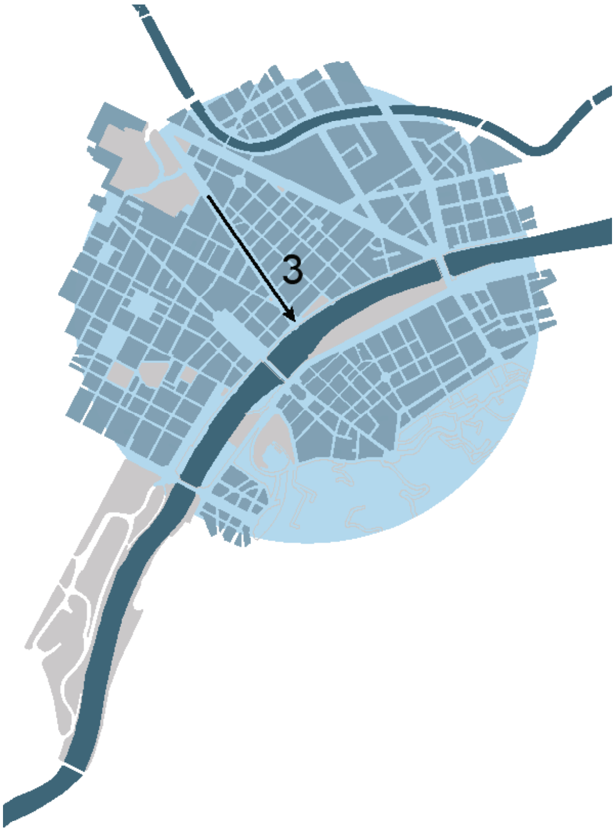
- to save the important environmental, historical and architectural value of the area, it must be remembered that the places of the project are in the city center of Turinand placed in the first habitative cores of the city, where everything started

- to open a new accessibility to the western part of the city for everyone that arrive from the northern and eastern parts of the river,from east it is mandatory to use Corso Casale, it is an important axes of the city, nowadays the connection between it and the western part it is possible only through the existing bridge

- to improve the urban mobility in the axis north-south of the eastern part of the city and specifically to preserve conditions of accessibility and usability of the districts of the area for inhabitants and companies' owners of the hills' territories.

OVERVIEW PATHS

from REGIO PARCO to PIAZZA VITTORIO



from CORSO S. MAURIZIO to the RIVER PO

from the HILLS to PONTE VITTORIO EMANUELE

from PONTE REGINA to PARCO MICHELOTTI

FIRST PATH NATURAL BACKGROUND

Walking from Piazza Castello to react Piazza Vittorio Veneto we pass through a huge portico that has its main function of shopping gallery and coffee opportunities. The walk here is always calm and constant, rhythmed by the sequence of the shop windows or by the fluxes of the people that are going on our direction.

The structure of the porches is a regular disposition of columns that are part of the ground floor of the building that compose the urban barrier. If it is rainy, we can arrive completely dry in Piazza Vittorio Veneto, but only if we are in the left side of the street Via Po, in this side, all the ground floor porches of the buildings are connected each other with an elegant extra structure, shaped like a Palladian serliana, that allows to cross the streets. That artifice permits to start from Palazzo Reale and arrive to the Po banks without to be exposed to climate conditions along all the path.

When we arrive in Piazza Vittorio Veneto the view is impressive: in front of us we have the largest Baroque square in Europe with the Gran Madre at the end. The structure of the porch, started in Piazza Castello, continues after Via Po in a circle shape to enlarge the space and create the square, Piazza Vittorio Veneto, and then regulate again the line path and arrive at the river with two orthogonal axes. The conformation of the arrival square is not a common arrangement in the world, another example could be Praca do Comercio in Lisbon. Two opposite sides are confined by the facades of the buildings with low permeability, then, one side is cut in two by a main road, by doing so a single front is not perceived and there is a high permeability, then, as in Turin the axis in quastione has as its arrival the square and is placed perfectly in the center of its side of the square. The last side does not exist, or rather in Turin it is the river, the Po, in Lisbon it is called the Tago. Back to Turin if we remain fixed at the beginning of the square we are encouraged by the porches shape that enforces our view to have a look over the river at the Gran Madre: the hills block the view to see behind the church and the church itself, posed in a central position is a regular infrastructure formally in contrast with the natural lines of the hills.

The church, Gran Madre di Dio, is the protagonist on a theatre performance where the stone balusters of the Po limited the stage, Piazza Vittorio Veneto is the audience space and the natural border of the hills is an amazing natural background.

Harmony is ruined by only one element: noise. Cars and means public transportation occupy the square constantly, and it is a constant honking and braking, bus windows vibrating and engines roaring.

FIRST PATH NATURAL BACKGROUND

Piazza Vittorio Veneto

SECOND PATH HISTORICAL BOOK

Walking from the square behind the Gran Madre to react Piazza Vittorio Veneto we have the opportunity to admire the less famous part of the church: looking from here it is clear the formal change in shape from the circle that supports the dome to the rectangle that supports the porch.

The complexity of the structure made by the unit of two different structures is an evident reference of the more famous Pantheon in Rome. From this point of view, we have opportunity to watch the church without the visual obstacle of the tram's cables. We can perceive the regularity of the shapes, the hierarchy of the ornaments, the precise radial disposition of the windows or the entire elegant composition of the parts from the basement to the dome. Moving in Veneto region, precisely in Possagno, we can admire the Tempio Canoviano. It is another architectural example that takes inspiration from the Roman Pantheon and, despite the shape, it shares with the Gran Madre the monumental position of the main facade: the Tempio is placed at the top of an hill and the colonade is in the axes with a staright street that finishes with the architecture itself, this street is is perfectly in axes and highlights the mass of the building. Only one missed opportunity which Turin has not deprived of: the chance to see the backstage, the back of the church.

Anyway we arrive in front of the Gran Madre the view of the river and Piazza Vittorio Veneto is particular: the imponent structure of the staircase, built precise in the axes of Via Po, allows to have a favored view from an upper position to the entire length of Ponte Vittorio Emanuele I, Piazza Vittorio Veneto and Via Po until the castle of Palazzo Madama. Turin is one of few cities that has these view opportunities.

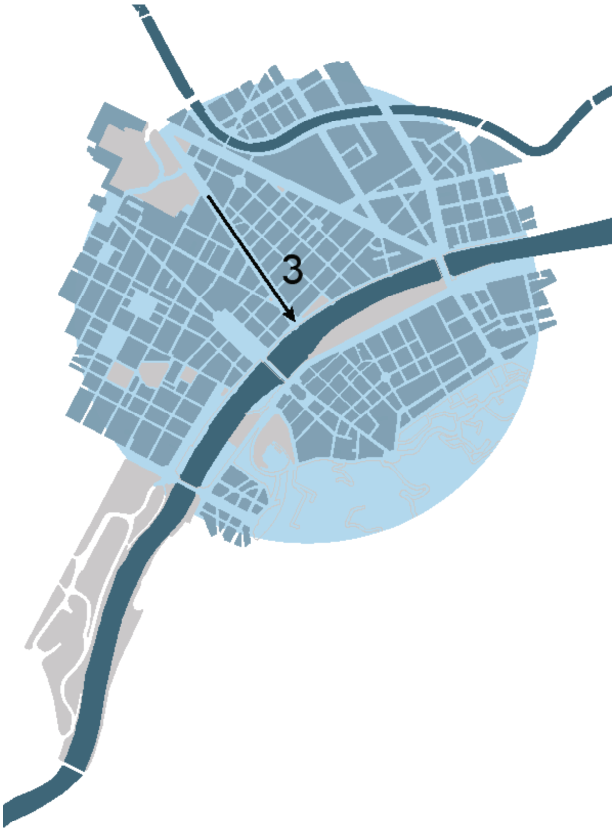
In other part of the city they are more powerful but quite every time supported by the grid of the urban structure that permits to have long street that cross a lot of spaces and interesting view opportunities.

The view that we can feel from the porch of the Gran Madre is an interesting historical document: the orientation of the Via Po axes in correspondence to the Piazza Castello, ancient entrance in the first foundation city, using the direction of Roman bridge that crosses the Po and the huge military square. All of these spaces could be seen like pages of an Italian historical book: the layout of the Roman Empire, a Medieval castle, a Baroque square, a church devoted to Mary but homage for the Italian king. The art, the religion, the power.

SECOND PATH HISTORICAL BOOK

Gran Madre di Dio

THIRD PATH WATER BARRIER



Walking from Regio Parco, ancient gardens of the royal palace, to react the river we can stroll in a huge tree-line corso: Corso San Maurizio. It is an important urban road characterized by a certain importance in the urban structure, it is composed by four lines for cars per direction, and two lines of threes that follow all the length of the road. Basically, the complexity of a corso is in three levels: its role in the urban structure like connection between important and congested points of the city, its role of structure in relation with its substructures identified like smaller streets that intersect the corso itself, and the last level under the compositional point of view the buildings that have a side oriented to the corso are usually the more beautiful and all them, one after to the other, respect a precise line direction parallel to the viability of the corso itself.

Walking along Corso San Maurizio we have the opportunity to see important architectures (like Palazzo Nuovo of Levi Montalcini or Fetta di Polenta of Alessandro Antonelli) in both the sides, escorted all the time of the walk by the Mole Antoneliana. It is visible over the roofs by different perspective maintaining the same visible result, a kind of protection.

When we arrive to the end of Corso San Maurizio we can find the limits of this corso: like substructure, in the macro-urban structure, the corso interrupts the continuity of the urban texture of the city and the interruption is made by the river Po that become a water barrier for the continuity of eight road directions; like main structure the corso intersects, at its end, the road Lungo Po Luigi Cadorna that is a normal two directions street and it is clearly not the “natural” continuity looking the mobility scale of Corso San Maurizio, compared to it.

We continue to walk, passed Lungo Po Luigi Cadorna, we are in an enlargement of the sidewalk that becomes a terrace to the Po: this terrace has an elegant stone balustrade and double staircase that connects the level zero of the streets with the downer level of the Murazzi sul Po: the structure of double staircase is composed by two massive stone stairs that have two ramps of steps each, all along the path that goes down, continuously the baluster starts in the upper terrace, goes down until the landing that is itself a terrace, and goes down again until the level of the river. We have a view point to the river, the hills, the bridges and Parco Michelotti. The water barrier is only physical all the other feelings, led by the view, are expressible.

THIRD PATH WATER BARRIER

Murazzi sul Po

FOURTH PATH SILENT DYNAMISM

Walking from the bridge Regina Margerita, that is the end of the same name corso, we can react the bridge Vittorio Emanuele I, in front of the Gran Madre, through a wide and in some parts narrow path. This path is included between the Po and the enormous trees of the Parco Michelotti.

The path is untarmacked road that follow the shape of the river and the heights of the park. For sure it is the result of an anthropic process but the perception is totally natural and untouchable by motorized vehicles: the main activity here is the jogging with obstacles like discontinuity
of the ground, little rocks mount in the land or spontaneous vegetation. The atmosphere is calm, the noise of the cars is farand the sound of the water rithms the steps of the runners

The high level of nature attacked also the nets that are borders between the park and the path, nowadays covered by every type of vegetation. Walking thought this path we are in a privilege place where we can clearly watch the river along its entire extension, also under the bridges, a good portion of Murazzi sul Po, the people that are living the city in ground level behind all the balusters and upper than our position.

Looking the river from this not famous place we can feel the power of the water: it passes thought the ground surface, continues in a straight direction, is increased by the rain, the underground aquifers and the glaciers' melting. The dynamism of the water is moving according to the dynamism of the city up to here: the continuous flux of the river cleans the banks, by natural wastes, like leaves or pieces of wood, and then permits to the animal that live inside to have the necessary oxygen. The silent dynamism of the river can realize an enormous power that destroy what it meets: its linear structure needs infrastructures, like the already built dam, to contain its enormous will to go over.

The slopes of the park have to be consolidated, there is the necessity to feel safe. A future project of the renovation of the park must to take care of the users: the dynamism of the water is charming but dangerous, to have fear of everything that is silent.

FOURTH PATH SILENT DYNAMISM

Parco Michelotti

River Po

CHAPTER TWO

WORD STRUCTURE

In English language you call everything structure. In Europe we don't. We all a shack a shack and not a structure. By structure we have a philosophical idea. The structure is the whole, from top to bottom, to the last detail with the same idea. That is what we call structure.

Mies van der Rohe (*Mies Van der Rohe at Work*, 1961)

structure (noun) is an organ in the body, or part of an organ, that does a particular job

Cambridge Dictionary

Reading the previous chapter, the term structure and infrastructure are highlighted: their use under the linguistic point of view is important to understand the logic that connect the language and the construction world. When we say "language", it is intended as "collection of signs", following the thinking of in Umberto Eco, and the construction world is the field of knowledge of the architects. The two areas of expertise, rules and close relationships have many things in common. Alan Berman in an article in the magazine "Architects Journal" identifies four main reason to justify the importance of the works written by architects:

- the successful communication is an important aspect of the figurative arts and architects through it, they use an efficient method accessible to everyone

- writing is a process that allows to explore and investigate new ways and ideas both under the theoretical and the practical point of view

- writing gives the opportunity to writers and readers to be critical and compare past architectures and precedents

- then, a more common reason is the development of mental skills that involves the creativity.

"Good writing fosters clear thinking, and better writing engenders better thinking", this sentence is the closing point of the article and it is important to know firstly that there is a strong link between writing and thinking where they have to be used always together. Important is the clarity, it has to be considered unit of quality. the parts. Writing, or thinking, needs order and clarity: language, used in a proper way, has a structure. Joining the concepts of writing and speaking inside the term language, it is possible step by step to define an architectural language, that takes its bases from the concept of structure.

The world structure can change meaning depending to the field of knowledge maintaining its basial sense: a mathematical structure is a set composed by additional mathematical objects that are useful for the comprehension of the initial set that can be used like calculator instrument; from here it is possible to define an algebraic structure where the mathematical set is composed by operations that could be nulls, unitarians or binaries; a structure in computer science is a method to organize a set of data inside a computing memory; in chemistry a structure is chemical formula that defines the nature of the atoms that are the components of the molecule.

Following this way, it is possible to define the meaning of structure in quite all the fields of the knowledge and there are four points that accumulate all the definitions:

- the basic meaning is equal in every field but it becomes unique with its subject of application;

- in many cases, as it is written before regarding the mathematics algebra computer science, one principle of structure related to a specific subject could develop other linked application to different field preserving the basic both to the subject and to the main concept of structure;

- in every field the structure gives a vision

OVERVIEW WORD STRUCTURE

of the knowledge system in scientific way where organizations and interconnection between the parts, substructures, are clearly visible;

- then, the common basic concept of structure gives also the opportunity to interconnect different disciplines that apparently don't have notions in common.

Now, defining the importance of using words to define a clear discourse around architecture and defined the importance also in the language to have a clear structure it is necessary to deepen on English language structure. It is important to analyze two levels:

- firstly, the relation between English and Italian, my mother tongue, and in which way we can connect the two linguistic structures

- in the second hand the meaning of structure and infrastructure, the main topics of this work, inside the English language structure, deeply analyzed by Adrian Forty in his work "Words and Buildings".

"Good writing fosters clear thinking, and better writing engenders better thinking"

Alan Berman

FIRST LEVEL IDEA OF "BRIDGE"

Like Adrian Forty clearly explains "*between European languages, there has always been a brisk trade in critical vocabulary*": for example, a word that took on life as architectural term in English in the translation to other language, though an historical and cultural process, has the basic meaning maintained but could have a wider meaning or maybe a limited meaning compared to the original, basically it is changed and could refer to different things than the original meaning. For example, the word "structure" overlooking its development in French, the English term would be incomplete and inadequate.

So, it is important to be aware about the original language of an architectural writing and the epoch when it was written to understand the original and the development of the meaning. In some case the trade between language it is difficult and it is necessary to explain in deep the term in other cases it is impossible to translate for the risk of losing something so the solution is to report the term in the original language. But what it was just written refers to a single word and not to a more complicate concept because a word is only a part of a linguist structure where, again, all the elements must be interconnected. A possible solution to avoid the wrong use of the words and the consequent precarious functioning of the whole structure is the "idea of bridge" developed by the mathematic Olivia Caramello.

Her theory tries to connect different ideas link to different mathematical theories, the "bridge" is a metaphor that wants to be the metaphoric connection between an element of one set to a similar element of another set. For example, the word "struttura" in the set Italian and the word "structure" in the set English.

To apply this theory, it is mandatory to define the concept of topos: from the ancient Greek philosophy it a basic meaning, an object that embodies all points of view in a theme, a place where different perspectives and languages meet by crossing each other, the same topos admits an infinity of different representations corresponding to the interpretations that are given to him the different languages.

Relationships between two elements, using unifying "bridge", through graphic analysis, compare different objects using invariants. Invariants are things that the objects have in common with each other. For example, Caramello uses men and rodents: they have in common a macro information, "they are mummifiers", but it is a general concept and particular cases and therefore don't allow a generalization. A unification based on a generalization is static and opens to a homogenization, a deep unification that allows effective, doesn't cancel out diversity but doesn't highlight it too.

The "bridge" is a third object, meeting point between two objects initially seen separately. A bridge object can transfer knowledge from one object to another, each bridge property is expressed differently if in contact with one or the other starting object.

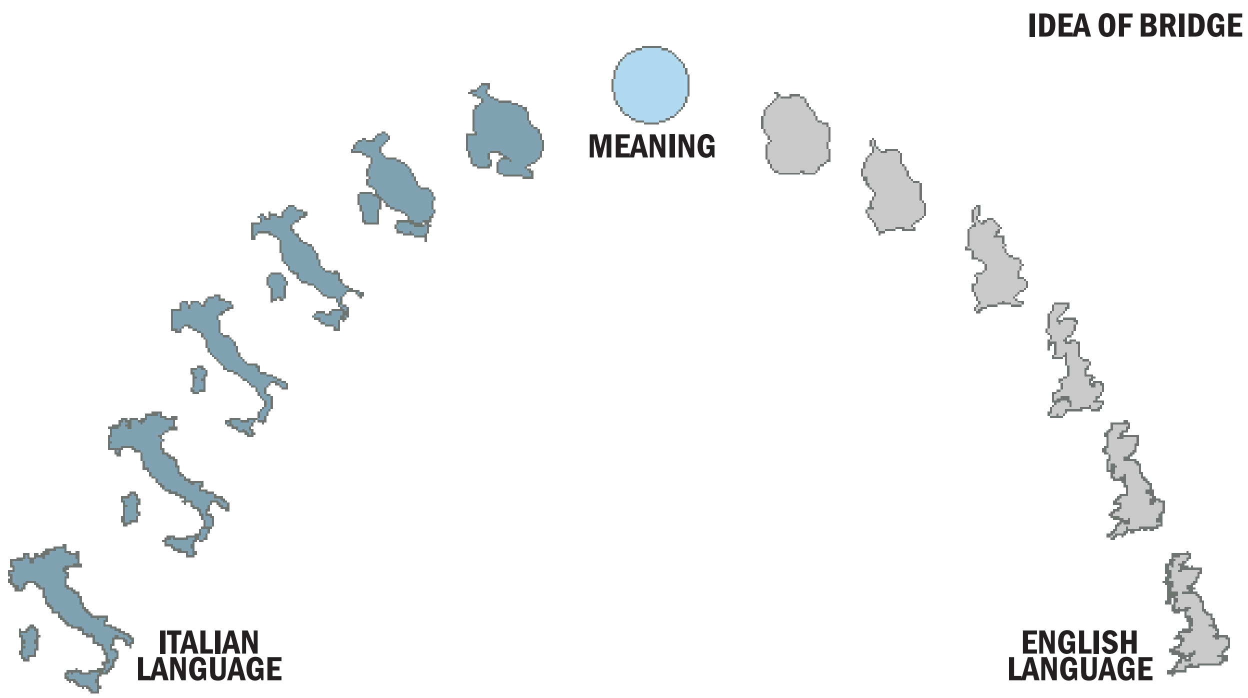
Between rodents and men an appropriate bridge object is the part of DNA that they share in fact despite being the DNA an invariant the context of men and rodents is different. The form of unification is evidenced by scientific studies done on rodents to find human subjects. The idea of bridge allows

FIRST LEVEL IDEA OF “BRIDGE”

for unification by enhancing diversity: morphogenesis that explains the origin of different expressions of the same invariable.

Looking the image, it is schematized the idea of bridge taking into account the languages: it is a scheme to explain the mathematical theory of Caramello for a translation: to make a literal translation, strict use of vocabulary, it means homogenization, not always possible for syntactic limits. To realize a good translation must be identified invariant, among them where in the major part of the cases is the meaning, but for example in the poetry maybe the meaning is not the most important among the invariants but is anyway one of them. Use the invariants should be translated according to them by understanding how they are expressed in the two different languages under consideration.

In mathematics it translates from one theory to another, the invariants are indefinite as only that allow rotations around them, two objects have many relationships and it is often necessary a point of view of a bridge object this because observable invariants without changing views are few and irrelevant so bridge object has very different nature from the initial objects, nature can be abstracted ineffable or distant. Then two levels: entities and bridge objects, invariants and concrete manifestations.



SECOND LEVEL STRUCTURE INFRASTRUCTURE

In the book “Mies Van der Rohe at Work”, written by Peter Carter there is a quote of the architect: “In English language you call everything structure. In Europe we don’t. We call a shack a shack and not a structure. By structure we have a philosophical idea. The structure is the whole, from top to bottom, to the last detail - with the same idea. That is what we call structure”. According to Adrian Forty the word “structure” in relation with architecture has three meanings:

- “structure” is “building” in its entirely, based on English language;

- in Viollet-le-Duc is the system that supports the building;

- the third meaning is the scheme useful to understand a project of a building, a group of buildings, a city or a part of territory.

Starting from these three meanings, abandoned the first one strongly connected to the English tradition, in this work the word “structure” has a meaning that takes in account the second meaning like a particular case of the third one: a building is orderly composition that follows a hierarchical logic of structure, that is physical supports of the building itself or an invisible scheme manifested through some other elements.

The role of the structure is to lead “a pure system of thrusts and restraints, invisible life”, it could be visible or not but essentially has the same role of the skeleton in an animal body. It is an assemblage of independent parts determining function and form of a building.

So it is basically valid the definition of Viollet-le-Duc, from the French tradition of the term, that described his idea of structure looking building like the Pantheon of Paris where the “invisible life” is inside huge masses of masonry and stones, at the same time a biological metaphor could be seen like the human skeleton where the bones are clearly distinguished and the membrane of invertebrate animals that is another type of structure with the same function of supporting the body.

So, the structure could be defined like a body that, throughout the period of its useful life it has to ensure the predetermined performance levels, it is destined to be subject to a system of forces, in balance with each other, but applied at different points, while defining a structural element is a portion of that body whose real behavior, generally very complex, is nevertheless expressed by direct formulas, characteristics of a simple model, commonly called a finite element.

The structure could be more or less complex depending to the structural system and the number of elements; in the case of shell or membrane structure the complexity is done by the dimensions.

A structural system, in building construction, is the particular method of assembling and constructing structural elements of an architecture, the functions of the elements are to support their weght and the various weights applied to them and transfer all the weights to the ground without generate collapses caused by stresses the tehe entire structure must to resist. In engineering, the meaning of “infrastructure” could be defined like an element or a set of components that structure a territory according to human needs.

SECOND LEVEL STRUCTURE INFRASTRUCTURE

Depending on its dislocation on the territory it is possible to find network infrastructure and punctual infrastructures.

A network of infrastructures is a set of inter-connected installations and services from specific key points to collect different parts. A network of infrastructure needs to reach large areas of territory or at least a large number of citizens to be efficient. In the case of bridge, it is a connection between two parts and its function is to collect one part to the other in order to insert the two parts that were in two different systems. For example, joining two part of a city divided by railways or natural obstacle, in an only one system or in the same previous system but more efficiency.

to structure (verb) is to plan, organize, or arrange the parts of something

Cambridge Dictionary

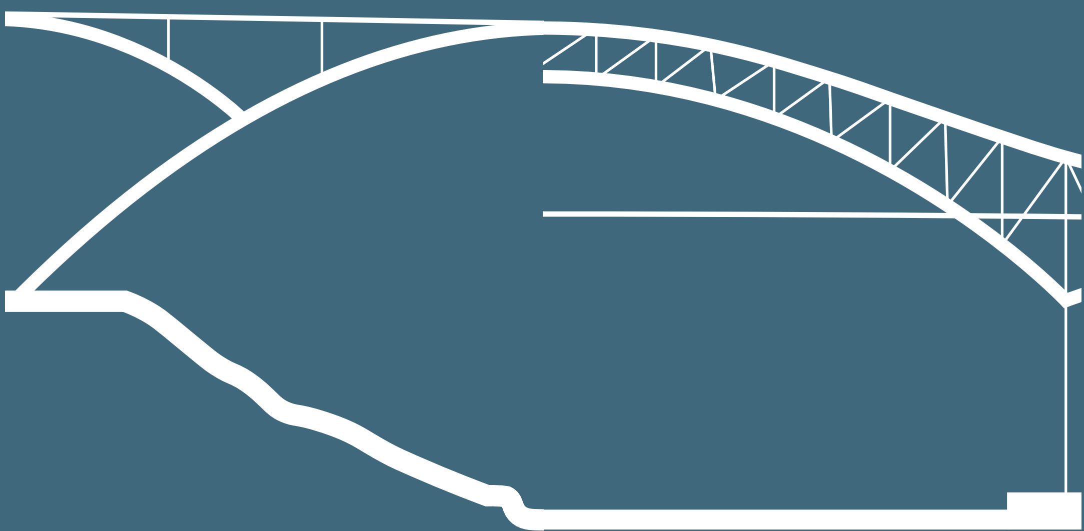
CHAPTER THREE

AREA ANALYSIS

Pontefice: dal lat. pontifĭce(m), comp. di pōns pŏntis ‘ponte’ e un deriv. di facĕre ‘fare’; in orig. ‘colui che cura la costruzione del ponte (sul Tevere)’

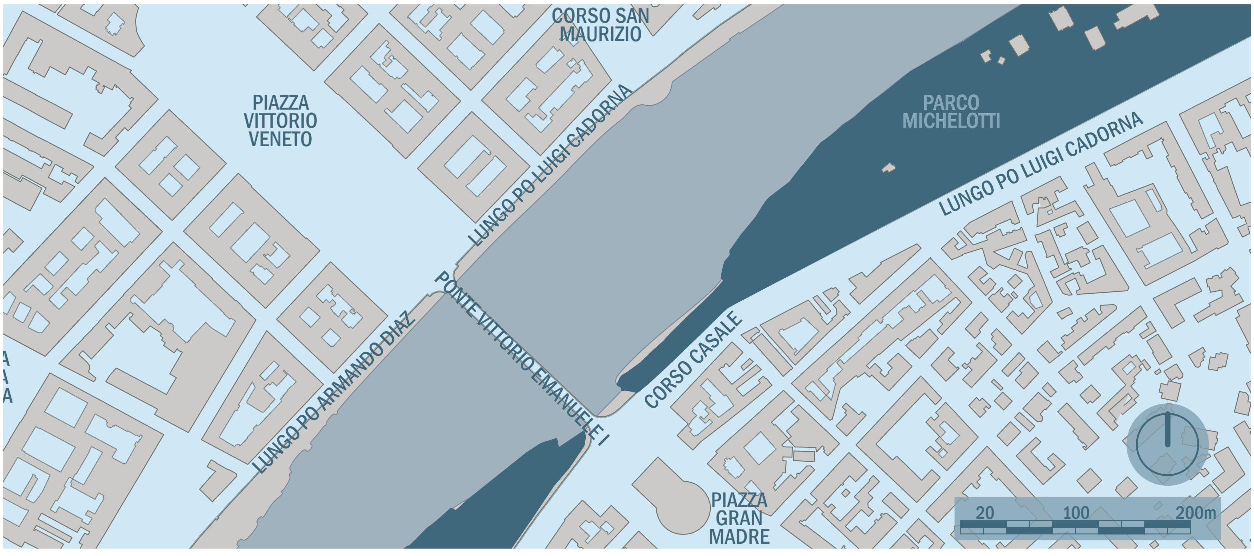
Garzanti Dictionary (2020)

Pontifex means “he who takes care of the construction of the bridge (over the Tiber)”



SITE OF THE PROJECT

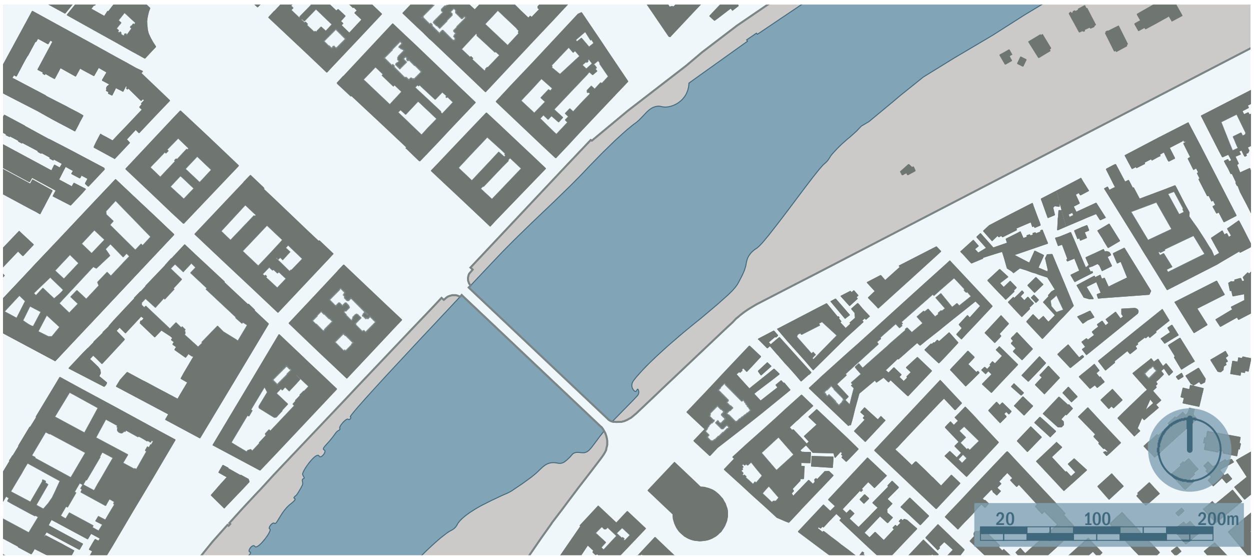
The site of the bridge project is in the central area of Turin between Piazza Vittorio Veneto, Parco Michelotti, Piazza Gran Madre: in the area the Po cuts the city in two parts, the eastern with the park and the hills characterized by a low dense urbanization, the western with designed river's sides, Murazzi, and an high density in the urban areas. The bridge is an opportunity of improvement in the connections between the parts of the area.



CONNECTIONS

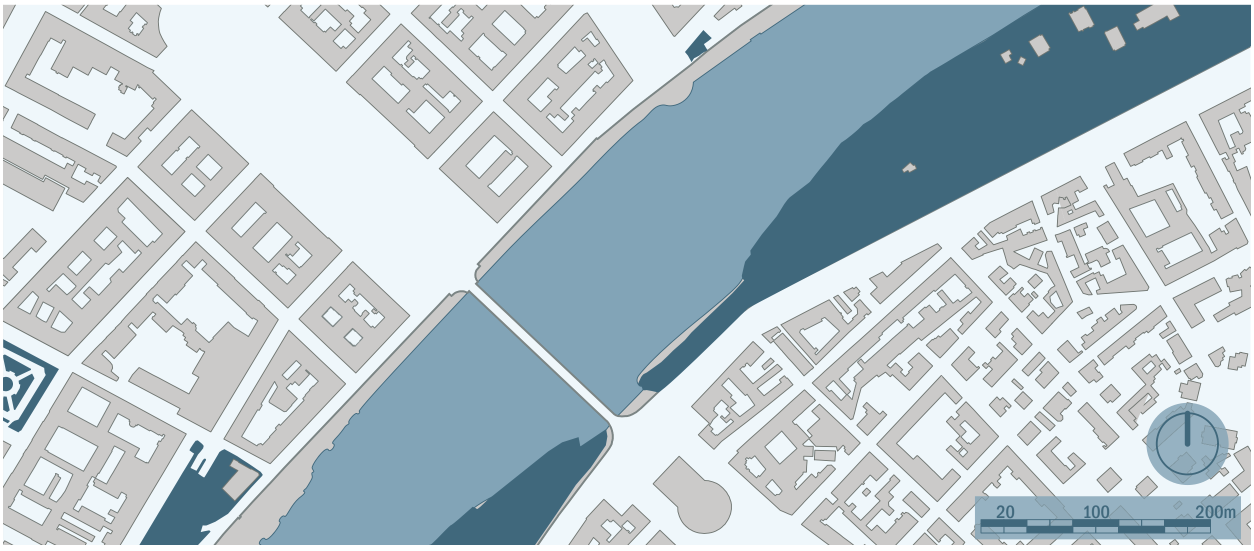
URBAN ANALYSIS BRIDGE SITE

Plan of *"Fills and Voids"* shows that the site is inserted in an urban area, central place of Turin. The project of the new bridge is developed between two squares surrounded by a homogeneous set of buildings both in terms of heights and densities. This plan shows also various forms of urban crossing considered tools of urban transformation and re-definition of the parts of the city.



FILLS AND VOIDS

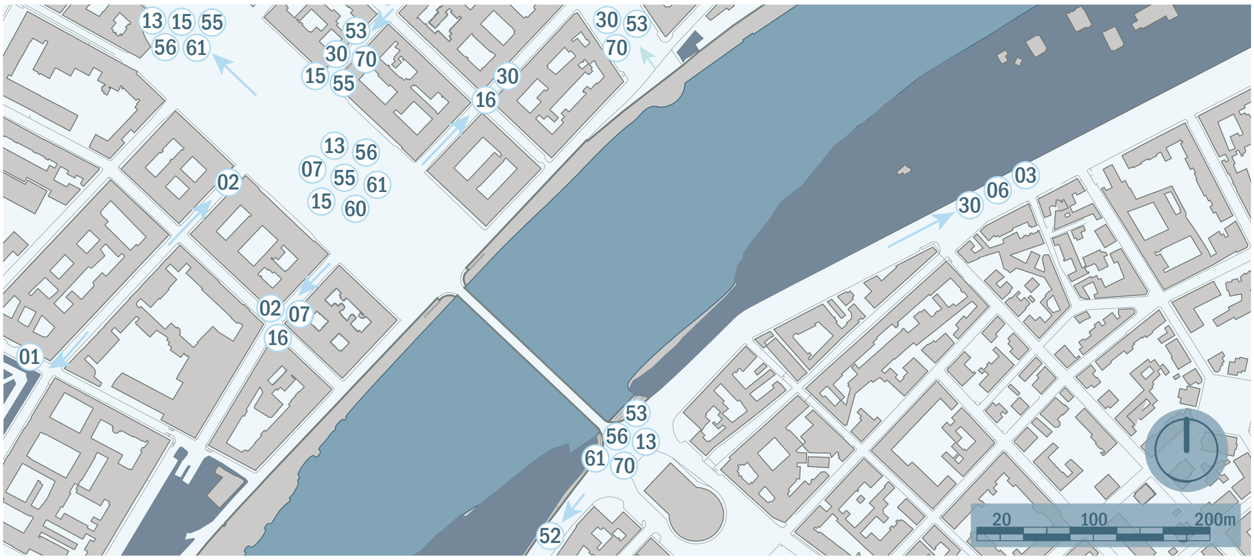
Plan of "*Green Areas*" shows the direct contact of the site of the new bridge with Parco Michelotti. Again, in the site of Borgo Po there is a large part of greenery linked with the feet of the hills. In the other side of the river the city is dense where the only one case is Piazza Maria Teresa, considering only the public greenery. The new bridge fosters the use of the green in the area allowing more connections and different speeds.



GREEN AREAS

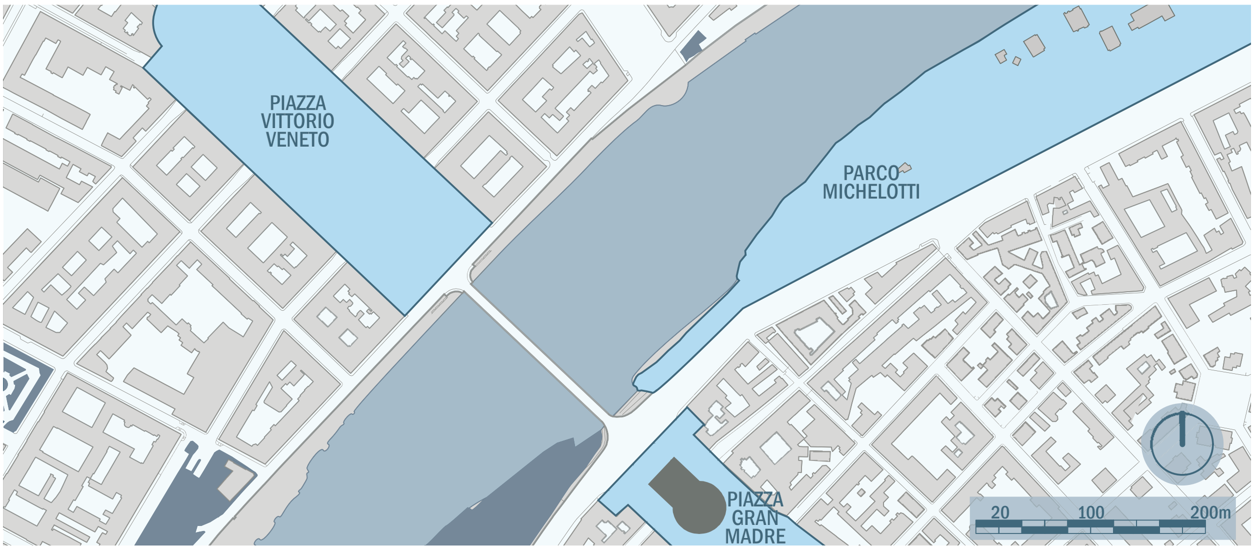
URBAN ANALYSIS BRIDGE SITE

Plan of "*Mobility*" shows how many paths interested the area of the project. In this part of the city all the lines of the public transport system that collect the two sides of the river, parts of the city, pass through Ponte Vittorio Emanuele. The traffic of the bridge is result of private and public characters: the existing bridge collects two ways, one each sides of the river, parallel to them. Then Piazza Vittorio is crossed four times within its surface.

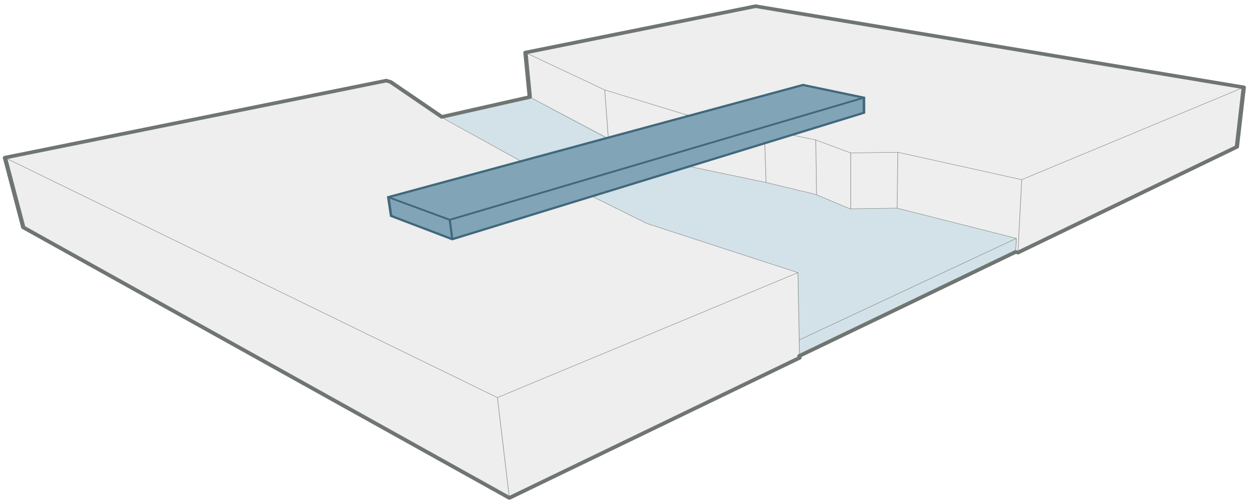


MOBILITIES

Plan of "*Connections*" shows the direct nearness with different focus points of the city. Piazza Vittorio Veneto and all the connections that it has in turn. In the other side, Piazza Gran Madre, with the respective church, so from here start the ascent to the hills. The new bridge is the prolongation of Corso San Maurizio, important way for the city center and for extension for the all city. The bridge itself has the purpose to be a connection.



CONNECTIONS



BEAM BRIDGE

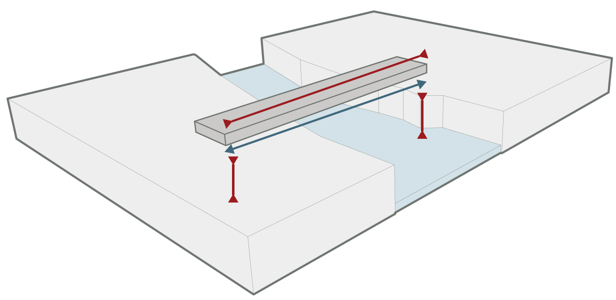
Beam bridges are the simplest shape type, composed by one or more horizontal beams where le length of a beam corresponds to a span. Each span needs to pass an obstacle, the sum of spans covers the area between two sides unloading the forces of the road to the structural pillars.

The main load that plays in this type of bridge is the transformation of the vertical force in shear load and bending moment that are transferred to the supporting structures; from the pillars to the foundations. Reinforced concrete and steel or the combination of both are the most used materials for the construction. The concrete, resistant to hight pressures in the spans, must be prestressed or post-tensioned.

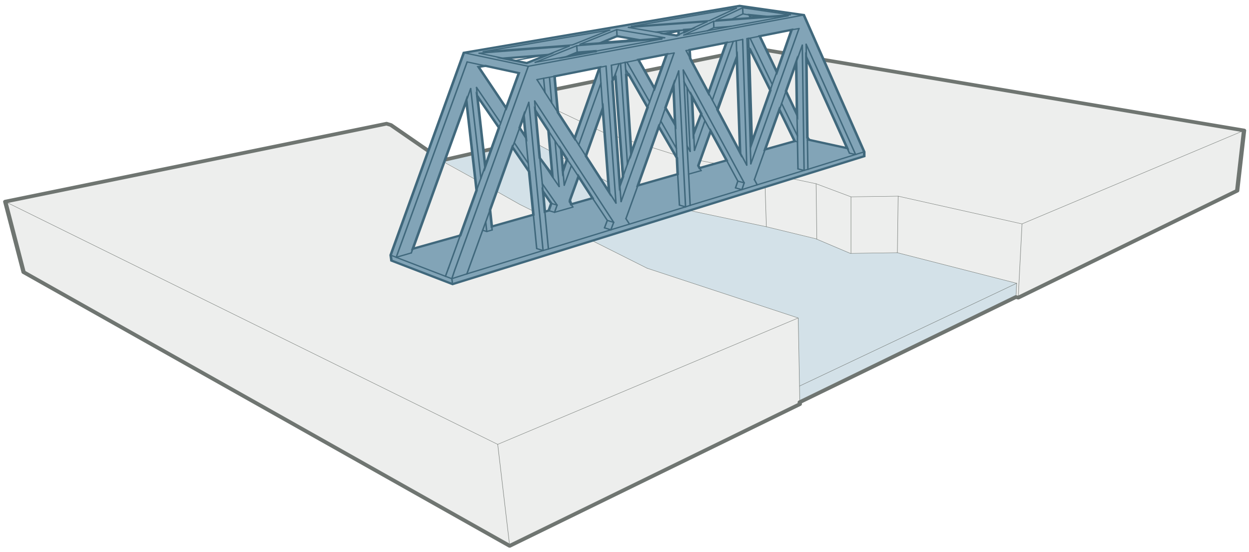
This type of bridge, looking the simplicity, is the oldest built by the man, initially projected using wooden trunk to pass little rivers or mountain creeks then abandoned because not able to cover big distances and reintroduced with the invention of the recent materials like steel, reinforced concrete and prestressed concrete.

Compression: as lived loads that pass though the road travelling across the bridge, produce forces of compression act on the top of the roadway that have consequences into the structure like a supported beam that passes down into the pillar.

Tension: the forces of tension act on the underside of the roadway, the deformation of the beam is a downward bulging caused by the live loads that produce a compression in the upper part of the beam a consequent tension in the lower part of the roadway.



TYPOLOGICAL ANALYSIS **POSSIBILITIES**



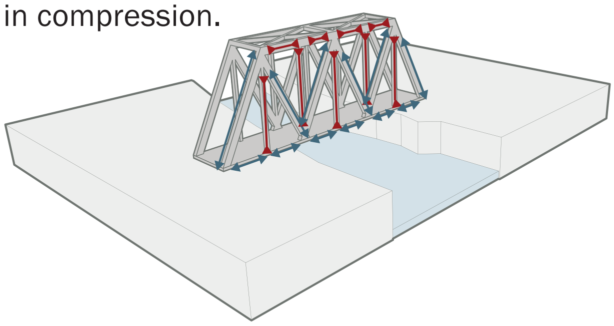
TRUSS BRIDGE

Truss bridges have a popular design style composed by a superstructure constructed by using trusses which are made of many small elements forming triangular trusses. The diagonal beams positioned triangularly has the purpose to support the roadway of the bridge and that is the reason why it is used the rigidity of the trusses to transfer the load from a single point to a much wider area, the load divided will be difficult to be supported. Every single piece of the structure, mainly straight beams, can support dynamic loads both in tension and compression, distributing all the loads along the entire structure, this type of bridge can support different type of forces and, compared to other types of bridge, high intensity loads. Truss structures are divided into two categories: the strut of the king, two diagonal beams supported by a single vertical beam in the middle, and the strut of the queen, two diagonal beams with two vertical beams in the superior part.

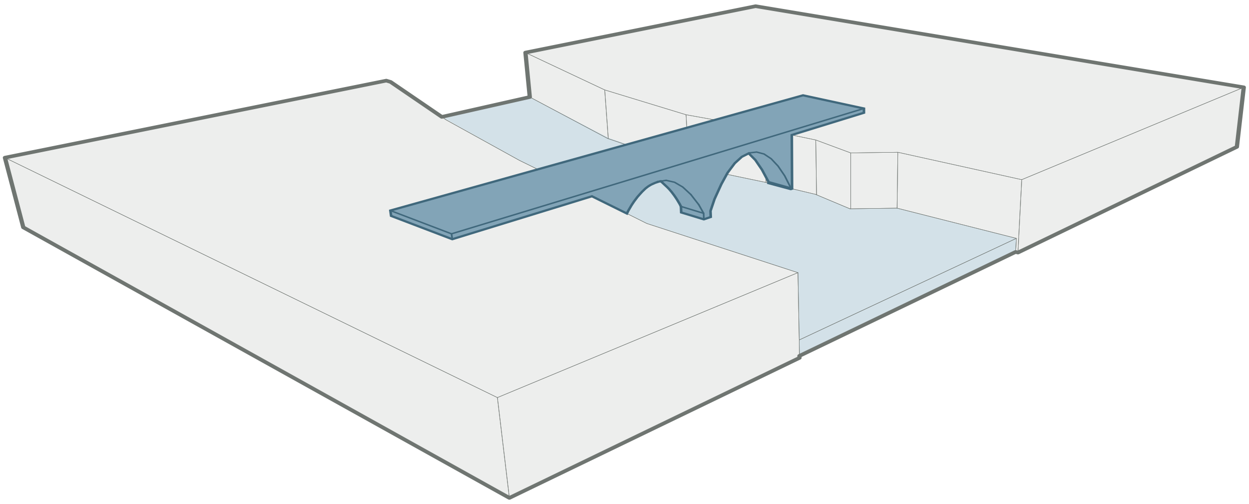
This type of bridge became popular after the Industrial Revolution, the reasons of the success are linked with the important resilience and the cheapness of the construction: small quantity of material entirely manufactured with industrial processes.

Compression: as traffic pushes down on the roadway, the truss structure deforms dividing the forces of the tension and compression shared by the triangular parts and the compression acts upper on the horizontal members of the structure.

Tension: tension acts on the bottom horizontal members of the truss structure reacting from the deformation of the upper pieces of the superstructure and transferring the loads to the ground that in turn supports all in compression.



TYPOLOGICAL ANALYSIS **POSSIBILITIES**



ARCH BRIDGE

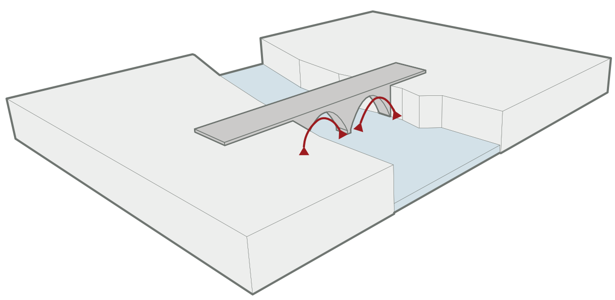
Arch bridges were built by the Romans and have been in use even since. The tradition in Europe, came from the Roman Empire, is visible in arch bridges used for different functions, like construction of aqueducts or urban infrastructures.

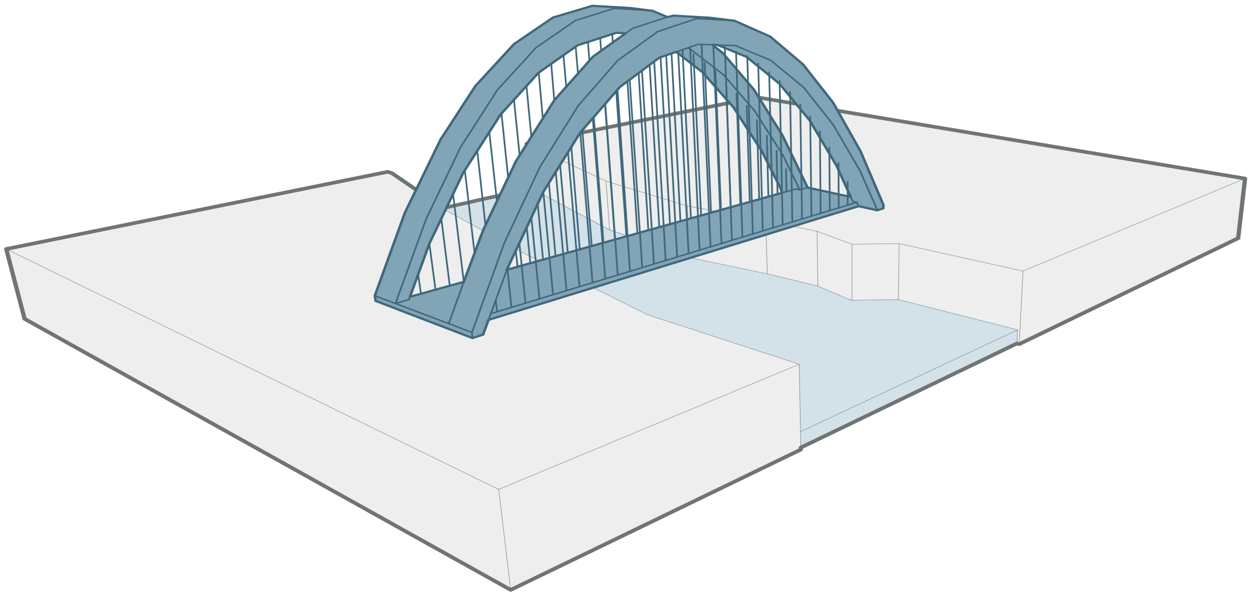
This type of bridge uses the arch like structural component, the arch is always under the decking and not up to it. The shape of the arch gives to the bridge its strength, reinforced by placing supports, or by abutments, at its bases. The help of pillar, englobed between two arches, in the ground and in the bed of the river uploads the load down. The main components of this type of bridge are the pillars and the stumps, they must be solid because will support the entire weight of the all structure of the bridge and the forces derived by the structure itself.

This type of bridge is common because can have every type of user from the pedestrian use to the support of train ways. Arch-bridges can be built from various material, including wood, stone, concrete and steel.

Compression: the force of compression is greatest at the top of the arch, the force of compression is distributed along the arch until the bases that contrast the movement with reaction forces, here the abutments press against the bottom of the arch, preventing the bases of the arch from being pushed outward.

Tension: the force of tension is strongest at the bottom of the arch and pulls the side outward, the need for abutment support that contrasts the effects of tension is much needed when the arch is increasingly large and shallow.





TIED ARCH BRIDGE

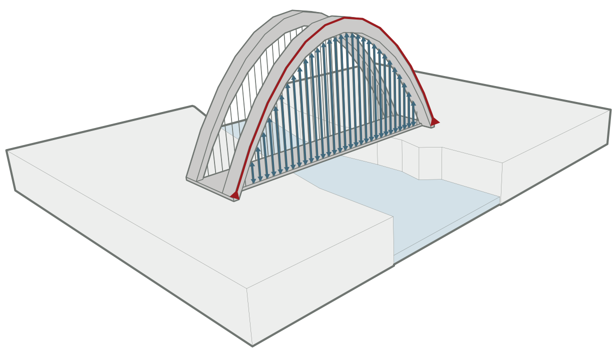
Tied-arch bridge is a type of bridge composed by an arch rib every side of the roadway, one beam each arch posed under the bridge's deck and the cables that connect the roadway with the arches above. This type of bridge is between the use of the cables in the sunspension and cable-stayed bridge and the structurally supported by shape.

The main advantage of this type of bridge is linked to the points of the arch which, connected by the deck, allows to build the bridge with thinner foundations because they exercise a lower forces at the ends.

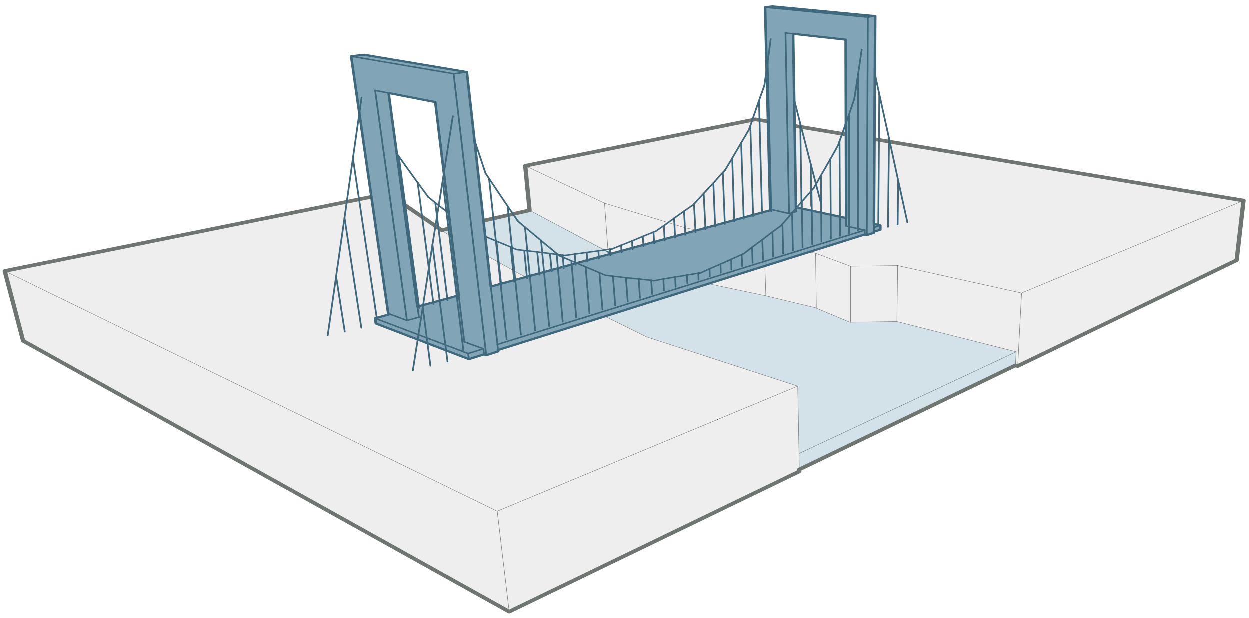
Then this type of bridge doesn't depend on horizontal compression forces for its integrity it can be built out of site and transported into place in a second moment.

Compression: the archs work like in the arch bridges, because force of the load on the deck is translated as tension to the curved top: in this case transfer from the roadway throught the cables in the arch bridge the live loads of the roadway pass directly to the arch from above. So, the arch resists with compression to the forces that try to flatten the arch and to push its tips outward into the abutments.

Tension: the forces of tension, present in the cables, are the connection between the deck and the structural arch: the road way that is suspended transfers its movable load to the cables that react with a tension resistance.



TYPOLOGICAL ANALYSIS POSSIBILITIES



SUSPENSION BRIDGE

Examples of suspension bridges are the Brooklyn Bridge in New York or the Golden Gate of San Francisco: the entire distance of the sides is covered by the deck that is in part suspend and in part support by the bases of the towers that also play the role of supporting the steel cables.

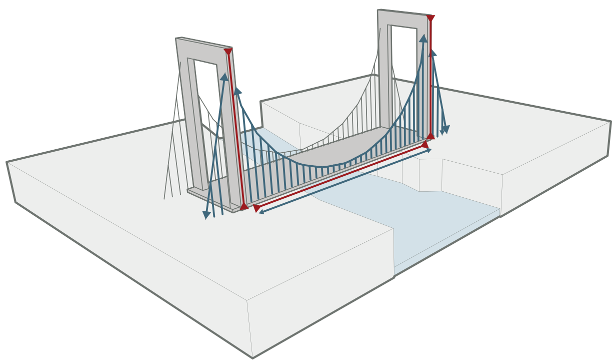
The deck slab, to cover long spans (usually from 600 meters to more than 2000 meters), is supended using ropes, chains or cables; materials and shapes need to have an high tensile strength that is why is steel the most used one.

The deck of the bridge is supported by large steel cables which, in turn, are fixed by a cable positioned by gravity in the shape of a catenary which, in turn, is supported by two large portals in turn anchored to the ground with concrete blocks.

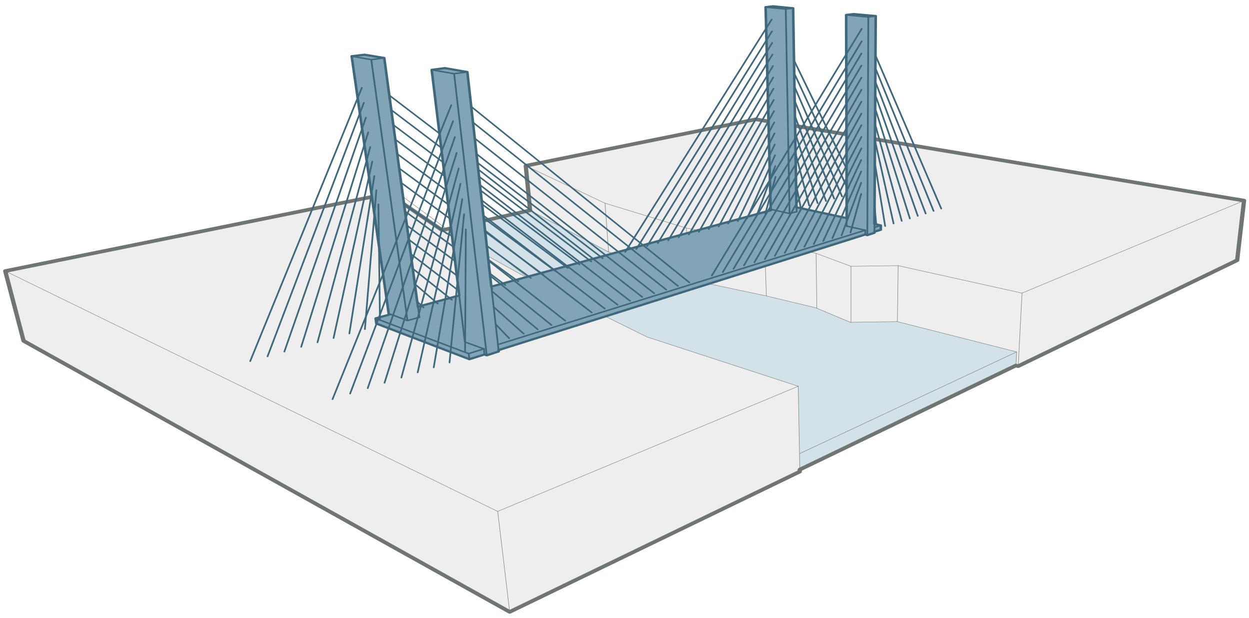
The cable system transfers the weight of the deck in compression to the portals.

Compression: the live load pushes down on the roadway, but because it is suspended by the cables, the weight is carried by the cables, which transfer the force of compression to the two towers, inthis case the towers react like the pillars of a beam bridge.

Tension: the forces of tension are constantly acting on the cables, which are stretched because the roadway is supended from them, the cables, that connect the roadway with the chains anchorered, transfer the load to the chains that react with the tension resistance.



TYPOLOGICAL ANALYSIS **POSSIBILITIES**



CABLE-STAYED BRIDGE

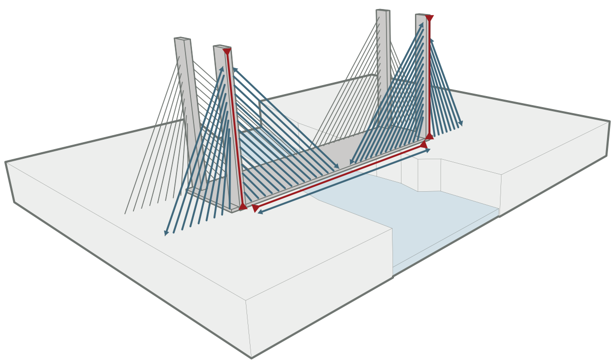
Looking the cable-stayed bridges can be seen similar to the sunspetion ones but they differ because don't require anchorages, and the number of towers is not necessary two. Then, the cables are fixed along the roadway up to a tower that bears the weight.

In a cable-stayed bridge the tower is responsible for absorbing and dealing with compressional forces. The cables are attached to the deck in several places. In the example of the scheme, the cables extend from several points on the road to other points of the tower, called parallel pattern, but it could be a radial scheme: different points in the roadway to a single point in the tower.

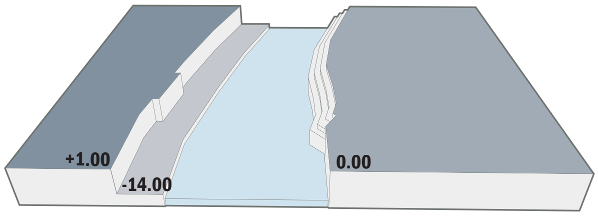
Cable-stayed bridges are a important choice for bridge of long spans, more or less from 150 to more than 850 meters. Important advantages are the use of less steel cable and the speed of construction based on precast sections.

Compression: the live load of the traffic, up to the roadway, pushes down and transfer through the cables, that are attached to the roadway, to the towers.The result in the towers is elements in compression.

Tension: the force, that is transfer from he roadway to the towers passing through the cables, is acting on the cables in a force of tension.

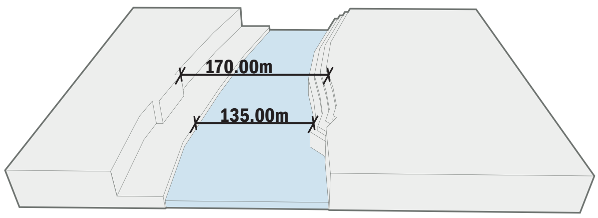


AREA ANALYSIS PARTICULIARITES



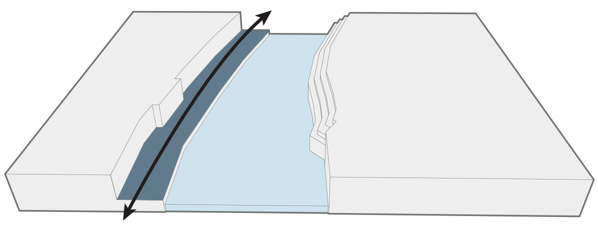
DIFFERENCE IN LEVEL

The new bridge has to touch both the river's banks to connect them with a straight line, but the ground has not an equal height in both the sides, the main consequence is that the decking will be not flat and perfecly parallel with the river's plane. So, following precise standard related to the hydrographic parameters, fixed the position of the street, its middle must be higher than both river's sides in order to have two different slopes: in the middle where the level of the river is deeper the position of a user is most distant from the sides.



MAIN DISTANCES

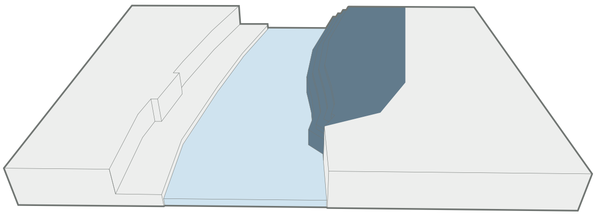
The area of the project, as we already know, is basically composed by the river and its bank: the western is built and composed by two different and distinguishable steps, in the other side, the eastern bank is a natural location where the urban park goes in to the river with a slope. Considering that the decking of the bridge will connect the two higher parts of the sides, covering a span of 170 meters, the lenght is too high to be covered by an unique beam. So, the help arrives from the location itself: the step, at the Murazzi level, covers a smaller distance, equal to 135 meters, facilitated also by the inclination of the slope. In these lower parts of the plot it is possible to place the anchor points of the structure that will support the bridge.



MURAZZI PATHWAY

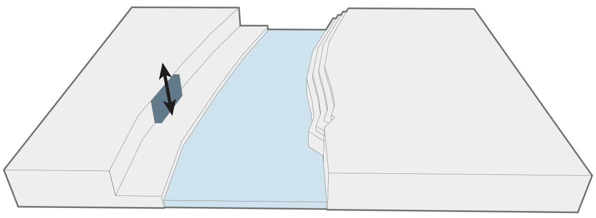
The step, at the Murazzi level, is a pedestrian way used as a connection path and square for different activities, likes pubs or events. This place is called Murazzi del Po Ferdinando Buscaglione, according to the examples of bridge present in Turin, the historical position and the environmental conditions of the place, make it perfect to design the structure in order to develope the infrastructure under the level of the road implementing the use of the Murazzi too.

AREA ANALYSIS PARTICULIARITES



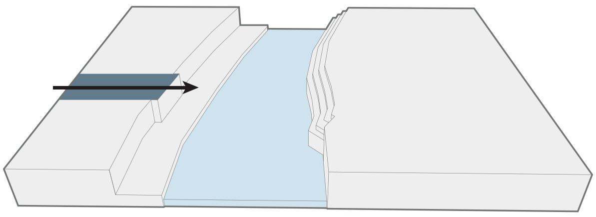
PARCO MICHELOTTI

In the eastern side of the river the setting is an urban park: the wooded aspect of the area and its historicity linked as a place of the city make it an object of preservation. Moreover, inside the park there are architectures, today in a state of neglect, belonging to an era considered historical and at the same time communicating with each other. These relationships between the places give the new bridge the possibility of being regenerative push of the area, also for these reasons the urban green area must be occupied as little as possible and the connections on the east bank must be faster.



ANCIENT STAIRCASE

Currently the connection between the two steps, in the western part of the river, is possible through an ancient staircase, completely built in stone and aligned with Corso San Maurizio. This staircase will have to be preserved, by virtue of its historical and distributive value. Although it will be impossible not to demolish some parts of the balustrade, its function will be preserved and expanded both at its street level and at the level of its mid-run landing. The importance of this staircase is also linked to its relationship with Corso San Maurizio; it, placed at its end, is a panoramic point of view: the new pedestrian walkway on the new bridge will expand the potential of this staircase while preserving its principles.



CORSO SAN MAURIZIO

Dimension and importance of Corso San Maurizio are reasons themselves to justify the project of a new bridge like a prolongation of the street. The decking of the bridge has to connect the two sides of the river maintaining the direction until the crossroad of the bridge itself and Corso Casale. The decision to have a straight road is to simplify the trips and to consume the less surface of park, basically, less consumption of greenery and optimization of time.

PROJECT ANALYSIS REFERENCES

photo source
article “New Port of Long Beach bridge reaches milestone” | date Wednesday 22 April 2020
link <https://www.freightwaves.com/news/new-port-of-long-beach-bridge-reaches-milestone>

GERALD DESMOND BRIDGE

PLACE Long Beach, California
CROSSES Back Canal
FUNCTION connection Terminal Island and Long Beach

OWNER Port of Long Beach
DESIGNER Moffatt & Nichol

MATERIAL steel + concrete
TYPOLOGY mixed type (arch + beam)

LENGTH 1565 meters
WIDTH 21 meters
HEIGHT 76 mters
MAIN SPAN 161 mters

CONSTRUTION 1965-1968
LIFE 1968-2020

As we can see in the picture above and in the characteristics’ list to the side, Gerald Desmond Bridge is a large connection infrastructure, a bridge, of mixed typology. Considering both the materials and the structures that make up the bridge, it is clear that it is a composition of different parts that cooperate together.

The bridge is in a strategic position, oriented east-west, it connects the east side of Terminal Island, then downtown of Long Beach, and the Port of Long Beach, which in turn extends north and south of the west arrival of the bridge. So, the entire infrasructure has to be higher than all the harbor structures above it and to pass a stream, the Back Canal. Only the channel is mandatory and the larger distance, equal to 161 meters.

Basically, Gerald Desmond Bridge is a beam bridge: simple horizontal shape, composed by eighteen spans, and related beams, the length of every beam is costant. The composition of the span is not perfectly horizontal but follows a slope that reaches its maximum height at the cannel. The joints between one beam and another have pillars, they unload the forces of five lanes of Ocean Boulevard road.

Given the size of the decking, the pillars are frames formed by two supporting columns and joining beams between the two. Considering the uneven ground, the columns rest on different heights, so each column of the frame for the entire length of the bridge has a different length to keep the deck at a constant height. The designers therefore decided to adopt a "lame frame" as a pillar: receiving constant forces, given the perfect symmetry of the bridge, the deck discharges to the ground differently, the various constraint reactions in turn will give shape to different foundations, all of which will not be visible on the outside.

All the part of structure described until now is in reinforced concrete. The typology beam bridge", as it is already explained, is optimal for bridges that can have spans of constant size and where the total length of the bridge is much greater than its height in order to achieve regular compression stiffening. But, in the reference's case of Gerald Desmond Bridge, where the infrastructure meets the channel it cannot maintain the costant dimention of the spans, except by placing pillars in the riverbed or using a bigger beam only in the central span. Both the solution in this case had problems:

- the pillars in the riverbed would have blocked, or greatly complicated by the passage of merchant ships through the canal. This point of the Back Canal was considered the best because of its connect to the city with a central point of the port, and not with an extremity, minimizing the movements both in terms of time and distances, moreover, the infrastructure crosses the course of water in a point of great restriction of the canal, considering the place one of the minor lights will be positioned there. Therefore the presence of pillars in the riverbed would also be proof of a hypothetical wrong choice of the place of construction

- the larger beam only in the central span should have been much thicker than the others to have greater inertia, at which point it would have also had a greater weight and a consequent enlargement of the supporting fabrics at the ends. From a logistical point of view, the beam would have encumbered the ships below and therefore it would have been necessary to raise the deck height, the consequences could be multiple: the greater heights of the frames with the same length of the bridge would have made the infrastructure unstable , the different measures of beams would have had either pillars of various sizes or spans of various sizes, achieving even easier instability. From the compositional point of view, the bridge would not have had a regular rhythm of structure and a homogeneity of the dimensions at all levels.

The solution adopted by the designers was a mixed typology: in correspondence with the central span, it passes from a "beam bridge" to a "tied arch bridge". Maintaining the same thickness of the deck, the arch rests on "lamellar frames" of the same thickness as the others used in the rest of the bridge, rises above the deck level and supports it with steel cables. The structure is in steel. The choice is appreciable as the concrete arch would have weighed down the structure and from a visible point of view it would have been heavy and would not have made the two types stand out. The final result is elegant and iconic of 60s engineering.

PROJECT ANALYSIS REFERENCES

photo source
article “Terni, Ponte delle Marmore, “opera strategica per lo sviluppo” | date Wednesday 11 December 2013
link <http://www.umbriadomani.it/news/terni-ponte-delle-marmore-polli-opera-strategica-per-lo-sviluppo-1717/>

PONTE DELLE MARMORE

PLACE Terni, Italy
CROSSES Nera River, road S.S.N. 209
FUNCTION connection highway Civitavecchia, Orte, Terni, Rieti; road a S.S. 79bis

OWNER UNITER c.s.a.r.l.
DESIGNER Matildi + Partners

MATERIAL steel
TYPOLOGY variant arch

LENGTH 300 meters
WIDTH 12 meters
HEIGHT 70 mters
MAIN SPAN 170 mters

CONSTRUTION 2005-2008
LIFE 2008-now

Looking the picture above and in the table of the characteristics, Ponte delle Marmore is complex infrastructure located in Val Nerina, it is a no-traditional arch bridge composed by mainly two levels of structures that cowork togheter following a hierarchy. Considering the composition of the structure we can see an example of a structure on top of another structure, using the same type and the same material.

The reference bridge completes a part of the highway, towards Civitavecchia Orte Terni Rieti, on the Italian regional border between Umbria and Lazio, for a 10 kilometers of highway development. The mountainous territory of the Valnerina has various landscape difficulties: the mountains are continuous and open in short stretches into narrow and steep valleys, the valleys themselves have been carved out by small streams that draw the landscape, even if built. Just along the small rivers, small inhabited centers and productive activities develop, which in turn are connected by secondary road connections. So, the bridge has to overcome the unevenness of the territory and in its larger span the Nera river and the road S.S.N. 209, continuing the connection of the highway at a height of 70 meters.

An hypothesis of the designer's process to reach the final project, we can start from an arch bridge like the iconic steel arch structure of the New River Gorge Bridge (1977) in West Virginia. It has a span of 518 meters and an hight of 267 meters, but the decking can't touch the arch only in the points of the arch's keystone so all along the arch there is a constant suddivision in frames that work s with the statics of the arch itself. The Ponte delle Marmore works in the same way but it has has many constraints that determine the shape:

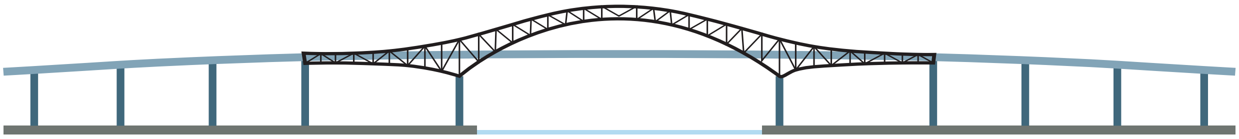
- height and span have fixed dimentions that must be respected because the location imposes them. So, the main arch must have the ends on the rock because at river level there is no gap for foundations and the same if anchored to the mountain sides work better statically. Therefore, given the street level as imposed, it was decided to adopt a lower arch in order to cover a large light without using a height greater than that available.

- in the case of the New River Gorge Bridge, the arch and the deck covered the entire width of the valley as an open "V"; on the other hand, in the case of the Ponte delle Marmore the rock has a more complex shape, on the two sides the slopes of the mountain have a change of section forming a shape similar to a "step" which is different on both sides so it is not possible to use frames bridge arch connection

Thus, the solution was to build a bridge consisting of a main arch with a span of 170m, width of the valley under the "steps", crossing the Nera river and the S.S.N. 209. Then, the designer has inserted semi-arches that go to end in key to the rocky walls to the connecting tunnels of the two axes of the motorway. The deck is supported in the intermediate parts on supports consisting of braced tubes and resting on a second order of arches. All the arches are made up of a pair of steel tubes and are braced with a St. Andrew's cross pattern. The arches are inclined inwards by 14 degree with respect to the vertical axis, with variable distance between 20 meters at the base and 3.35 meters at the top. The main arch is a polycentric curved arch, consisting of an upper section with a radius of 125 meters and the lower parts of a radius of 75 meters allow a better coupling between the arch itself and the road deck. In addition, the hierarchical composition of the lowered polycentric arches allows for arches of different sizes that adjust the inclination of the road axis, so one arch is longer than the other due to the tax difference.

Summary, the location has an uneven section and its lower part has the main span with obstacles that don't allow the anchoring of the foundation. So, the resulting bridge project is the main span covered by the bigger arch, inclined policentric and lower arch, but just one arch is not enough because the keystone in not in the middle of the deck and the deck itself is supported in only three point, keystone and the two junction with the highway. Now the decking is divided into two different part: first side-keystone and keystone-second side. Dividing them in other two spans each using two semi-archs we obtain four spans: three of them with a reasonable measurement and the one that need another support with the main arch. So, we add another arch that has the ends that the main arch and the semi-arch of the first side. the designer solved the problem of the span dividing it in smaller and smaller parts using archs.

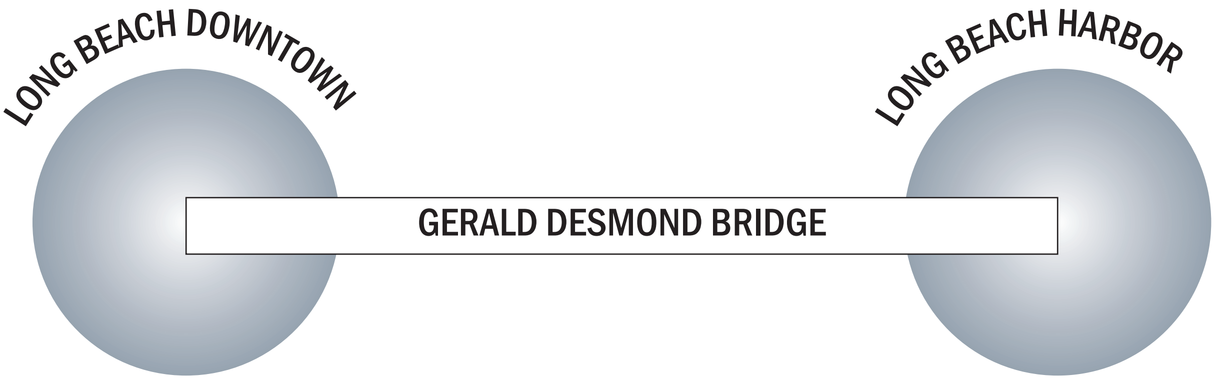
PROJECT ANALYSIS GERALD DESMOND BRIDGE



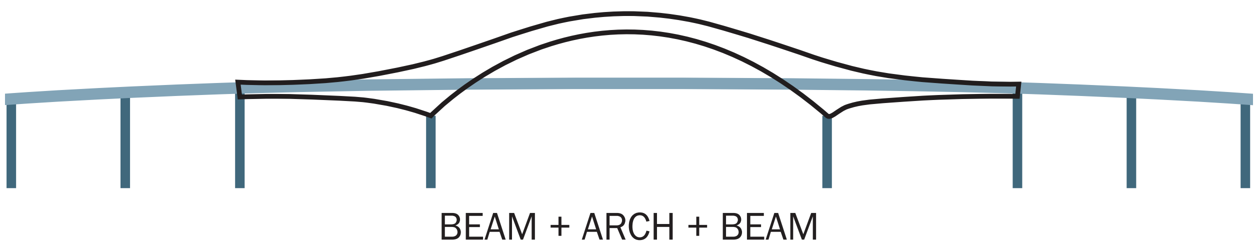
scheme of GERALD DESMOND BRIDGE

By analyzing the two bridges taken as a reference, it is possible to obtain ideas and principles useful for the realization of the generative algorithm of the bridge object of the thesis project.

The determination of the teachings takes place through the comparison of the particularities of the project lot with the places where the analyzed bridges were built. The problems that were presented to the designers of Long Beach and Terni were solved through the design of mixed structures. Overcoming the application of a fixed typology of bridge, a project can also be carried out using more than one type together or

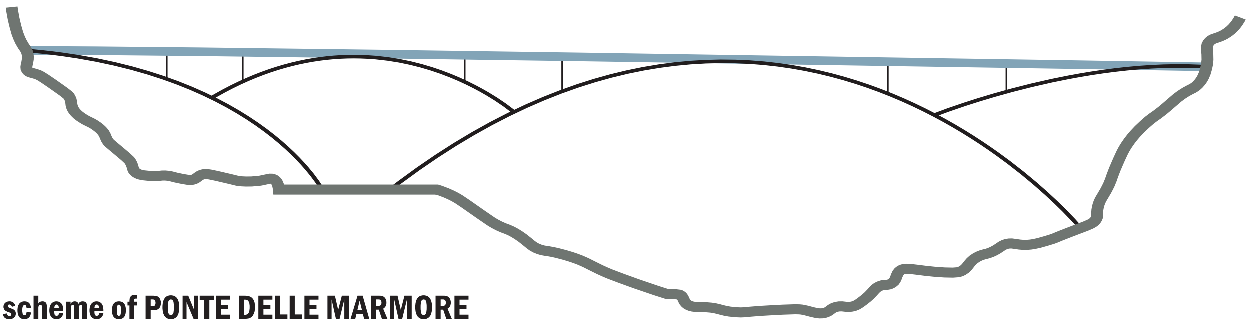


connections



types of structure

PROJECT ANALYSIS PONTE DELLE MARMORE

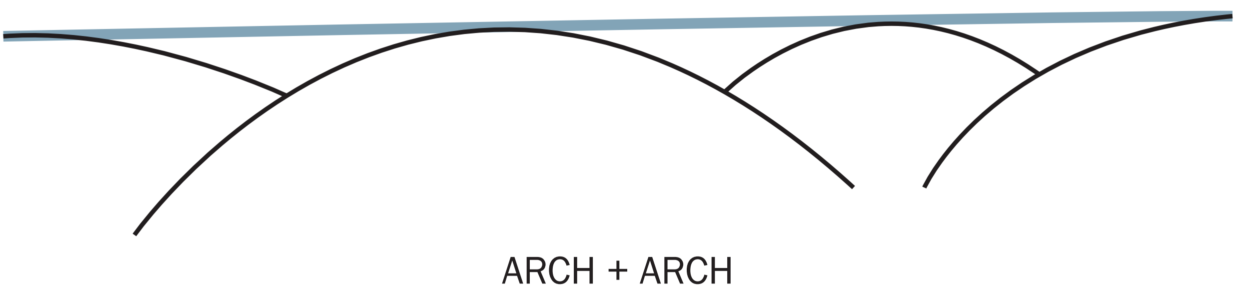


scheme of PONTE DELLE MARMORE

proposing the same type at different levels.

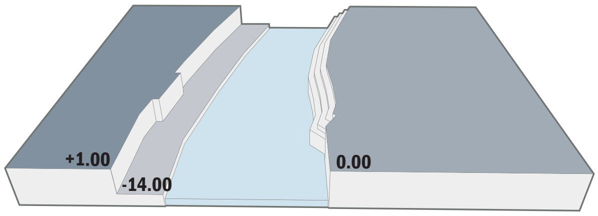
The two reference bridges are not a precise typology, but a mix of structures which, by virtue of their diversity, can overcome the problems linked to the territory, the needs of the infrastructures and the consequent static problems. While Gerald Desmond Bridge has a horizontal distribution of the types of structures, the Ponte delle Marmore has a vertical distribution, they have different functions and different contexts, but the typological mix fulfills the overcoming of the various problems.

connections



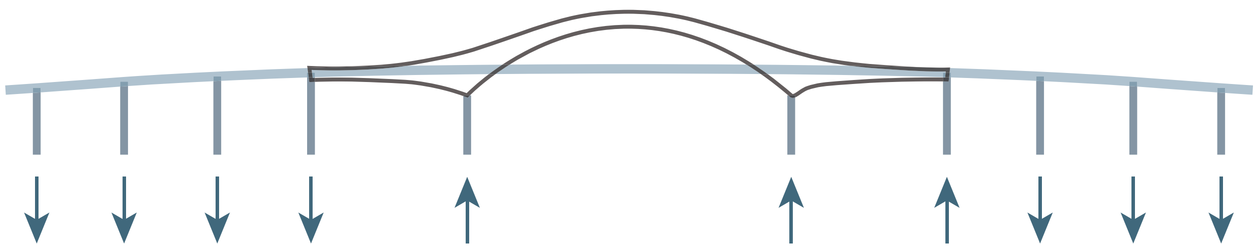
types of structure

PROJECT ANALYSIS GERALD DESMOND BRIDGE



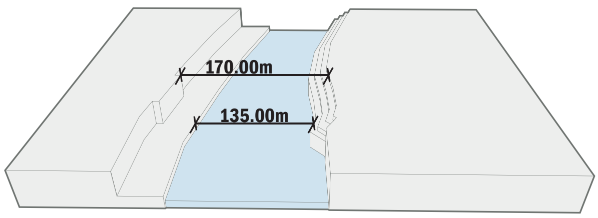
DIFFERENCE IN LEVEL

The thesis project bridge must have anchoring points to the ground similar to those of the Ponte delle Marmore in the east and the Gerald Desmond Bridge in the west, in relation to the points where it will be possible to place the anchors.



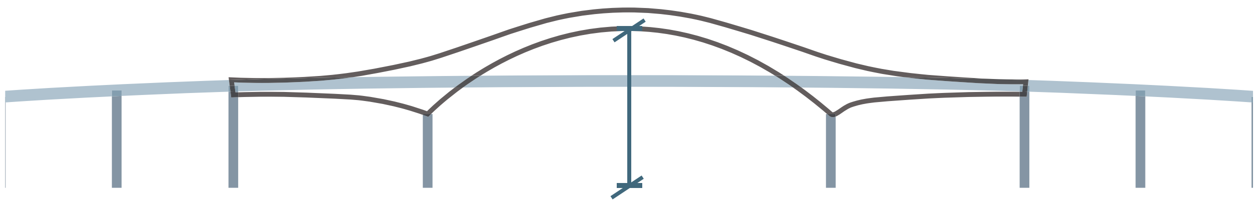
FLAT FRAME

The entire structure have to allow thethe passage of large vehicles below it. For this reason, the designer envisaged a slight inclination of the bridge beams so as to real great heights both near the main arch and constantly variable towards the entrance and exit of the bridge itself.



MAIN DISTANCES

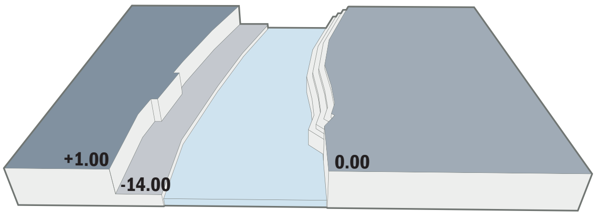
The thesis project bridge must have a regular monocentric arch to cover the main span, like in the case of the Gerald Desmond Bridge, because the relation length/height can’t be high, imposed by the plot, but at the same time the arch can’t be parallel to the ground, so more similar to the Ponte delle Marmore, because the space for the anchors can be larger than the space occupied by the arch’s shape at the top.



RAISING THE ARCH

The main span, covered by the arch, has a relation length/height e qual to 2,11 maintang the same centre and direction perpedincular to the ground level. The space for the anchors is vast and allows to use the same type of structure because the the geomorphological differences are minimal.

PROJECT ANALYSIS PONTE DELLE MARMORE



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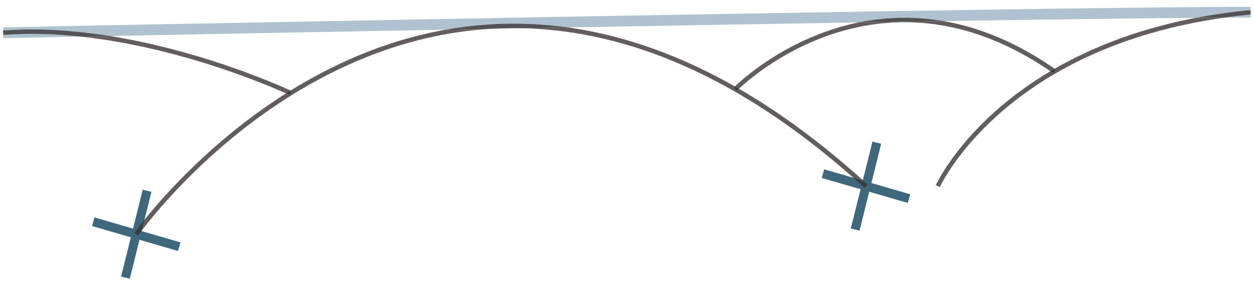
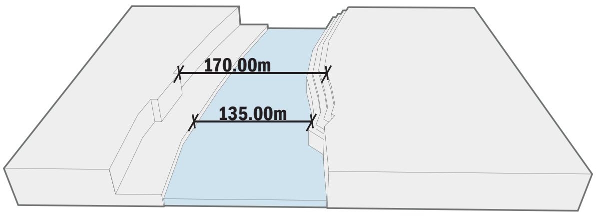


ARCHES DIFFERENT IN THE ENDS

The main arch has a considerable height because the carriageway is imposed at a predetermined level. The obstacles at the base of the arch are at various heights so as not to occupy the river and road level. Thus, the main arch, resisting without the need for structures below it, reaches such a height that any vehicle can pass beneath it.



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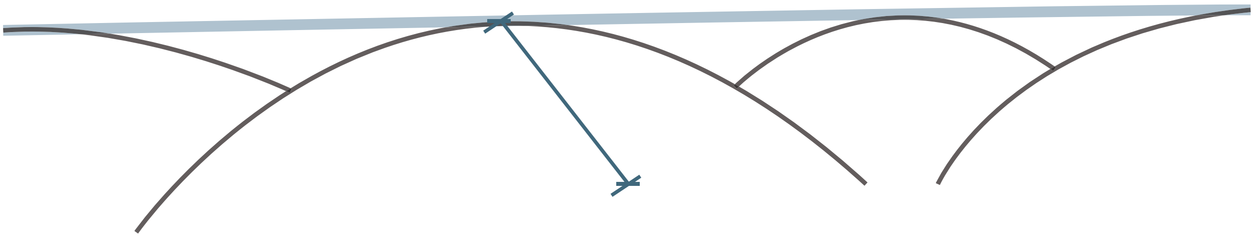
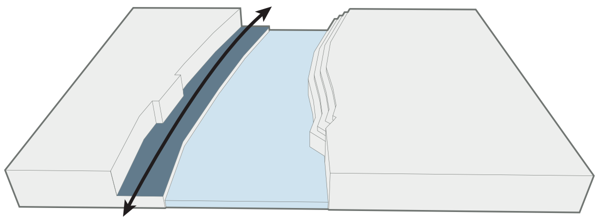


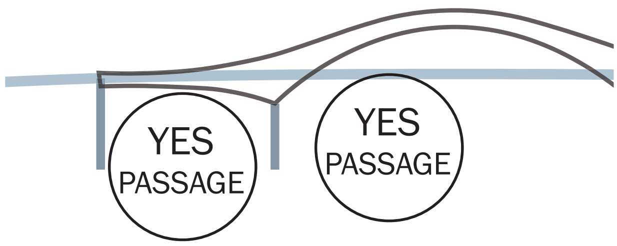
TILTING OF THE ARCH

The main span of the bigger arch has a relation length/height e qual to 2,42. The entire height is policentric and inclined to cover an high span a variable height at the ends.

PROJECT ANALYSIS GERALD DESMOND BRIDGE

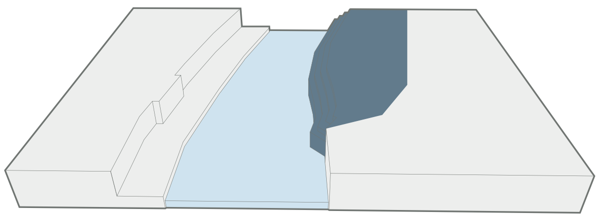


MURAZZI PATHWAY

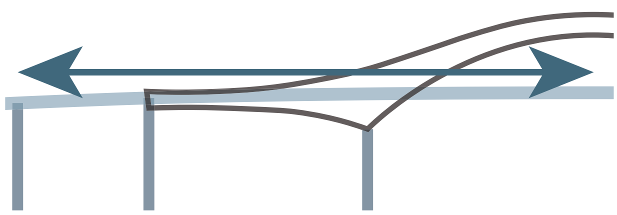


The thesis project bridge must have to respect the hydrogeological level below the structure that will cover the greater span and the pedestrian passage in correspondence of the pathway of the Murazzi. The solution adopted in the Gerald Desmond Bridge is not possible because the entire structure will be in the section of the river banks, in the other case the shape of the smaller semi-archs of the Ponte delle Marmore is functional to the passage below as a linear and space-saving form.

PASSAGE EVERYWHERE
The frames, that simulate the pillars in the “beam bridge” parts, follow the the slightly irregular ground by changing the heights of the frames, through the use of the “lame frame”.



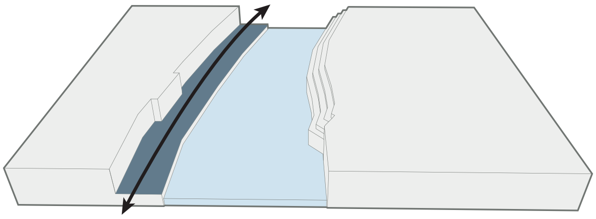
PARCO MICHELOTTI



The thesis project bridge must occupy as little space as possible inside Parco Michelotti, eastern side of the river. The bridge doesn’t influence the wooded aspect of the area inside the park but under the level of it the structure will be in a central position inside the city and visible from different point of view. Its presence will certainly be relevant from a visual point of view whatever structure the algorithm will generate, its position is in a very frequented part of the city and central to various activities in the city of Turin.

STRAIGHT CONNECTION
The bridge is located in a highly urbanized area, the function is to connect downtown and the port area of Long Beach. The port is an area of industrialization, the bridge is mainly a communication route linked to the activities of the port, although it has become a symbol of the place, the designer’s choices were not oriented to contextualize the bridge with the insertion area.

PROJECT ANALYSIS PONTE DELLE MARMORE



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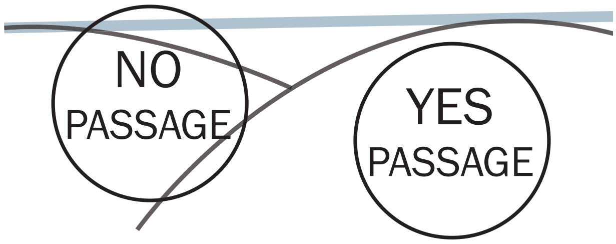

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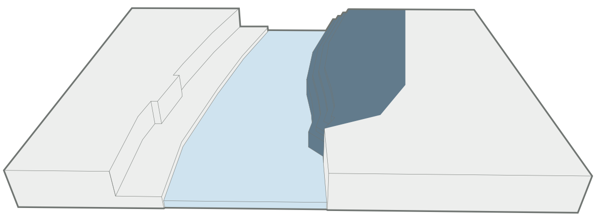
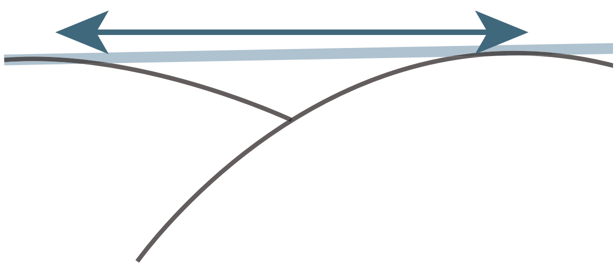
PASSAGE SOMEWHERE

The ends of the various arches do not rest in the same horizontal plane while the keystone is always at the peak point of the arch itself. The position of the arches are inclined and the sections of the tubes that compose the archs are not costant, bigger at the foundations and finer at the deck.



PARCO MICHELOTTI



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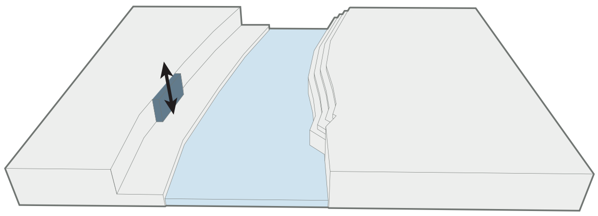
STRAIGHT CONNETION

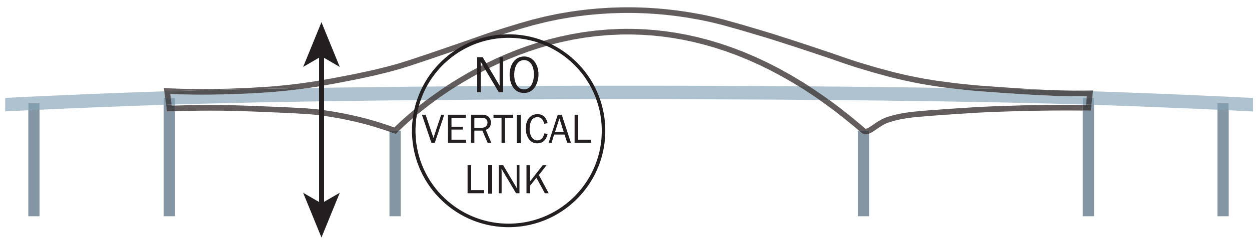
The bridge is located in a mainly naturalistic area where the only sign of urbanization is found at the level of the Nera river and these are small towns not immediately below the structure. The function of the bridge is to join two sections of motorway both passing through tunnels dug into the rock and resulting at different heights. The context required a light and harmonious structure with the mountains, the encumbrance had to be reduced to a minimum to allow the surrounding vegetation to grow.

PROJECT ANALYSIS GERALD DESMOND BRIDGE



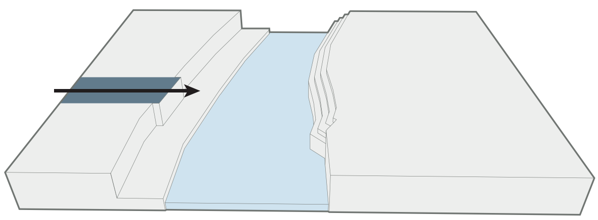
ANCIENT STAIRCASE

The thesis project bridge will have to take into consideration the existing and still accessible ancient stairway, used with a vertical connection between the wall level and the area above it at street level. The algorithm will have to take into account the overall dimensions and size the parts of the structure, guaranteeing access and height in correspondence with the staircase.



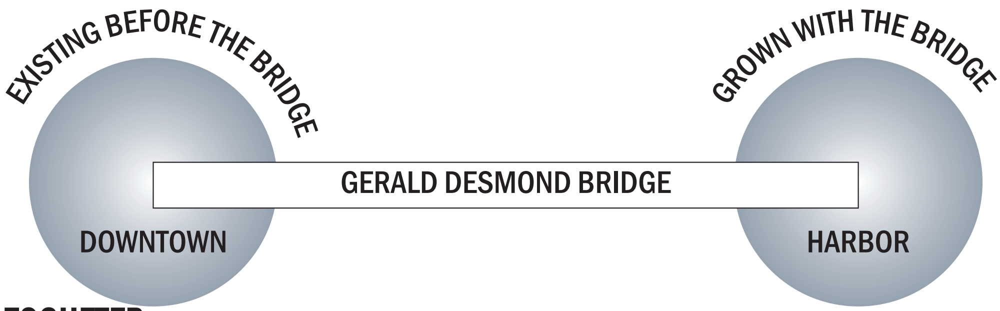
ACCESS ONLY TO THE ENTRANCES

The structure allows the passage below itself everywhere, both by land and by water, the bridge does not have a vertical connection, therefore access is possible through the entrance and exit of the bridge itself.



CORSO SAN MAURIZIO

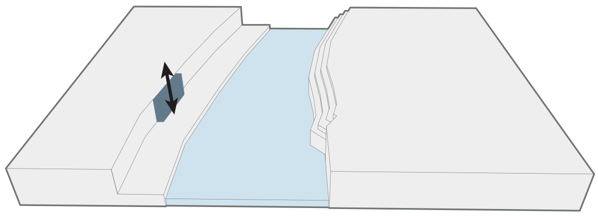
The thesis project bridge will have a road that continues the direction of Corso San Maurizio, the reasons are many but, from a social point of view, Corso San Maurizio needs to be connect with the road network of the eastern part of the city: improvement of communications, speeding up of movements and development of abandoned areas of the urban park.



GROWTH TOGHETER

The bridge was built with the city as a point of industrial development for the area and as an enhancement of the port of Long Beach. Nowadays, the bridge has been closed to traffic and replaced with another one of a much larger "cable stayed bridge" typology: the construction of the new one is therefore a sign that the objectives of the old have been largely achieved.

PROJECT ANALYSIS PONTE DELLE MARMORE



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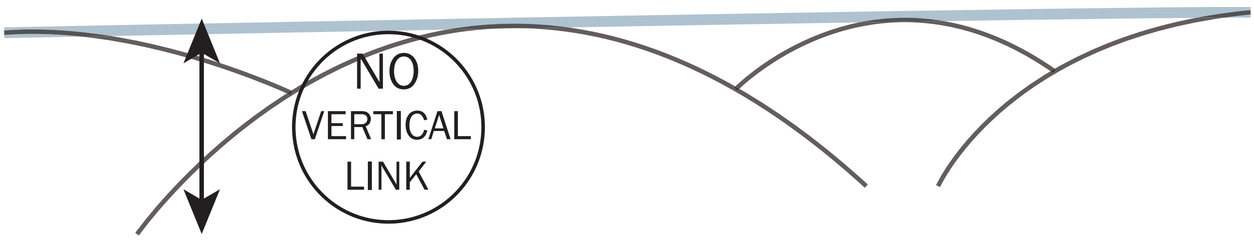
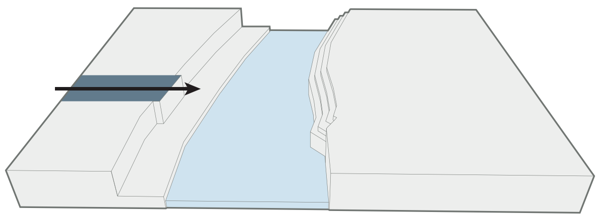


ACCESS ONLY TO THE ENTRANCES

The structure allows the passage under itself only in correspondence of the greater arch, under the smaller arches the passage is not allowed for two reasons: the first is that their position in non-accessible places and the second is linked to a design choice, the sizing of the curvature does not favor the passage of a flow of people. Again, there are no vertical connections.



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The thesis project bridge will have a road that continues the direction of Corso San Maurizio, the reasons are many but, from a social point of view, Corso San Maurizio needs to be connect with the road network of the eastern part of the city: improvement of communications, speeding up of movements and development of abandoned areas of the urban park.

EXISTING BEFORE

The bridge was built as the infrastructure of a much larger project linked to national roads. Its existence is linked to the construction of an important road junction for the development of alternative communication routes. Nowadays, the bridge is in use without affecting the surrounding area.

PONTE SUL BASENTO , project of Sergio Musmeci

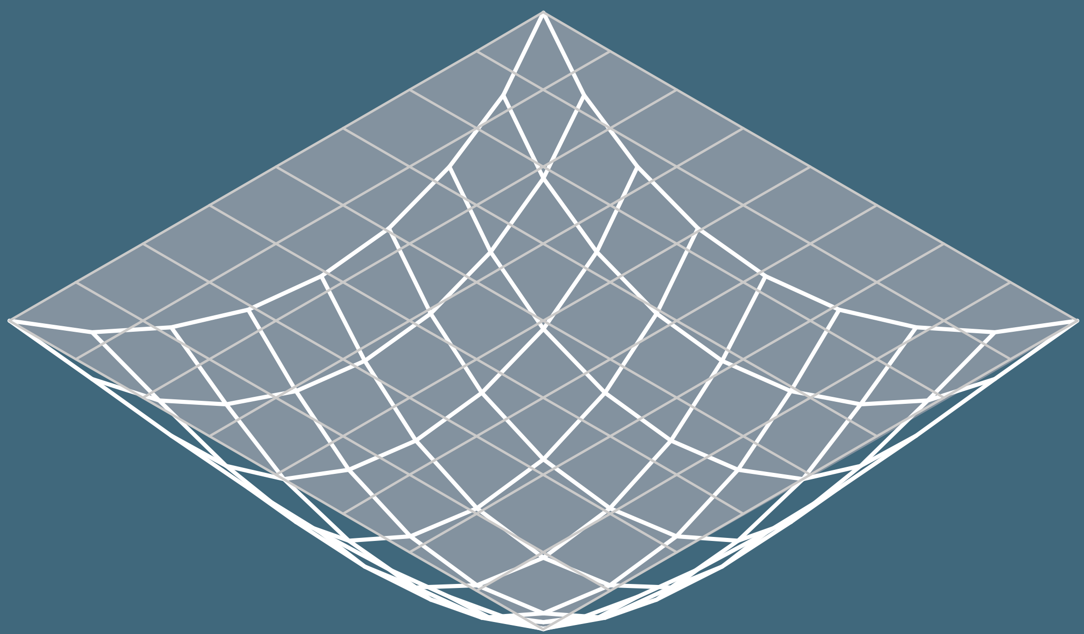
photo source
article “Restauro Conservativo del Ponte Musmeci a Potenza, il concorso” | date Monday 20 January 2020
link <https://www.architetti.com/restauro-ponte-musmeci-potenza-concorso.html>

CHAPTER FOUR

INSTRUMENTS

“One and one and one is three.”

The Beatles (Come Together; 1969)



Starting from the study of the Ponte sul Basento, located in Potenza, work of Sergio Musmeci it is possible to analyze limitations of the drawing like an instrument for the architect. The drawing, used by the architects, is a starting point to organize ideas, image spaces and simulate the formal aspects of the future physical constructions. The correctness of the instrument, whatever it is a line of a pencil on a paper or made by a CAD software in a digital space, is always verified by the designer's experience. Looking the shape of the Musmeci's work it is clear to understand that the drawing can't take into account physical and structural aspects that influence the final shape.

Parametric design is not to design the final shape that is an expected result but to set rules that will generate the form. The parametric approach has its bases in the parametric calculation that is composed by variable parameters that interacting modify the algorithms result. Parametric architecture is possible thank to the use of the mathematic language though the use of the computer and the first experiment was developed by the architect Luigi Moretti during the Triennale di Milano 1960, where he presented different model of stadium parametrically designed, results of twenty years of research in the relation between the architectural design and the parametric equations.

Contemporary architecture has clearly divided the role of the architect and the engineer one, both cooperating in the infrastructural development. Technological innovations and contemporary architectural researches have tried to merge creativity and structural calculation to reach a design integrated with the structures where the final result is optimized by the preset parameters. In the case of the Ponte sul Basento, Sergio Musmeci had clear sions of spans to overpass different types of obstacle, and a continuous shape with the capacity to withstand statical loads.

The bridges designed by Musmeci date back to the 70s and, even if the approach is parametric and the strategies were form-finding, they are not result of computational software but results of precise and large time-consuming analysis that compare complex physical models with hand-made calculations using different types of material that had to simulate the real material of construction. Examples can be hanging chain networks, stretched fabrics, soap film, rubber membranes. The goal of this thesis is the design a structure that transmit forces through axial compression or tension in order to have an increased capacity to withstand loads with smaller cross-sectional areas. The most common examples of structural optimization in architecture are the shells in reinforced concrete: to quote some designer Felix Candela, Heinz Isler, Eduardo Torroja.

The equilibrium between geometry and load that characterized the projects of the previous designers, and in the case of Musmeci, is the base to have "expressive architecture" and "structural efficiency". The Parametricism as Patrick Schumacher has theorized, is a style that use expressive structures of the surfaces, allowing the geometry in architecture to satisfy complex needs in the contemporary.

Shell structures, not fashion during the XX century when the Modernism preferred different formal results, needed a parametric approach to optimize the physical object and to quickly solve statical problems. A computational design software is programmed to simulate what in last century was made in the laboratories: particle-spring systems is a method to simulate digitally tradition-

OVERVIEW INSTRUMENTS

al form-finding techniques, the method, explained by Arturo Tedeschi in "AAD_Algorithms Aidded Design", is a physical simulation of deformed bodies. When traditional techniques, as it is explained before, are difficult to apply, this method investigate the form in real time, by uploading forces, supports and physical properties. Every single change is immediately upload by the algorithm in the digital visualization to monitor the variations in the time from a state to another.

Starting from a continuous model, for example a cable or a more complex membrane, the application of a particle-spring system envisages a discretization of the model into particles, that are a finite number of masses, and the connections between them, that the system analyzes like perfect elastic springs. To summarize the main parts of the particles spring systems are:

- particles are masses, that in the imagery can be seen like spheres, that in the different stages of the simulation change position and velocity, these masses are fixed in the initial position and in the final one

- springs, every mass is connected to another one with a linear connection that has physical characteristics of a real spring and a behavior coherent with the Hooke's law, all the spring in a object under simulation has equal characteristics including an initial resting length and a stiffness value

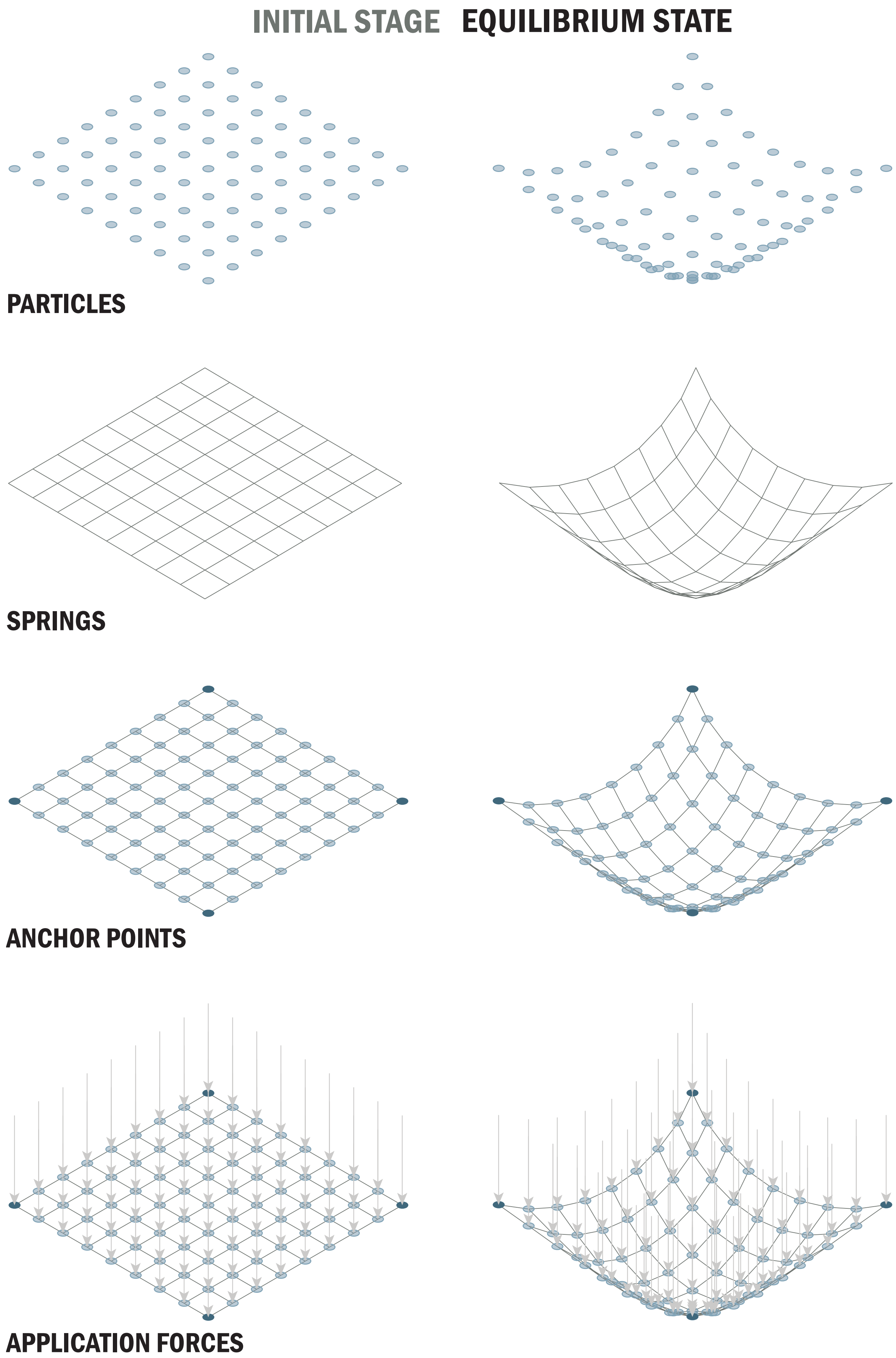
- anchor points are single or group of points that can't change position in order to set the supports of the object under simulation, if anchor points are not set the object in the moment after the application of the forces it collapse due to a lack of opposition forces

- forces are vectors directly applied to the particles, the distribution of the weights and the external loads simulate the object under simulation in different parts and with intensities set by the decision maker

Every algorithm that uses particles-spring systems has a switch that can turn on or off the application of the load: so, the simulation has a precise start, switching from off to on and the simulation is activated the particles move from the initial state to the equilibrium one. This last arrangement of the object, that has experienced the simulation, depends to the initial geometry, the intensities of the vector's forces and the Hooke's law that leads the springs' behavior.

The mathematical processes of the algorithm respects the properties that have to set in the process: the Hooke's law needs a precise stiffness that is set in relation with the material chosen for the object's project (also called k value) and a domain that gives to the elongation of the spring a range where the deformation in the equilibrium state has to contain in it.

In the particles-spring system the particles have properties of spherical hinges without the capacity to resist moment forces. The ideal condition for form finding strategies and methods is to reach equilibrium solutions though the exclusively use of axial forces.


INITIAL STAGE
EQUILIBRIUM STATE
PARTICLES
SPRINGS
ANCHOR POINTS
APPLICATION FORCES

FIRST INSTRUMENT KANGAROO

In the article “Math helps explain design”, written by the architect Marco Trimarchi for Domus in the copy of November 2018, he said: “Math resolves simple problems such as paying taxes, measuring the time left before the world’s end and explain nature with compass and ruler.” Then “Design resolves simple problems: cutting tree branches and preserving fire, as well as praying to the gods and driving demons away”. In few words, he wants to highlight that a mathematic approach for solving design questions is a way to understand very well the problem that has to be solved and to decompose it in easier situation. Solving the basic components, the evolution of the problems will always be roots that can be modified without addition reasonings. All to understand that math and design both treat problems that are constantly evolving and the instruments need to simplify the processes. In this way language and methods evolve to resolve ever more complex issues. In the case study of this thesis the standard tools of Grasshopper are not enough to develop what the thesis set itself, the consequence is the use of different plug-ins that step by step will be explained.

The mathematical reasoning follows the selection and the utilization of every step of the design. To mathematically repropose a form finding method though the particles-spring system the plug-in selected is Kangaroo. It is a physics engine, a collection of algorithms, that enable the software to simulate physical behaviors of the real objects. The simulations of this thesis focus on the dynamics of the particles. The attention is focused on the position of the particles:

- the initial state describes a condition imposed by external reasons, it is anyway positioned in an X Y Z coordinate, working in a 3D space, the velocity is zero because the vectors applied have no intensity and the particles’ mass is zero following the geometrical definition of point like element without dimensions

- the equilibrium state is a new positional arrangement of the particles that, after the simulation where they have lived a velocity without changes in terms of mass, have a new position in the space X Y Z and are the base to define a membrane that will be a step to reach the final object definition

In both the states exist an equilibrium where the sum of the forces thar act on the particles is zero: mathematical solvers perform the calculation leading position and velocities during the simulation. Kangaroo is an engine that fix all these conditions to a model, in the case of a membrane the necessity is to pass three phases and the use of another plug-in called Weaverbird. The three phases before mentioned are proper of the algorithm’s scheme and in particular way of what concern the use of Kangaroo and Weaverbird, these stages are in realty components of the software and are schematized so: discretization, particles-spring system and kangaroo-physics. So, the basic algorithm to apply a form-finding process to model a geometry shaped by forces using a particles-spring system is composed by five steps:

1 initial state

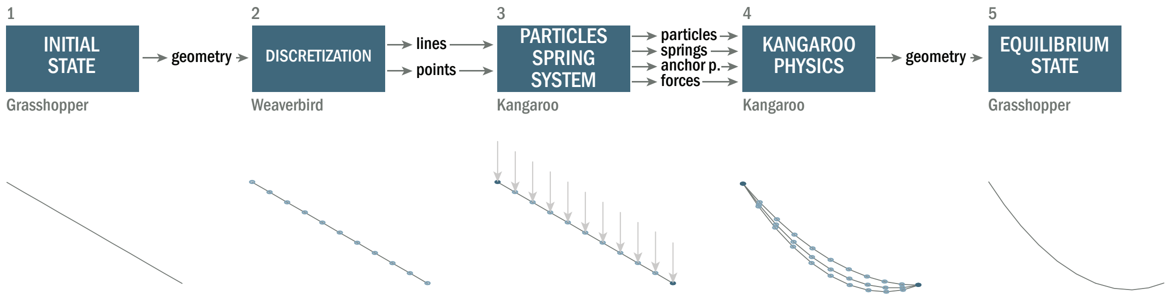
2 discretization

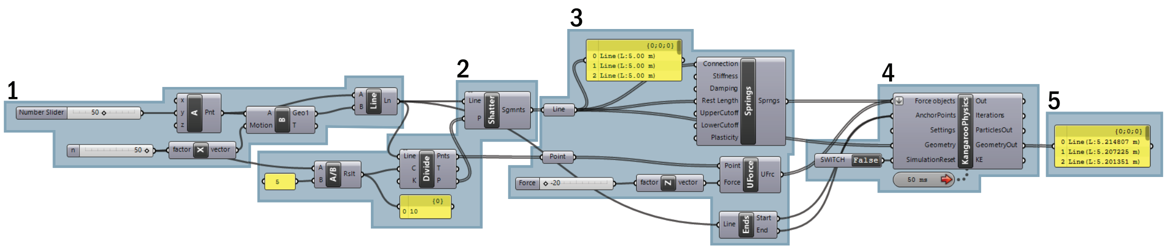
3 particles-spring system

4 Kangaroo physics

5 equilibrium state

FIRST INSTRUMENT KANGAROO





Analyzing step by step every phase using the first experiment of an elastic cable suspended between two ends point with the imposition of a load from the top to the bottom allows to take a look a first algorithm that generates not pre conceptual shapes.

1 The initial state is simply to set a horizontal line, parametric itself, using the basic tools of Grasshopper. Defined two points, that are the two end points of the curve, the tool “Line” connects the point constructing a line. That line has variable dimensions and directions the only imposition that this construction doesn’t permit is a vertical line typology. The reason is linked with the intention to apply in a second moment loads imposed by self-weight.

2 Taking into account a deformable body, it is created by NURBS geometries but Kangaroo requires lines and points: the discretization is the Weaverbird process that transform NURBS in two set, points and lines. Coming back to the experiment illustrated before the discretization of the initial geometry is done with the components “Divide Curve” that allows to decide a domain of division of the curve and “Shatter” to diversify the lines and the points and to act to them separately.

3 In a particles-spring system the points become the particles and the lines are the springs. After the discretization of the geometry with components of Kangaroo the other two outputs that this phase has to give are the anchor points of the object and the vectors representing forces that will be applied to the particles. The component “Springs from Line” generates the system of springs; the lines are an outputs from “Shatter” and inputs for “Connection”-input and “Rest Length”-input, the first one for the conversion and the second for a limitation in the extension of the springs after deformation. Keeping the points, became particles, from the division with “Divide Curve” is connected with the “Unary Force”-input: it is the components that generates vectors that are forces that are applied to the particles, this component needs a direction, that in the experiment is along the Z axes, and an intensity, that in the experiment is negative because the direction is specifically from the top to

FIRST INSTRUMENT KANGAROO

the bottom. The last characteristic of the particles-spring system phase is the anchor points: they are the not movable points of the object, summarizing they are the place where are the forces the contrast the forces applied with the component “Unary Force” and allow the equilibrium. In the case of the experiment in the previous page the anchor points are the end points of the set of points resulted from the division in the phase of discretization.

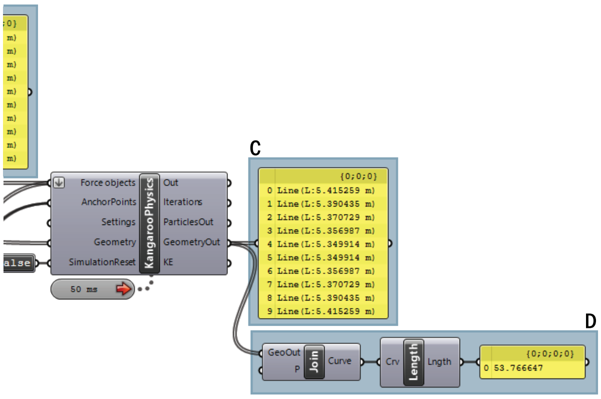
4 “Kangaroo Physics” is the name of the component of the plug-in that merges and connects all the data outputs that comes from the third phase of the algorithm: the springs with their domain, the vectors that represent the forces, the anchor points, and every single line discretized. Everything is ready for the simulation: the particles will move changing potions and velocities and the springs will deform their lengths; the goal is to reach the equilibrium. The component “Switch” is a sort of component-bottom that start and stop the simulation then to the Kangaroo’s component is connected a timer that manages the time of the simulation process, the utility is to analyze in the time the different phases of deformation, like it is possible to see in the previous page too.

5 When the simulation is finished, in other words when the particles of the object stop to move along the Z direction the equilibrium is reached and the resulting geometry is a form finding application. In the illustrated experiment it is possible to check two important considerations. The first one from the images we can see a sort of cable with the shape of a reverse arch: it could be a flattened arch, in this case the inner axes of a solid because it has not a thickness, that reversed it is resistant to the force of compression. The second consideration is clear analyzing the scheme of the algorithm: at the fifth phase it is highlighted a yellow panel with numbers inside, that numbers are the position of the particles in the space that compared to the yellow panel in the third phase, that correspond to the positions of the particles after the discretization, and for extension the same positions of the initial geometry, so the differences that are notable between the two panel are the global deformation that has had the object from the first to last phase of the process.

> “Math resolves simple problems such as paying taxes, measuring the time left before the world’s end”
>
> Marco Trimarchi

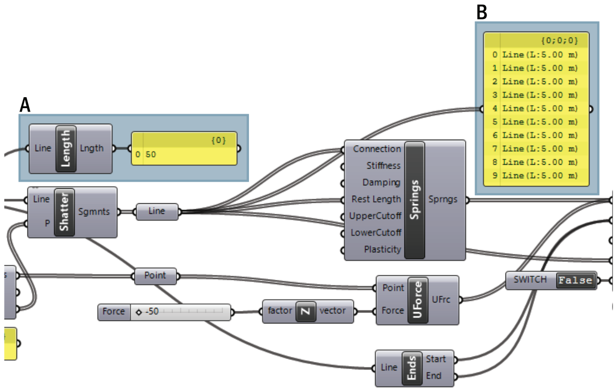
SECOND INSTRUMENT HOOKE'S LAW

Starting from the last line of reasoning of the previous paragraph and using the second example there is the opportunity to analyze in deep how the deformation of the initial geometry works. So, when an elastic cable, like the one in the example discussed until now, reaches the equilibrium, generated by the vector forces, and resists by the elasticity of the springs the length of every smaller line that compose the macro-curve increases. Taking into account this thinking it is possible to have a look to the resulting data that the algorithm shows through software panels.



In the first exact of the algorithm are highlighted two part: the "A" shows a yellow panel with the total length of the initial geometry, coherent with the number slider that in the full algorithm's scheme defines the distance between the two points that composes the initial line; instead the "B" shows a yellow panel with the dimension of every line generates after the discretization of the initial geometry, also here coherent with the division imposed by the algorithm in ten parts and a consequent set of lines equal dimensioned with a value of 5 meters, that it is an arbitrary dimension that need to support the theoretical knowledge of the design parametric approach.

In the second exact there are two yellow panels that show the total length and the partial dimension of the sublines of the geometry in the equilibrium state. In other words, the "C" shows the lengths of every single line, or spring, differently increases in relation to the distance of one particle to the anchor points; looking the "D" the yellow panel shows the total dimension of the deformed geometry.



Total length initial state:
(0) L: 50,000000 meters

Partial length initial state:
(0) L: 5,000000 meters
(1) L: 5,000000 meters
(2) L: 5,000000 meters
(3) L: 5,000000 meters
(4) L: 5,000000 meters
(5) L: 5,000000 meters
(6) L: 5,000000 meters
(7) L: 5,000000 meters
(8) L: 5,000000 meters
(9) L: 5,000000 meters

Total length equilibrium state:
(0) L: 53,766647 meters

Partial length initial state:
(0) L: 5,415259 meters
(1) L: 5,390435 meters
(2) L: 5,370729 meters
(3) L: 5,356987 meters
(4) L: 5,349914 meters

SECOND INSTRUMENT HOOKE'S LAW

(5) L: 5,349914 meters
(6) L: 5,356987 meters
(7) L: 5,370729 meters
(8) L: 5,390435 meters
(9) L: 5,415259 meters

Total length's increment (x):
(0) L: 3,766647 meters

Partial length's increment (x):
(0) L: 0,415259 meters
(1) L: 0,390435 meters
(2) L: 0,370729 meters
(3) L: 0,356987 meters
(4) L: 0,349914 meters
(5) L: 0,349914 meters
(6) L: 0,356987 meters
(7) L: 0,370729 meters
(8) L: 0,390435 meters
(9) L: 0,415259 meters

Percentage total length's increment:
(0) 1,8833235%

Percentage partial length's increment:
(0) 0,02076295%
(1) 0,01952175%
(2) 0,01853645%
(3) 0,01784935%
(4) 0,01749570%
(5) 0,01749570%
(6) 0,01784935%
(7) 0,01853645%
(8) 0,01952175%
(9) 0,02076295%

The component "Kangaroo Physics" applies an elastic behavior that follows the Hooke's law: Robert Hooke summarized his law of physics with the Latin anagram "ut tensio, sic vis" that in English can be translated with the sentence "the elongation is proportional to the force". The deformation of a body is directly proportional to the deforming force. The formula that justify this concept is:

$$F=k*x$$

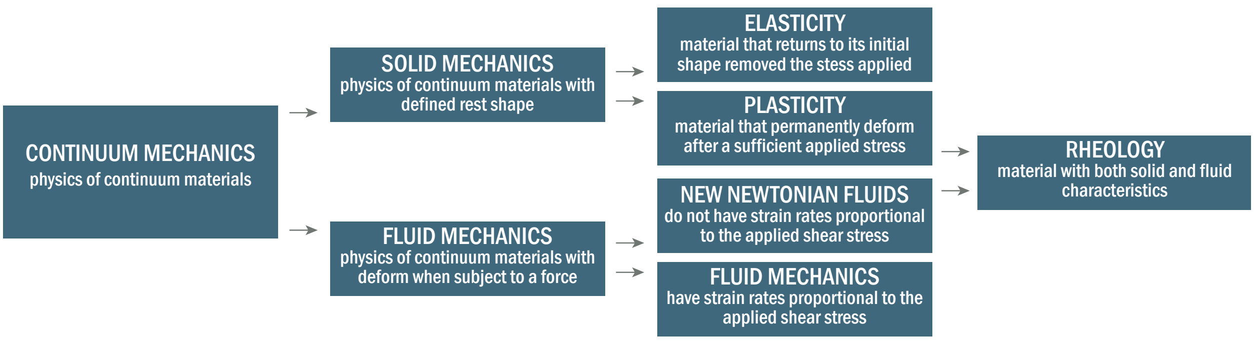
where:

- F is the force that, applied on the particles, is used to extend or compress the springs

- k is a positive constant factor, the stiffness, the value is characteristic of the spring's dependent to the material and the cross-sectional geometric properties of the elastic body

- x is the dimensional difference in length between the measure of the spring after and before deformation of the springs, the value must be small compared to the total possible deformation of the springs

Looking the data in the previous pages, related to the experiment explained in the previous paragraph, and linking them with the just explained Hooke's law it is possible to



SECOND INSTRUMENT HOOKE'S LAW

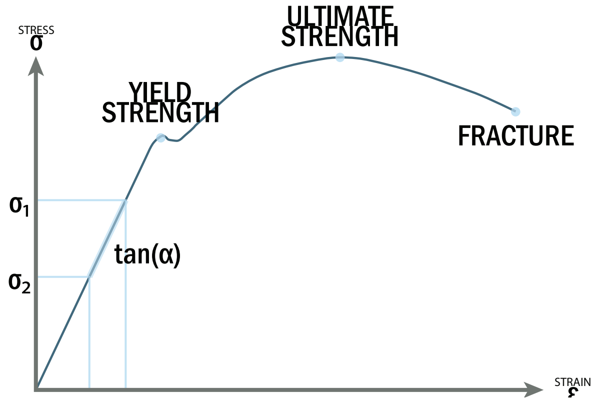
deduce two conclusions: the first one related to the characteristics of the materials and the second one the units of measure.

The Hooke's law is a theoretical method of simulating reality, a linear approximation of the first order to the real response of the springs to which forces are applied, this approximation is no longer valid when the forces exceed a maximum limit, the limit beyond which there are no materials which, when stretched or compressed, return to their resting state without having undergone permanent changes or deformations.

Anyway, a material has a rest shape in its initial state and a deformed shape when the forces applied are in equilibrium. The amount of difference between the rest shape and the deformed one is called deformation; the proportion of deformation is the strain. If the applied forces are relatively low, or the strain imposed is small enough, quite all the construction materials has a behavior such that the strain is proportional to the stress, the coefficient of the proportion is the Young modulus. The region of deformation is called linearly elastic region.

So, the use of the linear elasticity as mathematical model is justified by the fact that it regards infinitesimal strains and linear relationships between the components of stress and strain, then it is valid only for stress states that has not yielding. Linear elasticity is used in different fields of the construction industry linked to engineering materials. In this thesis the model resulting of the algorithm that uses the model of linear elasticity will be verified with the structural analysis supported by software FEM (finite element analysis).

Anyway, looking the already known Hooke's



law, F=k*x, to have a relation with material characteristics it is necessary to find the relation with the Young modulus (E). Using like reference a simple plank of an elastic material as a specimen, applied two opposite forces in its ends, to simulate a tension condition, the material will deform. The deformation is equal to:

$$\varepsilon=x/L$$

where ε is the linear expansion coefficient defined like the ratio between the amount of stretching (x), the length measured after force's application (L+x) minus initial length (L), and the initial length of the plank. In the same try analyzing the tension developed:

$$\sigma=F/A$$

where σ is the force of tension applied in a volume unite of surface, acting in an area of the specimen, defined like the ratio between the force applied (F) and the area of the section of the specimen (A).

Taking for example the stress-strain graph of the concrete it is possible to arrive to some conclusions:

-along the curve that describes the behavior of the material, or specimen, tested it is clear a first phase where increasing the

SECOND INSTRUMENT HOOKE'S LAW

force, and consequently the stress, deformation's value increases too, every ration between stress and correspondent strain is equal all along the curve

$$\sigma_1/\varepsilon_1=\sigma_2/\varepsilon_2$$

-then, the ratios between stress and strain are equal to the tangent of the angle generate by the inclination of the curve in the graph crossing a horizontal line (α), so that the tangent tan(α) is equal to the Young modulus of the material (E), that in this case is concrete

$$\sigma_n/\varepsilon_n=tan(\alpha)$$

where:

$$tan(\alpha)=E$$

so:

$$E=\sigma/\varepsilon \text{ and } \sigma=E*\varepsilon$$

so:

$$E*\varepsilon=F/A$$

and multiplying the area(A) in both the members of the equation and considering the deformation a-dimensional as $\varepsilon=x/L$:

$$A*[E*(x/L)]=A*(F/A)$$

so:

$$F=A*[E*(x/L)]$$

where, it is findable the relation with the Hooke's law:

$$k=(E*A)/L$$

this is the value of K with a relation with a specific material thank to the E modulus that is statistical tabled.

Going in deep and analyzing the real value of the concrete we can find the units of measure; it is useful in the Kangaroo setting where the units are not a-dimensional by default but it is possible to set them using the correct values and the right relations between them.

The Young modulus of the concrete is:

$$E=14\text{-}41\ GPa$$

that is equal to:

$$E=1{,}4\text{-}4{,}1*10^{10}\ N/m^2$$
$$\text{or } E=1{,}4\text{-}4{,}1*10^{4}\ N/mm^2$$

so, analyzing the k value, $k=(E*A)/L$, using a-dimensional relations the results are:

$$k=(E*A)/L=[N/m^2]*[m^2]/[m]$$

but $E=1{,}4\text{-}4{,}1*10^{10}\ N/m^2$ and:

$$k=1{,}4\text{-}4{,}1*10^{10}\ N/m$$

where the value of k is determined by a range between 1,4*1010 N/m and 4,1*1010 N/m, the difference of value is linked with the type of the concrete. The units of measure are justified by the a-dimensional correspondence with the Hooke's law:

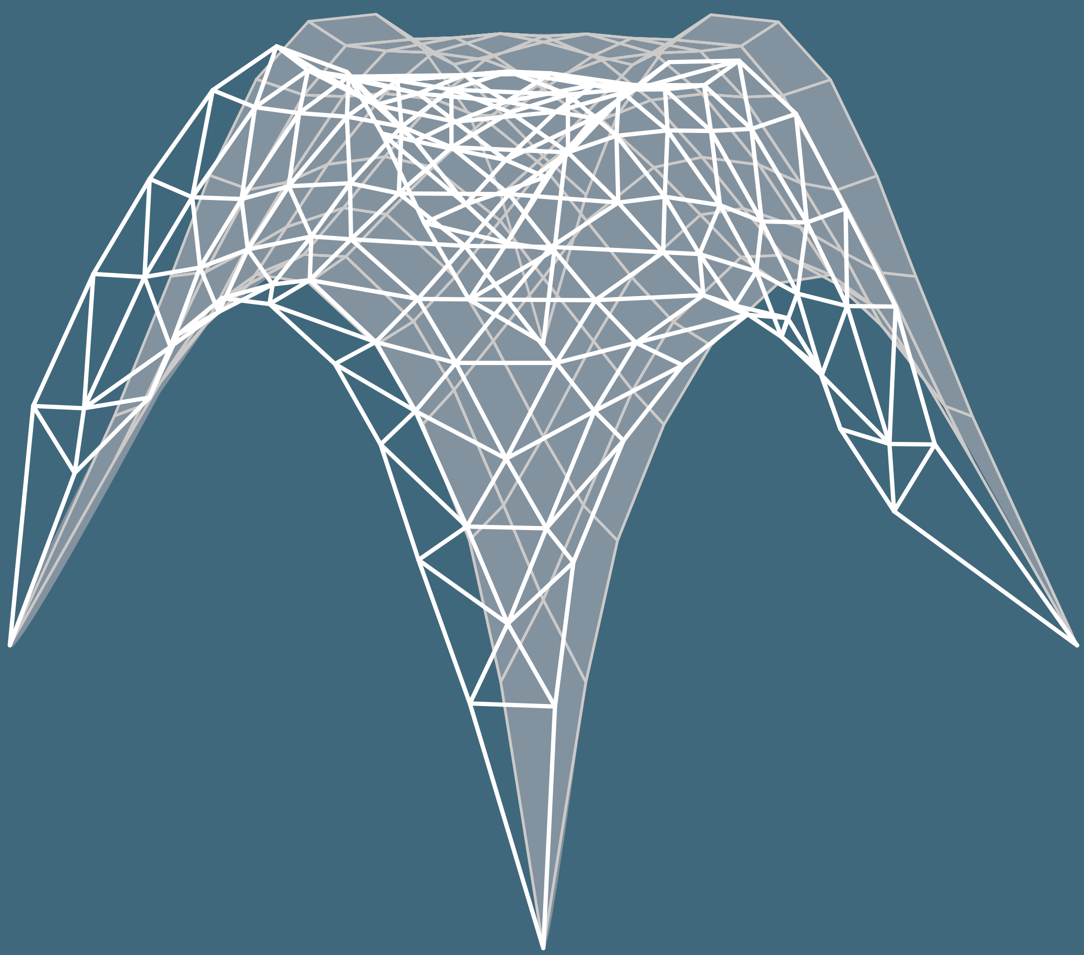
$$k=F/x\ [N/m]$$

CHAPTER FIVE

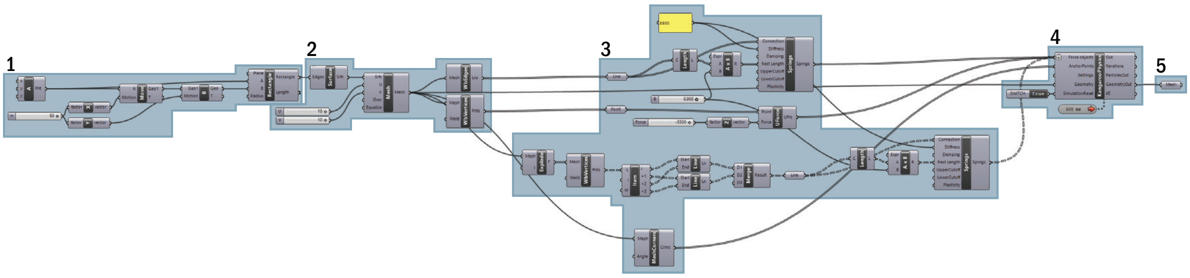
PARAMETRIZATION

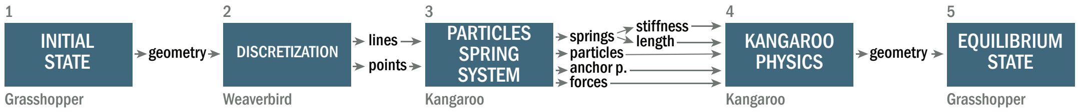
The form of universe is absolutely perfect, conceived by the wisest of creators, nothing happens in the world without the evidence some minimum or maximum rule

Euler (*Principles of Maximum and Minimum*)



Moving from the simulation of a cable to a membrane the first step is to convert a NURBS surface to a mesh, then, as in the example of the previous chapter, to extract edges and vertices from the mesh to transform them into particles and springs of a particles-spring system. The five steps are summarized in the schemes below. Analyzing step by step every phase of the algorithm allows to check the difference and improvements with the experiment of the previous chapter. The principles are the same and this is the approach that will be used for the final shape of the concrete membrane that will support the decking of the bridge subject of the thesis' work.





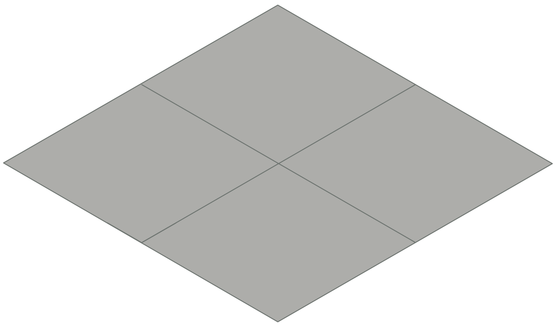
The image created specifically for the summary diagram of the first page of this chapter is a diagram that should summarize all the situations that the following chapter will present.

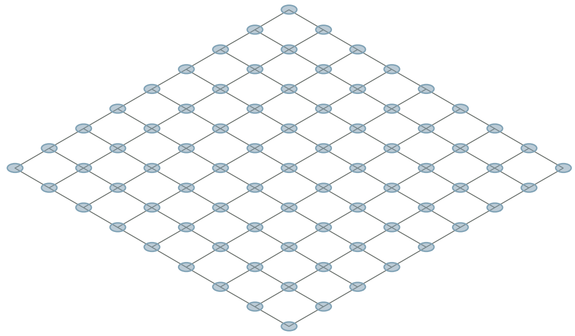
A mesh is a mathematical function that simulates forms, these gforms are discretized through simple and repeated geometric figures, on these functions it is possible to apply algorithms that simulate real behaviors by generating other deformed meshes. The shape of the deformations allows the designers to be able to interpret the structural behavior and act accordingly.

OVERVIEW PARAMETRIZATION

1 INITIAL STATE

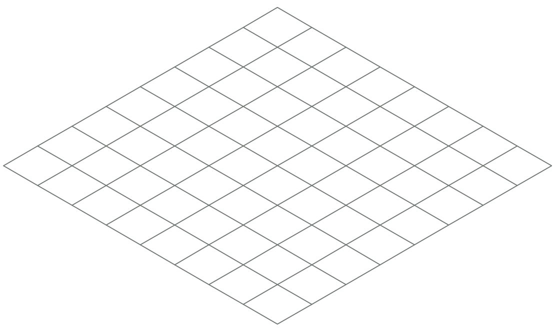
The initial state is the composition of the basic geometry: parametrically it is set two points, the distances are controlled by domain sliders to have the possibility to modify it from the beginning. The two points are the extremes of the diagonal line of a rectangular flat shape: it is mathematically a surface that will be converted in mesh object.

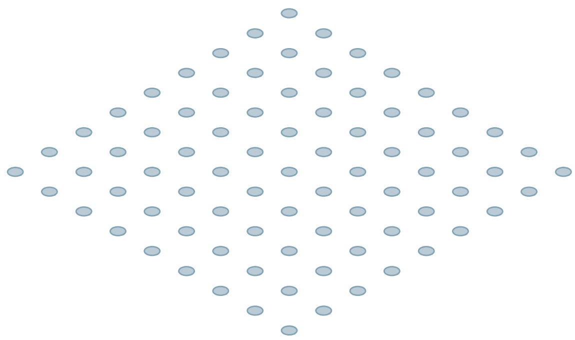




2 DISCRETIZATION

Considering the surface composed in the first step, keeping in mind the idea that it will have four anchor points at the four corners, to allow the discretization it is necessary to transform the surface into a mesh and from it to extract vertices and edges. The membrane, so obtained, will be subjected to gravity loads using the particles-springs systems.

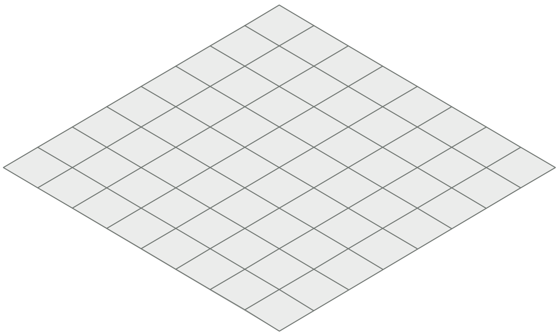


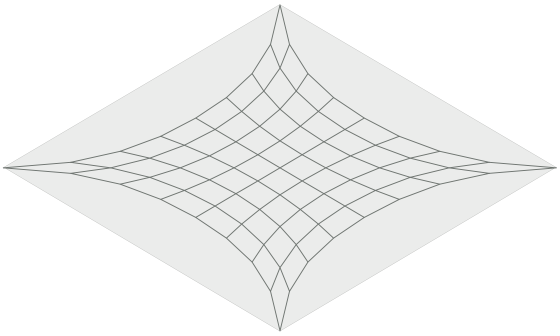


3 PARTICLES-SPRINGS SYSTEM

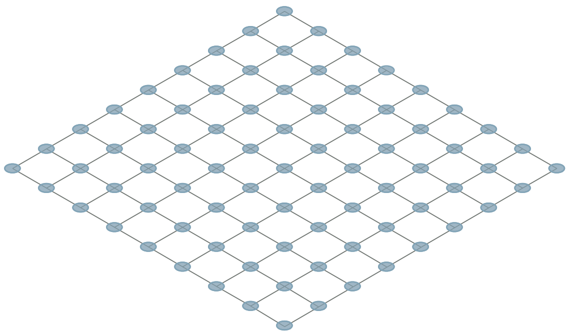
The particles-spring system is the process' phase after the discretization of the model where the points become particles and the lines are springs. Following the order of the algorithm schematized, initially we can find the "Weaverbird Edges" output connects to the "Rest length" input thought the component "Length" useful to determine the maximum length of every springs inside the mesh: the deformation of the springs is influenced by their position in the membrane, basically the distance from the anchor points, so the length of the springs has a common maximum dimension regulated by a slider that can limit the elongation and consequently also the position of the particles in the equilibrium state. Connected to "Springs" Kangaroo component there is a yellow panel with a fixed value: it is the k value of the stiffness of the springs in the membrane, this value is not referred to specific material but it was obtained by experiments with the algorithm following the goal to find the "limit anchor" matching forces' intensity and k value. The same stiffness value is reproposed also in the second "Springs" component to have an equal value everywhere in the model.

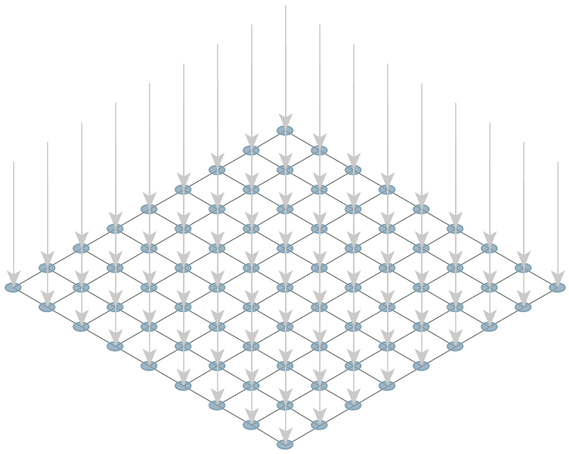
OVERVIEW PARAMETRIZATION



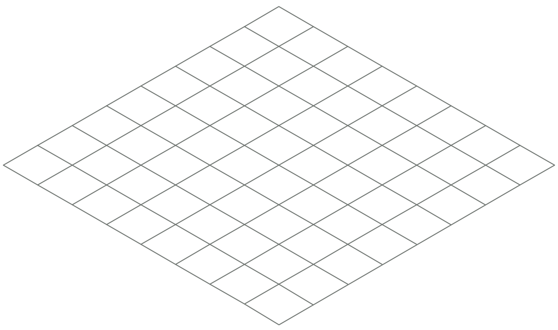


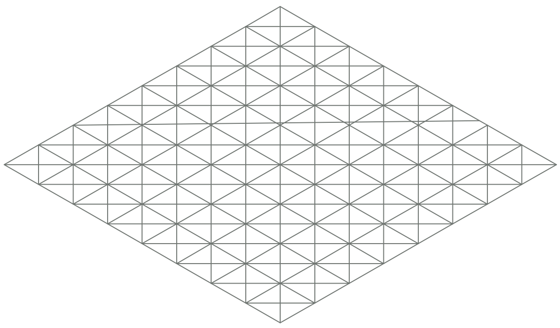
In the second part of the particles-springs system the output “Weaverbird Vertices” is connected directly to the engine “Kangaroo Physics” thought the component “Unary Force”: component generator of vectors, in other words forces applied to the particles along the Z axes, and the intensity, set by the slider that determines a domain, has a negative sign, the direction.





The third part of the of the particles-spring system is an imposed additional step that needs to simulate a more rigid membrane, basically the part of the algorithm generates diagonals in every square of the net to generate another mesh arrangement, the new cables generated are connected with the second “Springs” component, and a fixed k value. More rigidity needs to minimize the movement of the particles in the equilibrium state so that less deformation allows to apply a higher intensity of the loads and a consequent more resistance of the final structure.



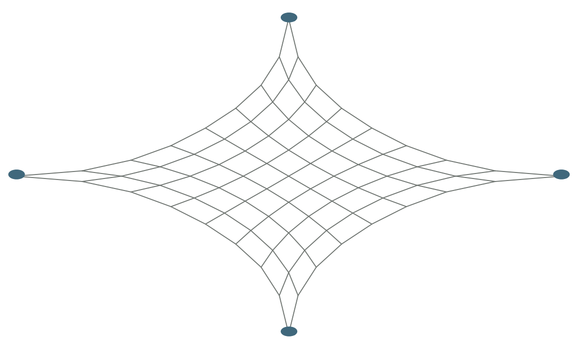


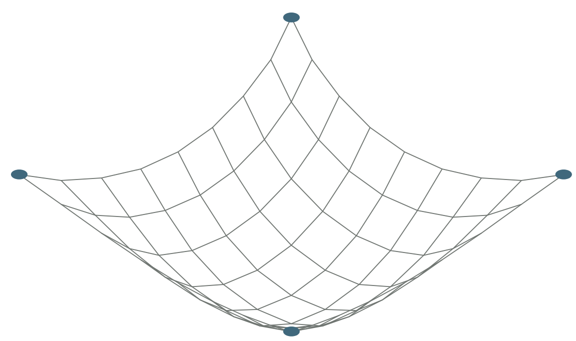
The fourth part of the particles-spring system phase is the anchor points: in this simulation are anchored the corners of the membrane in order to study, both in the initial and the equilibrium state, a symmetrical shape useful to analyze the statical model and propaedeutic for a bridge structure.

OVERVIEW PARAMETRIZATION

4 KANGAROO PHYSICS

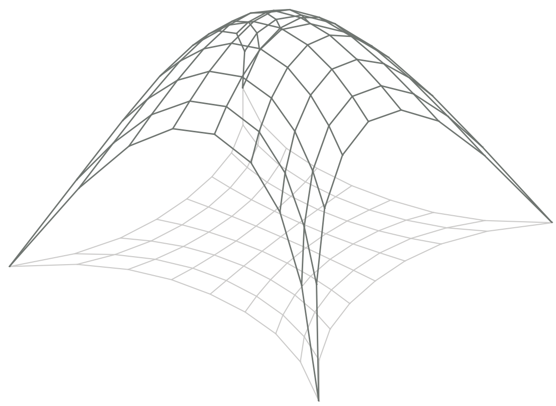
All the actions collected in the phase three, in other words the particles-springs system, are connected to the input “Force Objects” in the component “Kangaroo Physics”, except the anchor points that have a specific input. The component merges all the data at the same time and the algorithm transfer the same conditions every springs and particles discretized. The component “Switch” starts and stops the simulation: started the simulation in the membrane modifies the position of the particles and the length of the cables not directly to the equilibrium state but passing thought intermediate phases until the achievement of the equilibrium. The component of the particles-springs system can be modified also finished the simulation: the components “Rest Length”, “Unary Forces” and “Stiffness” can be managed to find the limit shape of the membrane. Simulating the model increasing gradually the value we can find the most performing form with the same distance of the anchor points in order to have the highest compressive strength reachable with this system of form-finding.

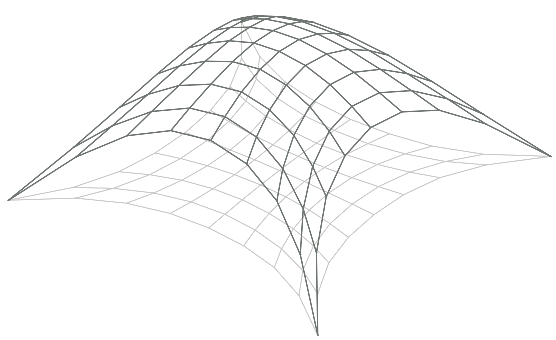




5 EQUILIBRIUM STATE

5 When the particles of the membrane stop to move stimulated by the parameters set in the particles-springs system phase the equilibrium is reached. The resulting geometry is a form-finding shape of a membrane. This membrane, in its reverse configuration, is most performing form that resists to the loads with intensity proportioned with the loads that were used to shape the structure itself.





FIRST TRANSFORMATION SHELL BEHAVIOR

From now going over in the approach explanation we don't act in the construction of the shape but in its behavior analysis. As it is introduced by the paragraph's title the subject is the transformation of the form-finding membrane "discovered" in a shell. In statics, to analyze a structure, its reactions are studied under stress, for this reason the necessity is to have a model that is able to behave as close as possible to reality. The main difference between a mesh and a shell is the behavior: the particles of a mesh have a behavior similar to a spherical hinge, without moment capacity, so a discretized model can't be rigid without additional restraints, the direct result of a reverse mesh, like the examples in the point five of the previous paragraph, stimulated by vertical forces is a crumpling more and more evident as strength increases.

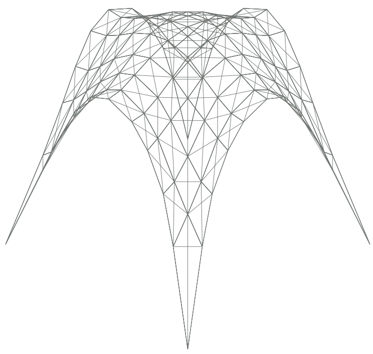
In the article "La Cupola Costa Paradiso", written by the architectural critic Giulia Ricci for Domus in the copy of August 2018, she told a collaboration between clients and architect for the realization of a house for vacation in Sardinia. All of the three characters were famous during the 60': the clients were a couple the film director Michelangelo Antonioni and the actress Monica Vitti, meanwhile the architect was Dante Bini the inventor of the "Binishell", patent for the realization of reinforced concrete hemispheres by spreading the materials on the ground and lifting them by the air pressure alone. The article is not an elegant description of an architecture realized, as it is typical in an architectural magazine, but the interpretation of a relationship between client and architect, then drawings and pictures leave to the reader the freedom to evaluate if the house satisfied or not the requests of the clients. As it is written in the article "Antonioni asked him (Dante Bini) to design a three-dimensional space, permeable by the sun that dries the soil all around, the rain that realizes the scents of the scrub, and the sound of the sea breaking on the rugged red coastal rocks". Taking a look to the representations of the architecture it is possible to admire an exposed concrete hemisphere perforated: the important lesson of design is the correct use of shape, structure and material in the same time. As Ponte sul Basento of Sergio Musmeci, Cupola Costa Paradiso is perfectly insert in the location and satisfies the needs for which it was designed. Then the resistance of the structure is easily readable: the location is exposed to the winds of the Sardinian coast and the dome itself is walkable in its exterior surface, the concrete is freely workable and perforable and the resulting shape is compositionally expressive.

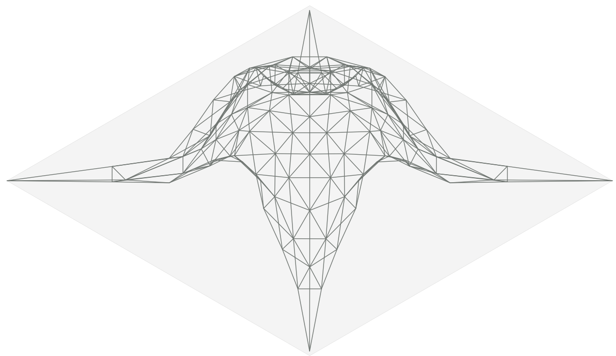
So, starting from the mesh realized in the point five of the previous paragraph of the current chapter, after the "Bake", the mesh itself is at the beginning of the following algorithm (schematized in the bottom of the page). After the discretization of the edges and the vertices of the mesh, set in Rhino, the points are connected to an "Unary Force" component and the edges are converted into springs while the diagonals are generated exploding the initial mesh and joining the opposite vertices.

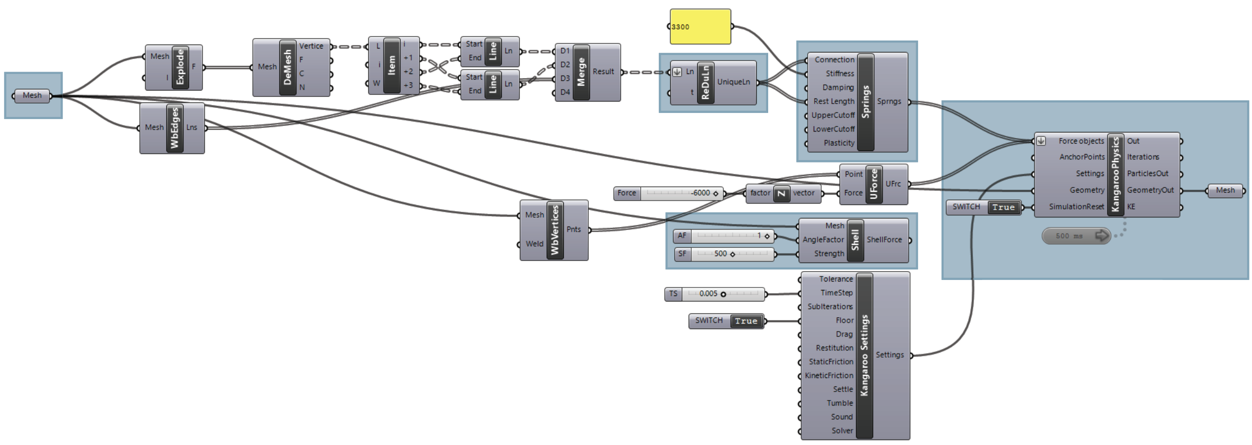
The starting mesh and the diagonals that take part of the consequent arrangement of the mesh are merged. The component "merge" units the data from more model's outputs merging them in a only one model, with the component "ReDuLn" (below highlighted, full name RemoveDuplicateLines) there is the remotion of equal elements and characteristics. The "Springs" component,

FIRST TRANSFORMATION SHELL BEHAVIOR

set a stiffness value, applies in the final model of the algorithm all the conditions set before. The component "Shell" the model acquires the characteristic of a shell, useful to analyze a prelaminar behavior and to use the plug-in "Karamba" in the following step of analysis.
Looking the drawings the shape of the model has an high resistance thank to its shape, both in terms of grid arrangement and symmetry of the parts. The most evident collapse is represented by the "feet" of this structure that in the bridge project phase will be improved in the connection with the ground.





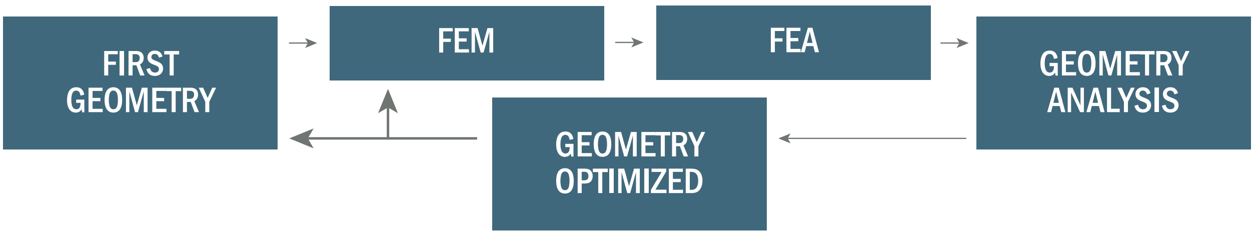


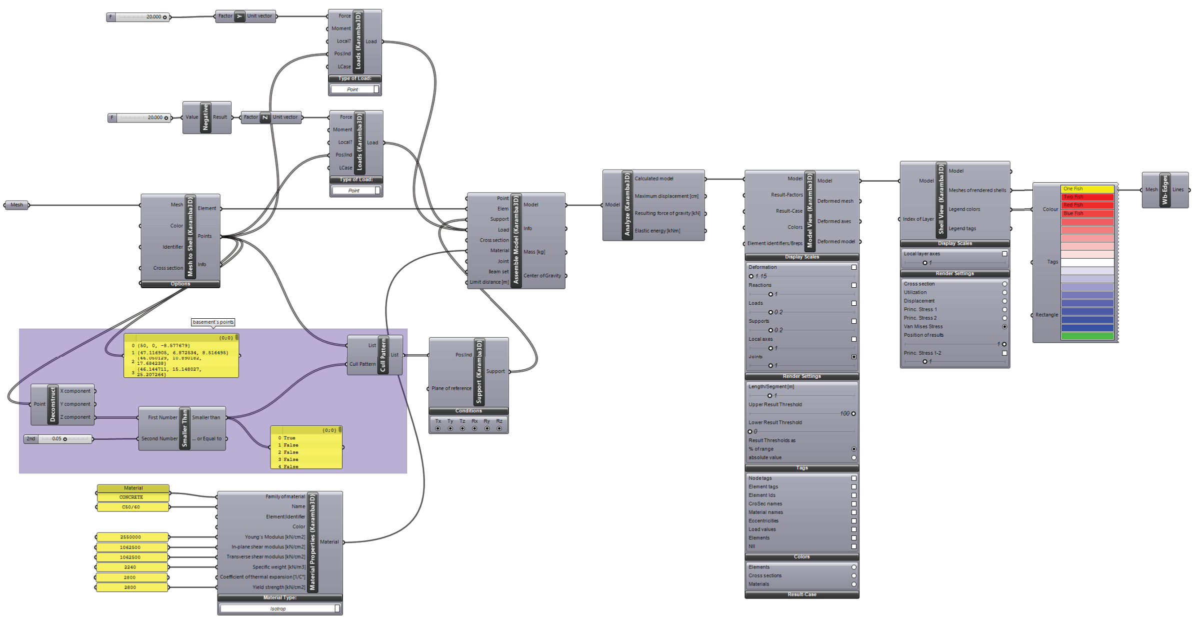
SECOND TRANSFORMATION **OPTIMIZATION**

From now going over the important lesson of design is the correct use of shape, structure and material in the same time. As Ponte sul Basento of Sergio Musmeci, Cupola Costa Paradiso is perfectly insert in the location and satisfies the needs for which it was designed. Then the resistance of the structure is easily readable: the location is exposed to the winds of the Sardinian coast and the dome itself is walkable in its exterior surface, the concrete is freely workable and perforable, the resulting shape is compositionally expressive.

Arrived at this point the geometry produced has to be optimized thought a calculation process that minimizes the assigned function of fitness within a boundary domain. After the optimization the process of generation of the shape is done. A geometric optimization is defined by some elements, as it is schematized below:

- starting from a geometry generated by the previous set of algorithms, called in the scheme “First Geometry”
- the geometry is then analyzed in two sub-processes “FEM” (Finite Element Method) and “FEA” (Finite Element Analysis)
- then the step “Geometry Analysis” is the observation of the graph resulted by the two previous steps, here the shape can be modified looking where the material is not necessary to the functioning of the shape
- finally, the last step, called “Geometry Optimized”, could be the final arrangement of the structure or if it not satisfy the needs fixed at the beginning there are two





SECOND TRANSFORMATION OPTIMIZATION

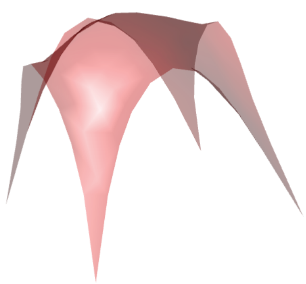
ways the first is the generation of another "First Geometry" acting in the initial algorithms or to do another time the analyses with the phases of the finite elements. the basial notion is that the "First Geometry" maintains during all the process its initial topology.

Looking the algorithm in the previous page, the first component is "Mesh", it contains the mesh resulted from the algorithms described until the current paragraph, the here called "First Geometry" is a baked geometry in Rhinoceros and all the changes acted to its from now will need for the future "Bake".

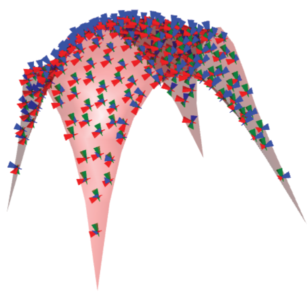
All the features set in the first geometry are components of "Karamba". It is a parametric structural engineering tool fully embedded in the parametric design environment of Grasshopper, Karamba simplifies the combination of parameterized geometric models, finite element calculations and optimization algorithms for spatial trusses, frames and shells. In the "First Geometry" we have to set: supports, loads, material; so automatically the visualization of the software shows them in the model view with local axes of every mesh's point and the reactions of the fixed supports.

- The location of fixed supports: in this case are the four corner points, in the component "Supports" the part "Conditions" allows to fix in every direction.

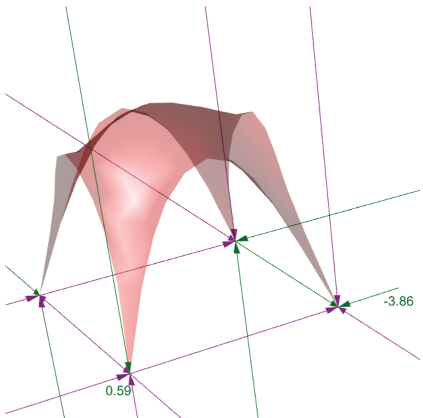
- The concentrated loads: in this case are described by vectors in two direction, Z and Y, with magnitude modifiable by sliders, these two conditions are an experiment to verify different type of loads like weight and wind forces.



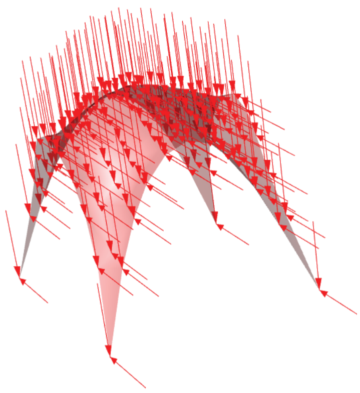
FIRST GEOMETRY



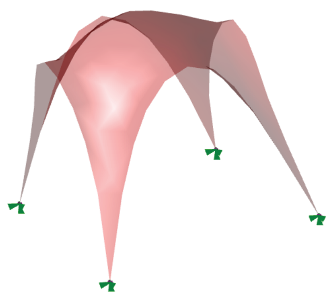
LOCAL AXES



SUPPORTS



LOCAL LOADS



FIXED SUPPORTS

- The material: in this case the concrete is inserted with a component that permits to personalize the material by it is possible also to choose one from the Karamba's libraries, the concrete C50/60 was selected to see the behavior of a simple shell before to use it in the bridge's structure.

Going over with the thinking, the algorithm generates different diagrams that are useful for the designer that has to take decisions for the project's result. The geometry generated and used until now is a sort of experimental shape useful to easily show the design process. So, in this chapter we can find some results of the algorithm but in the following chapters it will be a basic algorithm for FEM analysis, as it showed in the scheme at the beginning of the paragraph.

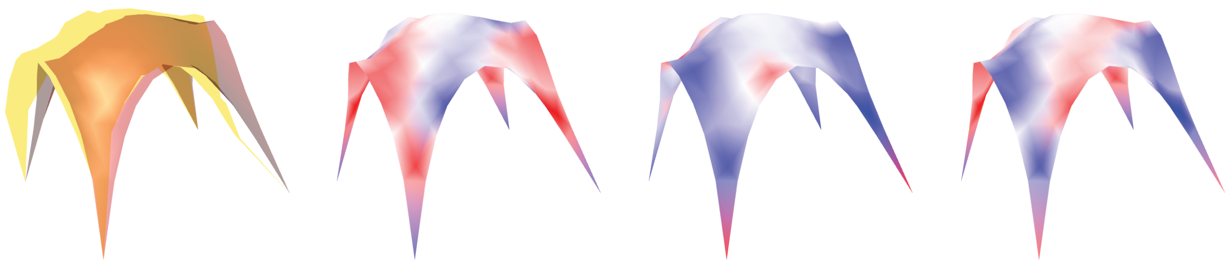
As below are sampled: fixing supports location, loads location and magnitude, material the algorithm generates diagrams:

- deformation, looking at the same time the "First Geometry" and the same deformed gives the opportunity to check the differences between the two states of the same elements

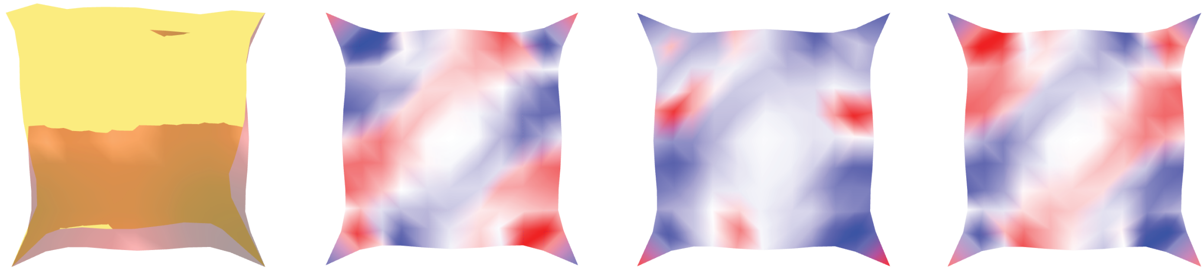
- utilization, it is the analysis of the distribution of forces on the geometry, according to the force pattern, set by the designer, the diagram is the application of a series of Rhinoceros-modeled modules

- princ. stress 1, the first principal stress is the value of stress that is normal to the plane where the shear value is zero, this colored diagram needs to understand the maximum tensile stress induced in the geometry due to the load conditions

- finally, Von Mises stress, it is a value used to determine if and where a material will yield or break, this diagram shows a geometry, with given material, under load has a yield limit that satisfies the Von Mises criterion, this criterion is equal or great-



DEFORMATION **UTILIZATION** **PRINC. STRESS 1** **VON MISES STRESS**



SECOND TRANSFORMATION OPTIMIZATION

er than the yield limit of the same material under simple tension.

The resulted diagrams, taking into account the principles that determine the colored patterns in the geometries, need to decide if the research can finish or it is necessary to come back and to modify something in order to solve the problems that this final analysis brought out.

“L’architettura, e non soltanto quella strutturale, è un campo dove oggi occorre rischiare. Chi non rischia vuol dire che sta imitando oppure ripetendo. Se si vuole invadere un campo nuovo, si deve affrontare l’ignoto“

Sergio Musmeci

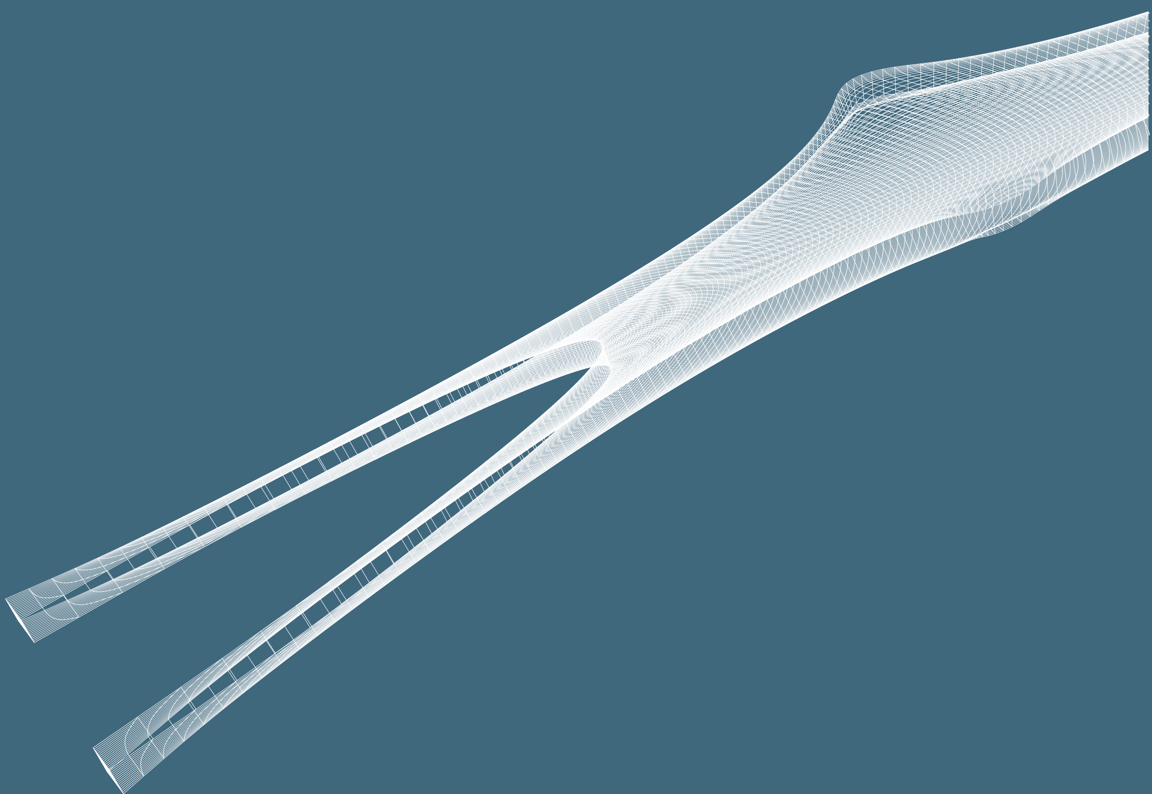
“Nowadays rchitecture, and not just the structural one, is a field where we need to take risks. Whoever does not take risks means that he is imitating or repeating. If you want to invade a new field, you have to face the unknown “

CHAPTER SIX

ARCHEAMPROJECT

Modernism was founded on the concept of space. Parametricism differentiates fields. Fields are full, as if filled with a fluid medium.

Patrik Schumacher (*Parametricist Manifesto*)



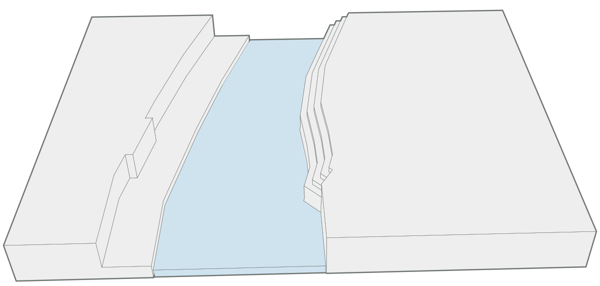
Going deeper in the in the thesis' project, in this chapter and the following one we will how the theory of the previous two chapters can be applied. The concept of form-finding lives in the project of a bridge in two souls and, in turn, every soul has inner mechanisms that lead the entire process.

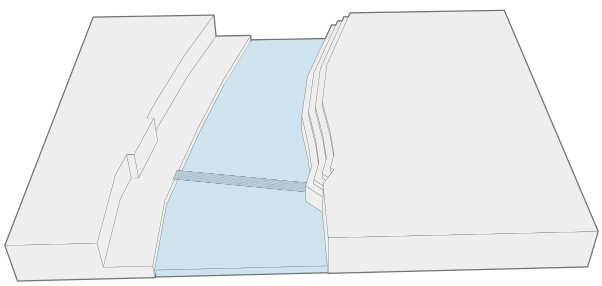
The goal that, as a designer, has been fixed is to pass the span of the river without piles in the riverbed. The solution could be a set of arches that supports the upper decking but the relation between height and length of these arches are not advantageous to support a 170-meter-long roadway. Moreover, the additional inclined beam that touch the decking in part different than the aches' keystone have mainly two problems: they would be cluttered for the activities of the ancient staircase and the activity in the Murazzi's pedestrian paths, then this type of proposal, to resist better, would be symmetrical in all its parts but the morphology of the place doesn't allow it.

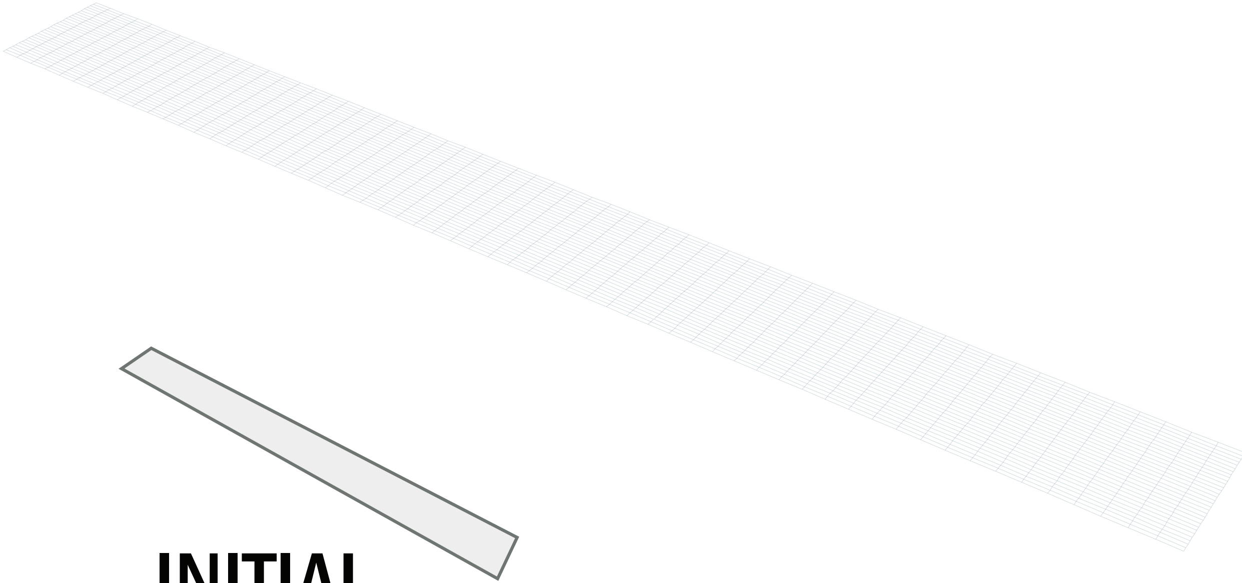
So, a smart solution is to use the Parametrical Design. The necessity is a curved surface that can be adaptable in both the river's banks and conceived as a single piece, it reacts in every part in the same way. The slab explained in this chapter is an architectural object that at the same time is form and structure. It wants to be a critique the modern architectural approach that defines curved surfaces like determined formal language. Many examples of contemporary Architecture use the forms end in themselves with the consequent large technical effort to solve statical problems that in building site stage they presented.

So, free from the concept of free-form the application of structures and statical notions to generate shape explains, with the Parametricism, in digital what Sergio Musmeci or Heinz Isler did with an experimental approach: form-finding of structural surfaces. The task of the architect is what the architects do since they lived the Ancient Greece: they coordinate all the professionals in order to achieve a mediated and qualitatively appreciable result. So, the research of statical optimal forms it is done through the study of the form itself. This approach is a sort of method that unifies the architectural freedom of design with the engineer's pursuit of efficient structures.

Below there are two schemes. The first one represents a portion of the plot of the project: clearly distinguishable spaces and proportion between the distances. In the second one we can see the first step of the argorithm inserted in the plot: what in the previous chapter is called "initial geometry" here is long rectangular with main dimensions, the algorithm, thanks to the parameters imposed, will modify the perception of the form until an equilibrium state where the membrane will be done.







INITIAL GEOMETRY

ALGORITHM'S PARTS

STATICAL PHASES

In this paragraph there is a sort of description of the parameters used to generate the structural slab of the bridge. Every page has a graphic reference: a sort of logo of the parameter used and the real membrane deformed without the parameter that the logo represents. In a few word, using the generative algorithm, reported in the last pages of the current chapter, every phase described has an image result of the same algorithm but with the parameter under description switched off. This rule is valid for all except the first two: “initial geometry” and “anchor points”.

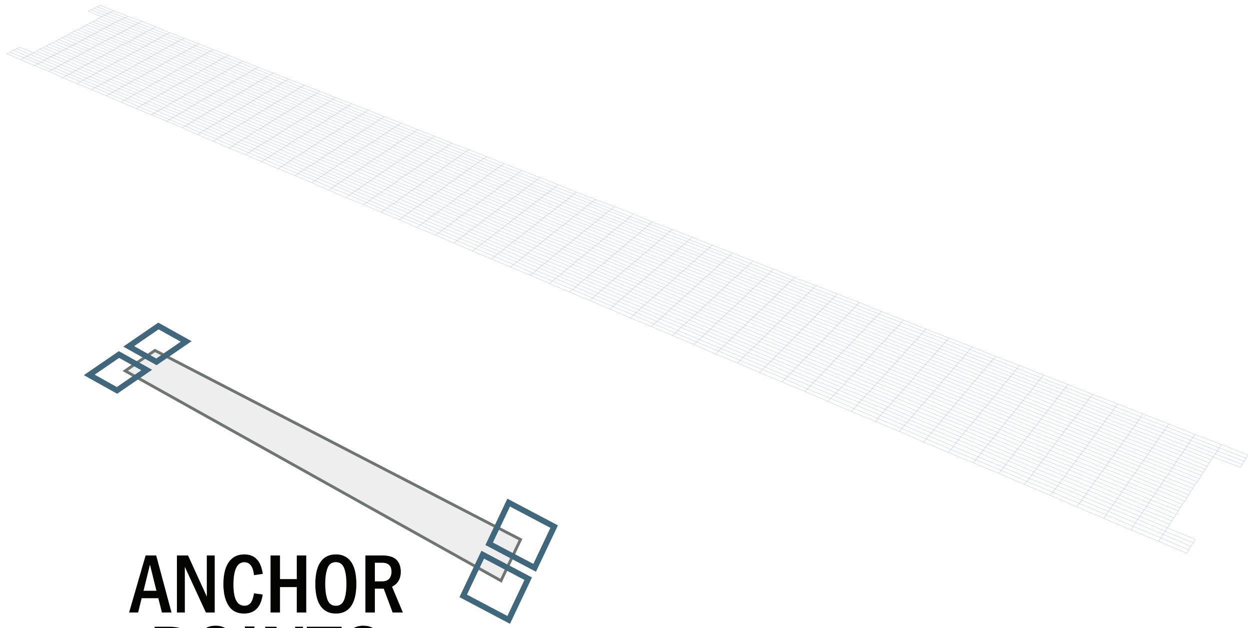
In this page we can see the first phase of the process where the Kangaroo Engine is turned off and all the parameters are not add to the draft geometry. As we can see in the previous page, the “initial geometry” is a rectangular portion of space fixed like flat and junction between the two banks of the river in order to have a preliminary arrangement of the elements that will make up the structure:

- an approximation of the position of the restrains

- the continuity of the of the material.

The first point is justified by the construction of the “initial geometry”: setting four points, all of them connect one to the others, and then assumed like corner of the rectangular. In a second moment, the generation of the shape gives to the designer the suggestion that the restrains have to be in the shorter sides of the rectangular.

Coming back for a second, as it is described in the chapter three during the analysis of the project’s place, using a parametric approch there are basically three options of design not invasive from the naturalistic and historical-artistic point of view:



ANCHOR POINTS

- a beam bridge between the two sides of the river at the streets' levels

- a bridge with every type of substructures but the use of the riverbed like place of supports

- a bridge that use the pedestrian path of the Murazzi, in the western side, and the slope of Parco MIchelotti, in the estern side, like place of supports.

The third one is the most advantageous: leaving the fisrt option where 170 meters of beams have disadvantafes under different points of view, the last is considered better than the second one because has a stronger relation with territory and, under the structural point of view, allows to have a less impact of the water loads in the substructure with consequent compositional design all visible.

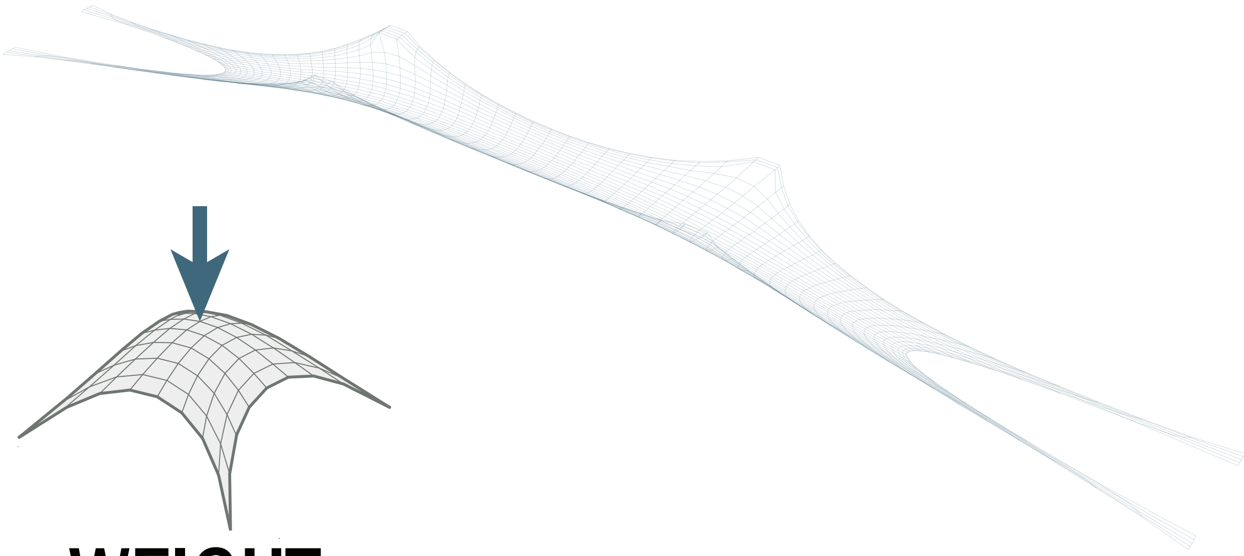
In this page, we can see a sort of evolution of the "initial geometry"'s thinking: more the process goes ahead, reaching the equilibrium phase, more the algorithm automates the process.

The "anchor points" are set of points located in areas of the geometry. The geomtry is conveterted in a mesh in order to act to her using the points that compose herself.

As we can see in the graphic above there are the cutted part resulted after the definition of the anchor areas: the removal of these points allows to decrease the number of points and lines in the entire mesh doing a first step of smilling of the membrane.

Now, the membrane can be seen like a flat structure with an hight number of beams all places along a flat plane with anchors in four parts. It has basically two problems:

- right now, it has been designed considering the distance between the banks in the Murazzi's level so it is usefull for an upper



WEIGHT LOADS

decking

- then, this sort of structure doesn't have a good resistance to compression loads and a consequent low resistance in general.

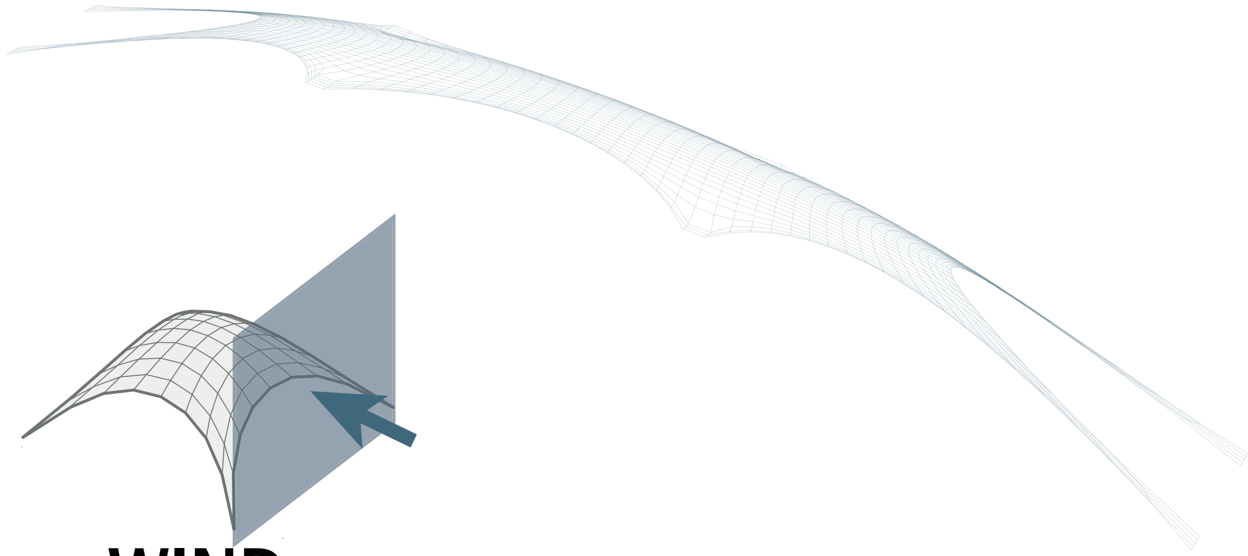
In the grapics of "weight loads" there is the application of the algorithm without the the loads that simulate the weight of the object slab itself and the upper decking. The result that we can see is a membrane with an arch really small which tends to flatten out. This condition comes infinitesimally close to the beam condition with all the consequences that a beam has.

Coming back for a second, as it is described in the chapters four and five, during the theoretical explanetion of the algorithm, all the condition are applied to the "initial geometry". Then, after reaching of the equilibrium with the use of the Kangaroo Engine, the membrane is turned upside down. In this way the resulting turned membrane support all the loads that arrive in the opposite direction to the one used during the generation of the shape.

So, even if in the logo the arrow represents the direction of the weight in the construction of the algorithm it would be positioned in the opposite direction. For these reasons is in the drawing of the membrane the loads are applied the form start to grown moving upward assuming a more toned and taut, resistant appearance.

In the algorithm the arrows that rappresent the weight loads are applied in every points of the mesh. All the arrows have the same magnitudo, it is the maximum that calculated the bridge has to support during its life. Anyway in the chapters four and five the application of the vertical loads from top to bottom are fully explained.

In the graphic "wind loads" we can take a look to the schemes that represent the applicatio of the loads that simulate the wind. In the earth's atmosphere, meteorological



WIND LOADS

phenomena are produced by the sun's radiation, they give rise to thermal regimes and pressure fields responsible for movements of the air masses. The analysis of wind actions and effects on constructions is based on the assessment of the wind speed V in the construction site.

The speed V applies on the construction, and for extension on each individual element, a system of aerodynamic actions F_s, functions of the shape, orientation and dimensions of the invested body. To analyze wind loads it is necessary to know the wind speed V and its direction in oder to find the height of the gradient, function of the parameter z_0, called roughness length.

So, considering the aerodynamic shape of the membrane with a maximum distance of 8 meters from the center and a nominal life of 50 years, we obtain from the NTC 2018 that the place of impact is in zone 1.

Zone 1: Valle d'Aosta, Piemonte, Lombardia, Trentino Alto Adige, Veneto, Friuli Venezia Giulia (without Trieste) where:

$$v_{b,0}=25 \text{ m/s}$$
$$a_0=1000 \text{ m}$$
$$k_s=0,40$$

$V_{b,0}$ is the basic reference speed at sea level, (Tab. 3.3.I, NTC 2018) according to the area in which the building is located. Then, a_0 and K_s are parameters provided in Tab. 3.3.I from the NTC 2018 according to the area in which the building is located. So, the reference speed:

$$v_r=v_{b,0}*c_r$$

where:

$$c_r=0,75* \sqrt{1-0,2*\ln*[-\ln*(1-1/T_r)]}$$
$$c_r=0,34$$

c_r is the return coefficient, a function of the project return period T_r, in this case equal to 50 years. So, came back to the reference speed, it is equal to:

$$v_r=25*0,34=8,5\ m/s$$

Now, we can calculate the reference kinetic pressure q_r, whose formula can be derived from the Bernoulli equation:

$$q_r=1/2*\rho*v_r^2$$
$$q_r=45,15\ N/m^2$$

ρ is the assumed air density conventionally constant and equal to 1,25 kg/m³. The exposure coefficient c_e depends on the height z above the ground of the point considered, the topography of the terrain and the category of exposure of the site where the construction is located. Then, considering the exhibition area A (Tab. 3.3.III from the NTC 2018, A class includes urban areas in which at least 15% of the surface is covered by buildings whose average height exceeds 15 m) and site exposure category V (Fig. 3.3.2 from the NTC 2018) we have to take into account:

$$k_r=0,23$$
$$z_0=0,70\ m$$
$$z_{min}=12\ m$$

so:

$$c_e(z)=k_r^2*c_t*\ln(z/z_0)*[7+c_t*\ln(z/z_0)]$$
$$\text{for } z\geq z_{min}$$
$$c_e(z)=c_e(z_{min})$$
$$\text{for } z<z_{min}$$

Then, conidering z_{min} equal to 12m all the volume of the membrane is under the value. now, the objective is to find the pressures of the wind against the structure in this project site. So, we consider two two significant values: one (z=12m) to z_{min} and therefore in correspondence with the membrane and the other (z=16m) greater than z_{min} and therefore not directly affecting the membrane. As it is schematized in the previus page, in the algorithm the higher pressure was set in the whole vertical wind speed profile in order to obtain a precautionary result and a more symmetrical shape. anyway, the calculation of the exposure coefficient is that:

$$c_{e1}(z=12)=1,37$$
$$c_{e2}(z=16)=1,51$$

c_t is the topography coefficient, generally set equal to 1, both for flat areas and for wavy, hilly and mountainous areas. The wind pressure is given by the expression:

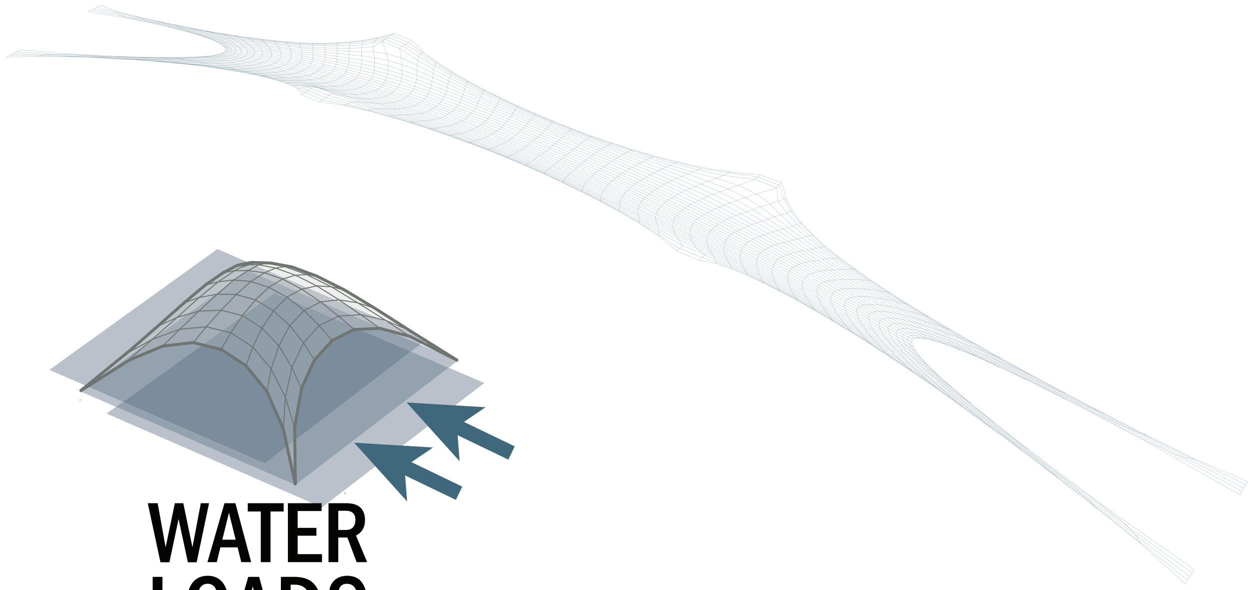
$$\rho=q_r*c_e*c_p*c_d$$

q_r is the reference kinetic pressure; c_e is is the exposure coefficient; c_p is is the pressure coefficient, it depends on the geometry of the construction and its orientation with respect to the direction of the wind, therefore considering the direction of the belly against the long side of the membrane, the slope of the curvatures of the same, the coefficient is equal to 0.8; c_d is the dynamic coefficient, it takes into account the effects associated with the non-contemporaneity of the maximum local pressures and their effects on the construction due to the dynamic response of the structure, it can be assumed as a precaution equal to 1 or statistically obtained.

$$\rho_{(z=12)}=49,48\ N/m^2$$
$$\rho_{(z=16)}=54,54\ N/m^2$$

As already mentioned above, the algorithm has been set with a constant and precautionary wind pressure value of ρ=60 N/m².

Moving to the graphic "water loads" we continue to analyze generative parameters. The membrane, object of this chapter, is the slab that, as a substructure, sopports the loads that act to the infrastructure. A design choice is not have pile or extrastructure inside the river, in other words the riverbed doesn't in-



WATER LOADS

fluence the work of the entire structure. But the with the expression “water loads” are all the forces that the river water exerts on the foot of the membrane every time the floods exceed the level of the Murazzi, covering the pathway.

Four foot, considered like 4 inclined piles, immersed in 5 meters of water for an approximate total of the submerged length of 11.11 meters. The feet are oriented at an angle of approximately 8 degrees to the direction of the flood current. The characteristics of the river flood in the section close to the project are obtained from a calculation of permanent motion in correspondence with the two hundred year flood, made available in the website of Aipo (Agenzia Interregionale per il fiume Po):

- progress of project 0,916 km

- height of riverbed 225 m (s.l.m.)

- height of flood 235 m (s.l.m.)

- water speed during the floods is an avarage of 2 m/s

- flow rate 1540 m^3/s

The first step is to define the flow class. Considering to make three sections of the river in correspondence with the axis of the bridge, these are located respectively, according to the direction of the current, one before the river, one in correspondence with the bridge and one after. The shrinkage ratio r is considered as a cross section of rectangular shape, it is defined as the ratio between the measure of the free section b_1, at the narrowing between its feet, and the transverse width b_0 of the river before and after construction, the obstacle.

$$r=b_1/b_0$$

where b_1 is equal to 141,74 m, meanwhile b_{0m} is equal to 156,60 m before the obstacle and b_{0v} is equal to 115,13 m after the obstacle, so:

$$r_m=b_1/b_{0m}=0{,}90$$
$$r_v=b_1/b_{0v}=0{,}91$$

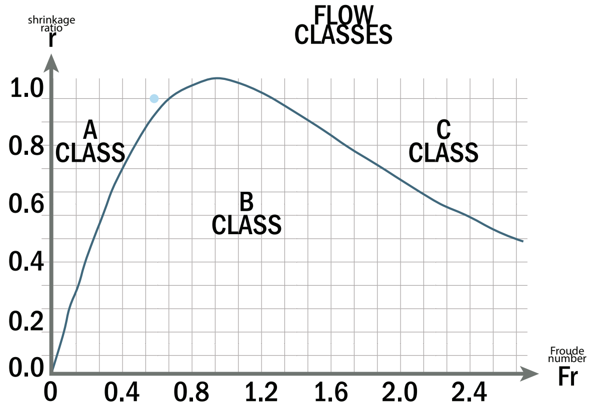
So, based on the hydraulic characteristics of the current and the degree of shrinkage due to the presence of the membrane feet in the bed, it is possible to divide the types of outflow into three classes (A, B and C). The different modes of outflow can be represented by a relationship between the Froude number Fr of the current in the section corresponding to the obstacle, b_0, and the one after the obstacle, b_{1v}, and the shrinkage ratio r, where neglecting the loss of energy in the passage from one section to another, the simplified equation is finally obtained:

$$r_v^2=27*[Fr^2/(2+Fr^2)^3]$$

so:

$$Fr=0{,}50$$

it represents the minimum energy condition for the passage through the shrinkage as the Froude number of the undisturbed current varies for the given shrinkage ratio r. If you report on the graph below the point with coordinates (0.50; 0.91) it is observed that the point is in the region that identifies the class A outflow: the current is slow before the obstacle and remains so through the narrowing and after the obstacle itself. Considering the



result of the graph, the currents being little turbulent Rehbock's formula is valid, it is:

$$\Delta y=K_R*(1\text{-}r)*(V^2/2g)$$

where Kr is Rehbock's form coefficient with approximate form semicircular nose and tail equal to 3,35, so:

$$\Delta y=0{,}06$$

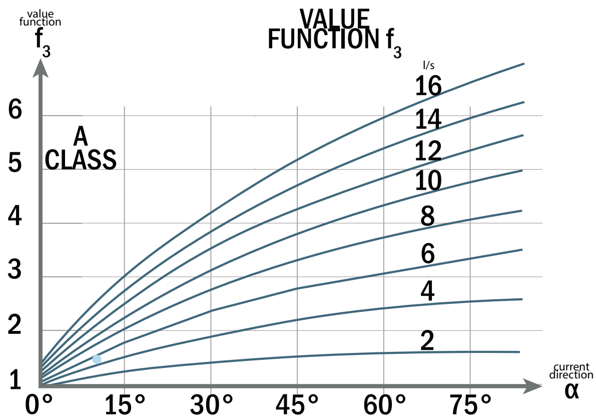
Then, considering the heigh of the water's level y_1 equal to 7 meters, because is the sum between the height of the river in Turin equal to 2 meters and the hypotesis of flood's level equal to 5 meters, the new level influnced by the presence of the obstacle is $y_0=y_1+\Delta y=7{,}06$ meters. So, having defined the hydraulic characteristics of the current at the bridge, one can proceed with the calculation of the pressures.

$$d_s/s=f_1*(v_0/v_{cr})*[2*TAN(h)*(y_0/s)]*f_2(shape)*f_3(\alpha,l/s)$$

where d_s is the depth of the excavation measured from the bottom of the undisturbed riverbed; s and l are the dimentions of the membrande feet; v_0 is the average speed of the current considered 2 m/s in the Po; v_{cr} is the critical speed and α is the angle that the current forms with the foot that in this case is 8 degree.

$$v_{cr}=0{,}85*\sqrt{2g*d*[(\gamma s-\gamma)/\gamma]}$$

Being γs the specific weight of the material (γ_s=26000 N/m³) which constitutes the bottom and γ that of the water (γ=9810 N/m³) and d=d50=0,12 meters we obtain v_{cr} equal to 1,68 and therefore V_0/V_{cr}=1,19. Therefore the function f_1 is equal to 1 because $V_0/V_{cr}>1$ and f_2(shape) is considered 1 because the foot have rounded face. The function f_3 takes on the value 1.5 because α=8 degrees the ratio between the dimensions is 5,5. As it is



summarized in the diagram above.

Now, to calculate the force exerted on the feet of the membrane by the water current, it is necessary to apply the global equation of dynamic equilibrium to the volume between the section before the obstacle, the section after the obstacle, the riverbed and the level. of the water in the direction of motion, obtaining:

$$S_{foot}= \Sigma_m-\Sigma_v$$

where:

$$\Sigma_m=[\gamma*y_g*A+\beta*\rho*(Q^2/A)]_m$$

$$\Sigma_v=[\gamma*y_g*A+\beta*\rho*(Q^2/A)]_v$$

where Σ represents the total thrust, divided into the two hydrostatic and hydrodynamic parts; yg is the sinking of the center of gravity of the section below the water level and β is a coefficient of the momentum, it is assumed equal to 1.

$$\Sigma_m=9810[N/m^3]*3,53[m]*1105,59[m^2]+1*6100000\ [N/m^2]*((1540)^2[m^3/s]/1105,59[m^2])=1,32*10^{10}$$

$$\Sigma_v=9810[N/m^3]*3,53[m]*1095,21[m^2]+1*6100000\ [N/m^2]*((1540)^2[m^3/s]/1095,21[m^2])$$

so $S_{footTOT}$= 123656378,9 N and the final thrust of the water to the foot is:

$$S_{foot}= 0,5*\gamma*(\Sigma_m-\Sigma_v)/1000 = 6,06*10^5\ kN$$

Continuing with logic started for the previous algorithm's steps, the lods set for the thrust of the water is a precautional value of $S_{foot}/4$= 1,5*10^5 kN.

Moving to the graph of the following page, calle "Young modulus" we analyze to parameter that gives to the algorithm the material characteristics of the membrane. The Young modulus is one of the three modulus of esticity: the longitudinal modulus of elasticity. This modulus is the stiffness and it is defined as the constant of Hooke's law, as it is already descrbed in the chapter four:

$$E=\sigma/\varepsilon=\sigma/(\lambda-1)$$

where ε is the deformation produced by the tension σ and λ is the stretching factor, therized like the relation between the final and the initial arrangement of the deformed object. So, from the definition of the Young modulus it is possible to ind the Young's law replacing from the last formule the specifications of each element:

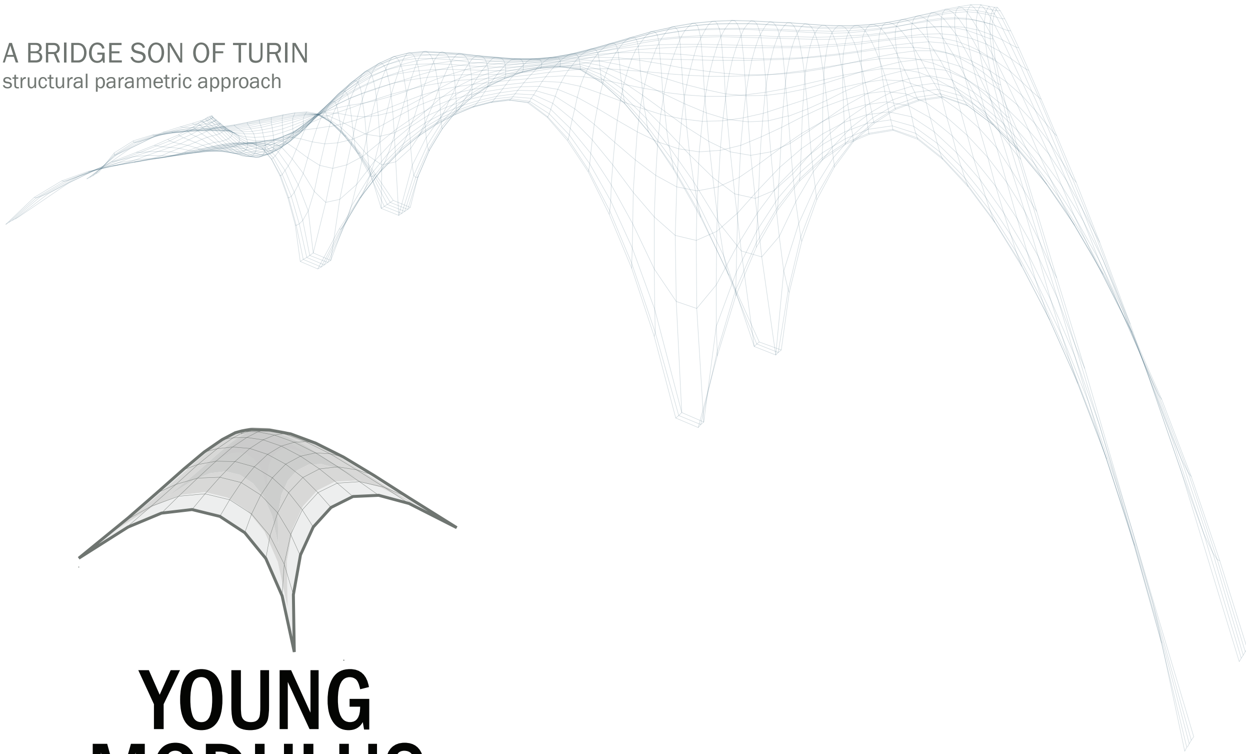
$$\sigma=E\varepsilon$$

where:

$$F/S=E*(\Delta l/l)$$

The Young's law allows to calculate the force to which an object is subjected by the modulus of elasticity, from the section perpendicular to the force, from the linear elongation and from the length at rest. The law can also be written by setting elongation as a research element:

$$\Delta l=(F*l)/(S*E)$$



YOUNG MODULUS

The correct use of the Young's law allow to set material's characteristics in the design's phase. Coming back to the algorithm's theory. The limit of the modulus is the inapplicability for structures made of several materials that work together: in the case of the designed membrane, reinforced concrete. So, a homogenization coefficient must be applied, it has a numerical value equal to the ratio between the elastic modulus of concrete and that of steel. These two materials work togheter properly:

- planar conservation of the cross section of the structural element

- perfect adhesion between concrete and steel

- uniform contraction of cement fibers and steel bars

- linear elastic behavior of materials respecting Hooke's law

So, considering the reinforced concrete like a singolar material is valid the condition of congruence where the two materials when are togheter have the same deformation:

$$\varepsilon_c=\varepsilon_s$$

so:

$$\sigma_c/E_c=\sigma_s/E_s$$

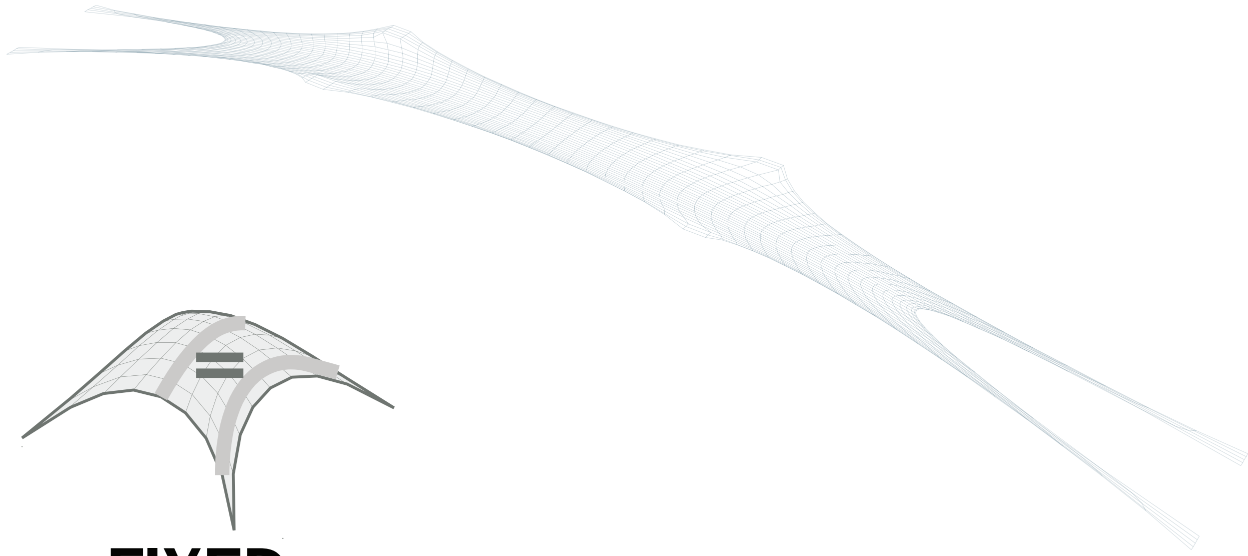
so:

$$\sigma_s=(E_c/E_s)*\sigma_c=n*\sigma_c$$

where n is the homogenization coefficient and its value depend by the types of concrete and steel used but considered its definition ($n=E_c/E_s$):

$$5<n=E_c/E_s>10$$

In the scheme above the membrane is the result of all the loads applied and reached the equilibrium with a stiffness equal to 0.
Concrete C40/50, E_c=35547,5, n=5,21.



FIXED LENGHTS

ALGORITHM'S PARTS COMPOSITIONAL PHASES

In this paragraph, the three parameters that have influenced the membrane at the compositional level have two different logics: in the first scheme, in the current page, we can see a parameter that is set before the equilibrium phase, the other two, in the following, page are set after the simulation of Kangaroo Physics.

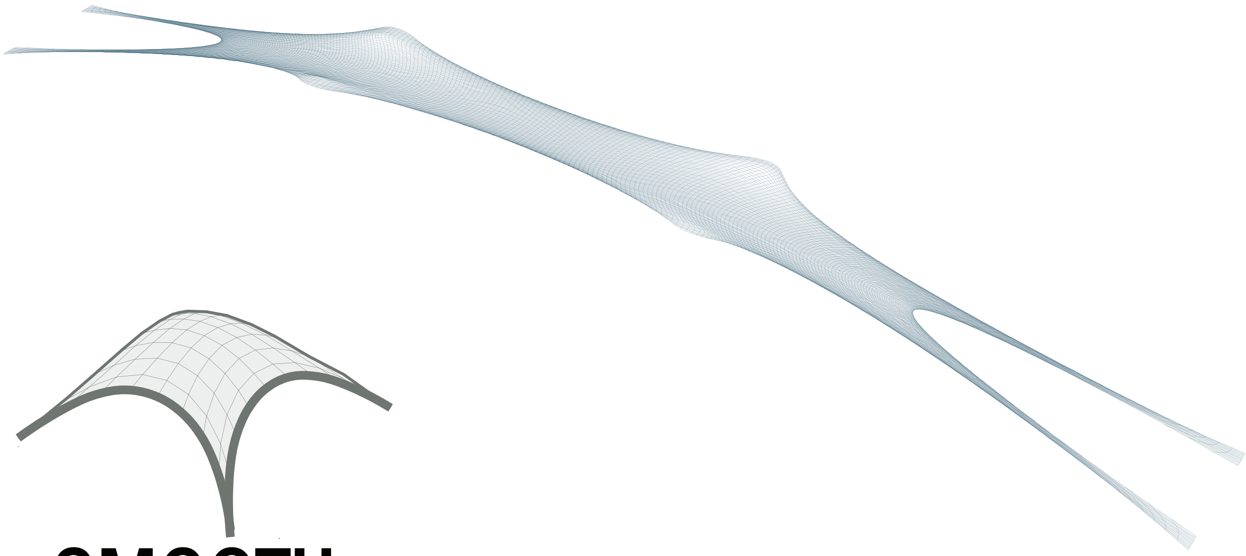
Step by step, in the scheme "fixed lenghts" there is a designer's choice: as we alread know, the membrane before to be a model of a reinfoiced concrete slab was a mesh and a mesh is made by lines and points.

After the equilibrium phase, according with the Hooke's law the points modify their poisition in space and thank to the points' movements the lines are deformed: they are no longer coplanar to a plane parallel to the ground and each line has a different deformation linked to its position within the mesh. This latter consequence is limiting from several points of view:

- in the design phase, the total number of rods is equal to the total number of reactions they have after a stress, this condition makes the sizing calculations unnecessarily burdensome, even if the deformations are very similar to areas they are however different, producing a non-homogeneity

- from the static point of view, symmetry is a condition that in bridge structures is not mandatory or indispensable but the tendency must always be in that direction, as the membrane is very closely linked in its shape to the territory in which it is located, as will be seen in the next chapter, it already has a dissymmetry in its generative phase that must be improved where it is possible

- during the construction phase, a so large reinforced concrete slab cannot be totally non-homogeneous in all its parts, looking



SMOOTH JOINS

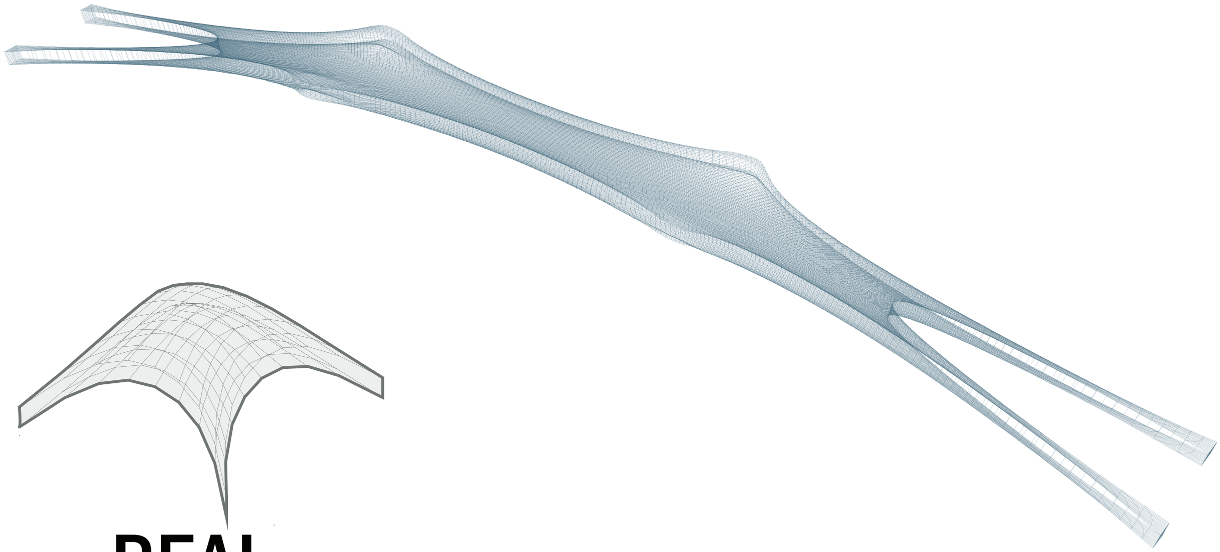
at the construction of the bridge over the Basento di Musmeci: the structure was cast with phased casting, assuming the current method as analogue an high difference between the parts leads to worsening of the site conditions, exposing oneself more easily to error.

The solution that it is set in the algorithm is to limitate the deformaion of the lines: a minimum length of the rods has been assigned, this condition for a free deformation to the largest rods and homogenizes all the smallest lines to a constant size. Under a mathematical point of view, a domain is set within which all the deformations of the members of the initial mesh must take place.

Following the same approach linked to the homogenization of the shape, to reach all the conditions that simplify the shape itself ,with the consequent approaching a condition of symmetry it is a precondition also for the scheme of the current page. In "smooth joints" is a prameter or the algorithm that modify the orientation of the deformed rods in order to smooth the entire membrane: the result of the application of this condition it is visible comparing the drawings "fixed lengths" and "smooth joints". The result favors the form under different points of view starting from a compositional approach.

The designed architecture becomes more organic, the basic concept of the intervention is the harmony that is created between the built and the natural, both elements present in the project lot. The aim of the structure is a single interconnected organism, an architectural space.

The resulting architecture is free from aesthetic research as an end in itself, the freedom of interpretation to tackle any theme, harmonizing it with the whole and seeking formally perfect solutions. various references could be made that come from Patrick Schumacher's Manifesto of Parametricism, to Frank Lloyd Wright's organic architecture and Paolo Soleri's theories. However, the monitoring of



REAL THICKNESS

the algorithm made it possible to implement some concepts:

- the membrane is itself a bridge where the material is reduced to a minimum and its continuous form implements an architectural unity

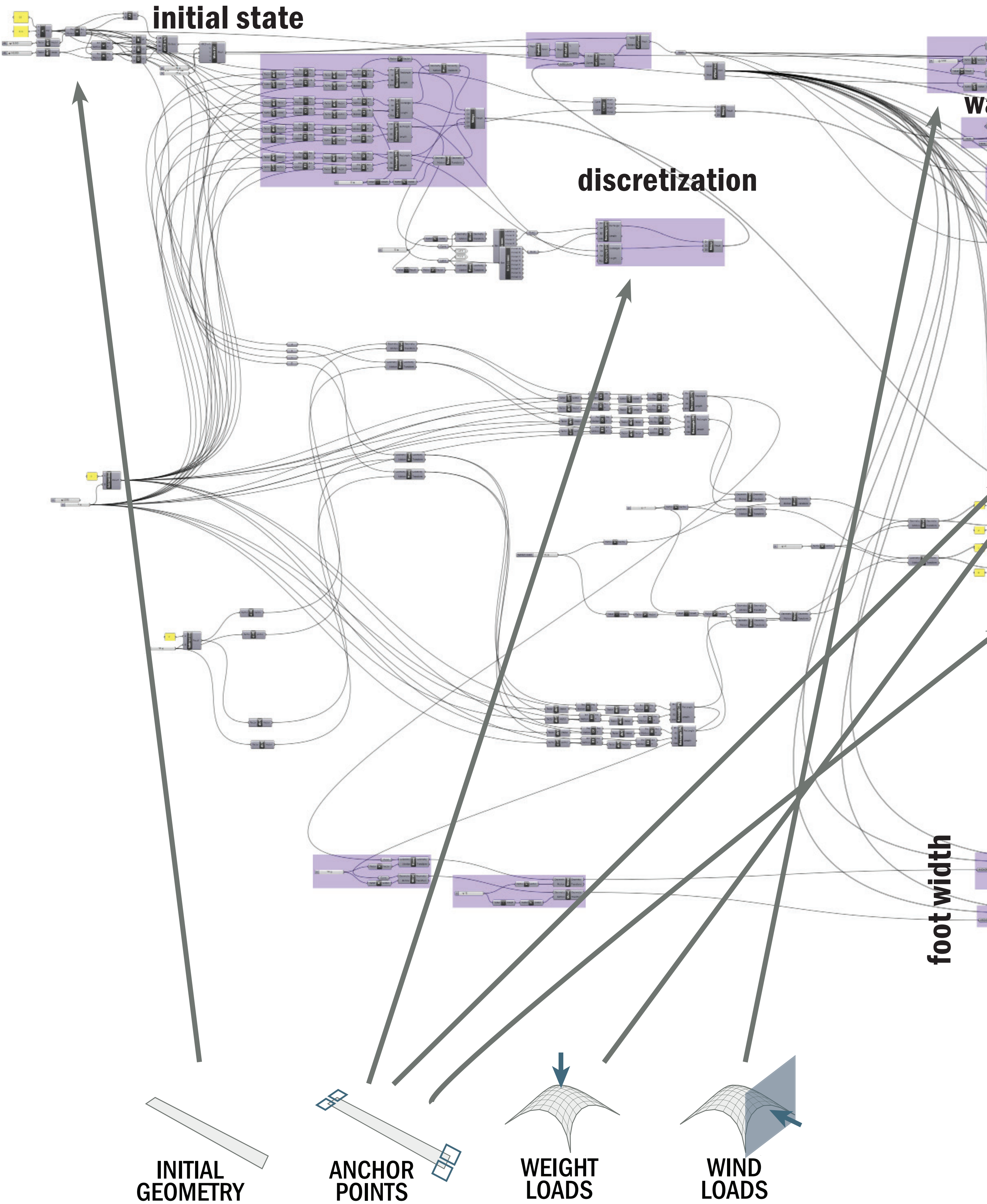
- structurally the proportions are logical and the spaces are calculated for human use, then, the mathematical control of the work allows modifications while maintaining the principles assigned to the algorithm from the beginning of the design.

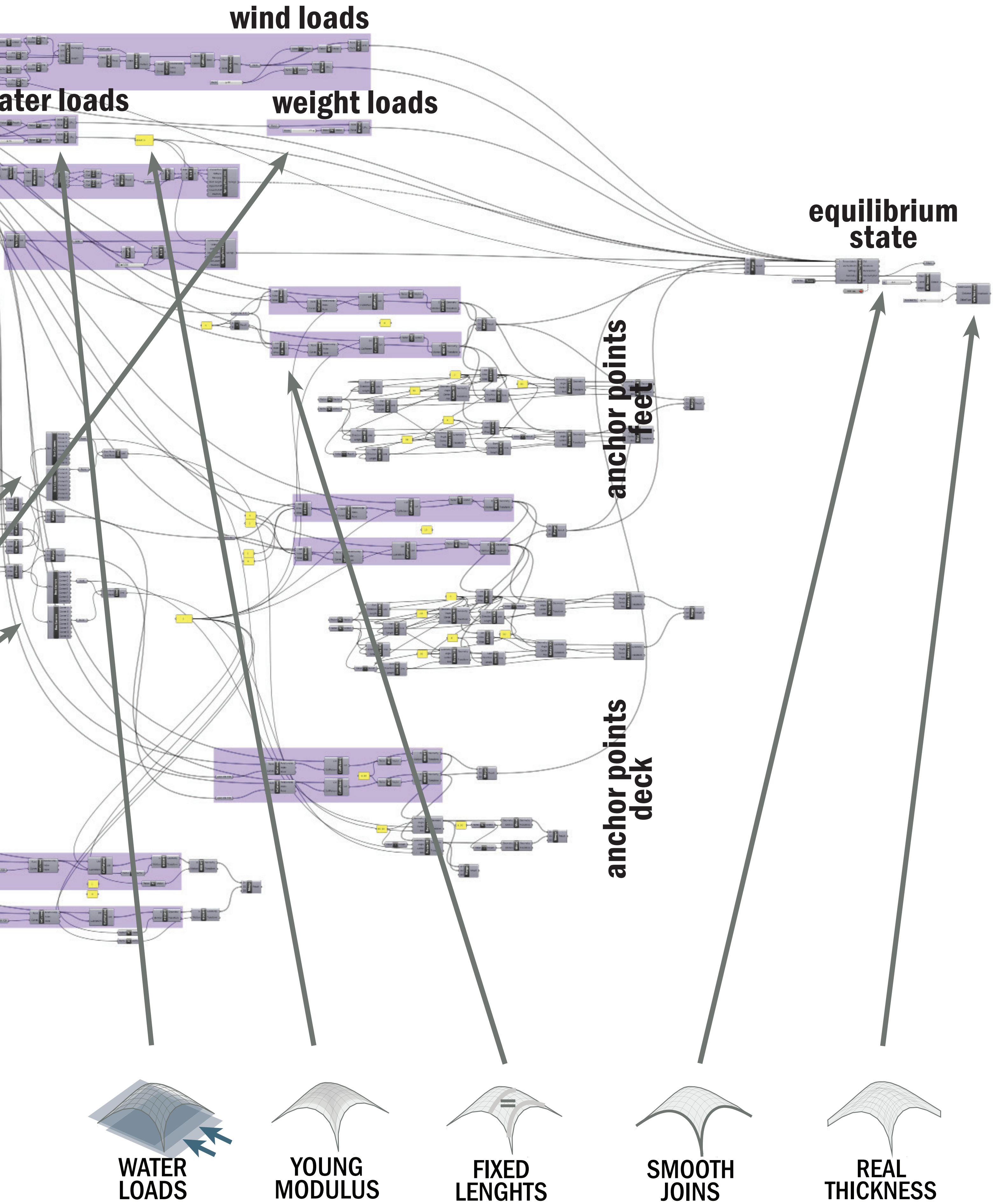
- avoid combinations of different materials, using as much as possible a single material whose nature must be linked to the construction becoming an expression of its function

- the structure of the membrane is aerodynamic external climatic forces, as already explained in the previous chapter, interact with the curved faces of the structure causing the minimum impact of them

The last step of this phase is the application through the algorithm of the thickness of the membrane resulted. Until now the menbrane was a mesh deformed with all the imposed conditions.

The parameters have sculpted the membrane to make it a statically resistant object by virtue of its shape. But in practice, a structure resists not only for its shape but also for the materiality of its thickness. The algorithm generates a thick consistent with the parts by swelling where it should thicken and shrinking where it should shrink. Like the human skeleton, bones are sized consistent with their function within the body.


initial state
discretization
foot width
INITIAL
GEOMETRY
ANCHOR
POINTS
WEIGHT
LOADS
WIND
LOADS


wind loads
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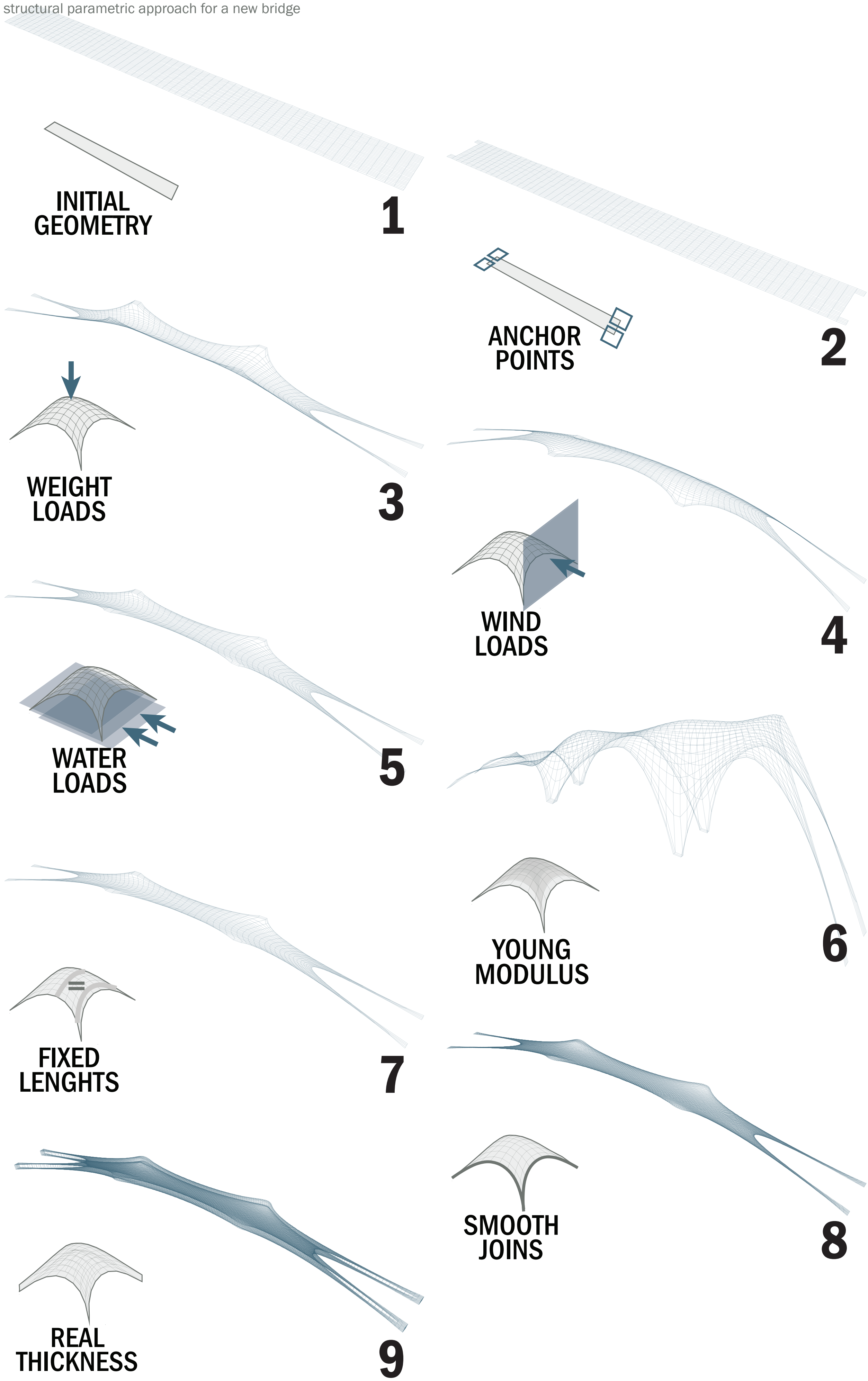
anchor points feet
anchor points deck
WATER LOADS
YOUNG MODULUS
FIXED LENGHTS
SMOOTH JOINS
REAL THICKNESS

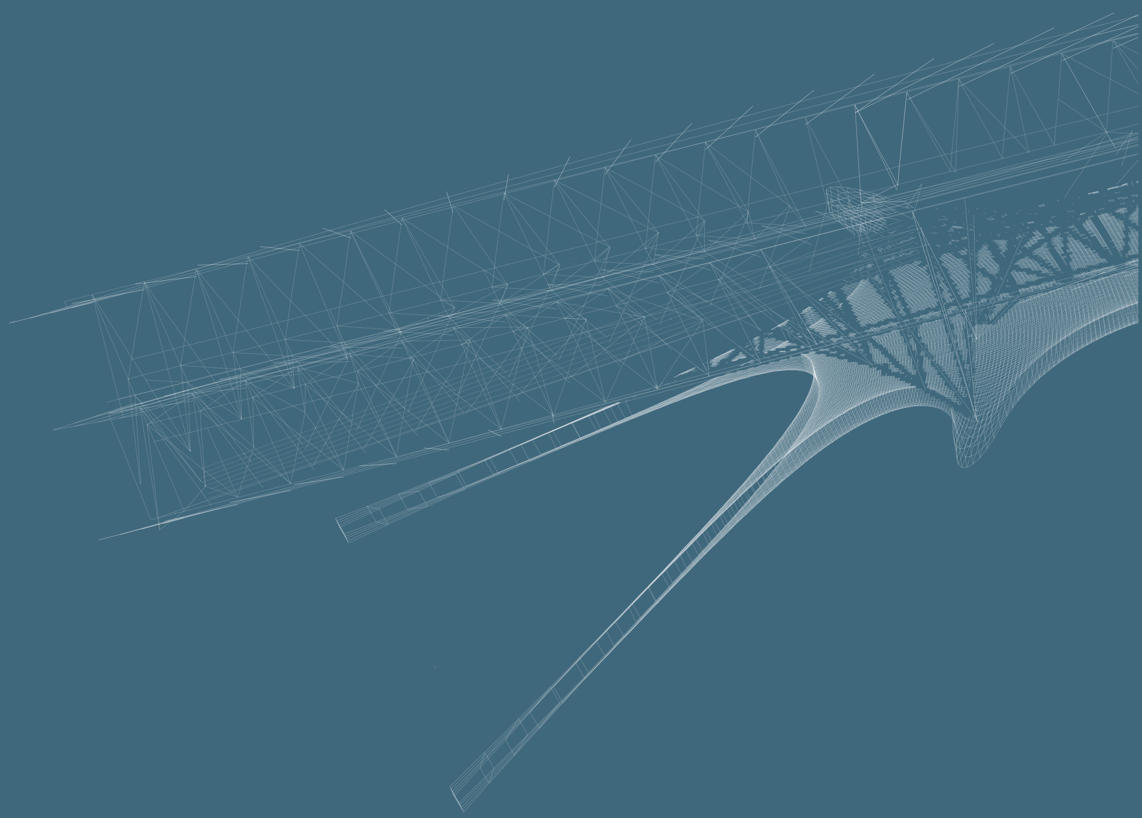

INITIAL GEOMETRY
1
ANCHOR POINTS
2
WEIGHT LOADS
3
WIND LOADS
4
WATER LOADS
5
YOUNG MODULUS
6
FIXED LENGHTS
7
SMOOTH JOINS
8
REAL THICKNESS
9

CHAPTER SEVEN

DECK PROJECT

Parametricism is a mature style. That the parametric paradigm is becoming pervasive in contemporary architecture and design is evident for quite some time.

Patrik Schumacher (*Parametricist Manifesto*)



Form-finding in Architecture is composed by a set of processes that use a more correct way in which to organize the infrastructures. It is a sort of study that has in the capability of discovering optimum form the goal of the methods. During all the macro-process the designer has to be a “controller” where the control is done continuously checking the relationships between the part of the object that he is designing. Again, the control is managed using parameters that can have different natures.

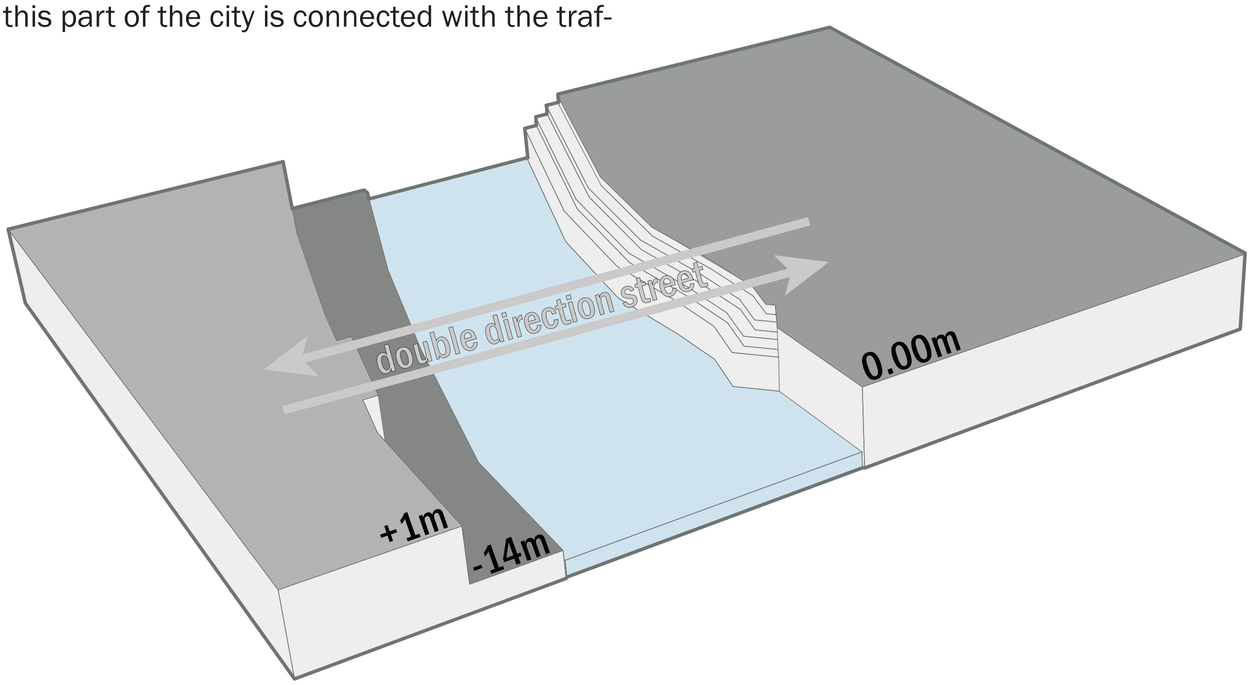
In this case, look the scheme below, we can see a schematic composition of the place where the project will be inserted. The two banks of the river are not in the same level and the distance between the two is 170 meters, the structure of the bridge has the opportunity to take advantage from the pedestrian path, part of the Murazzi, placed 15 meters below the street.

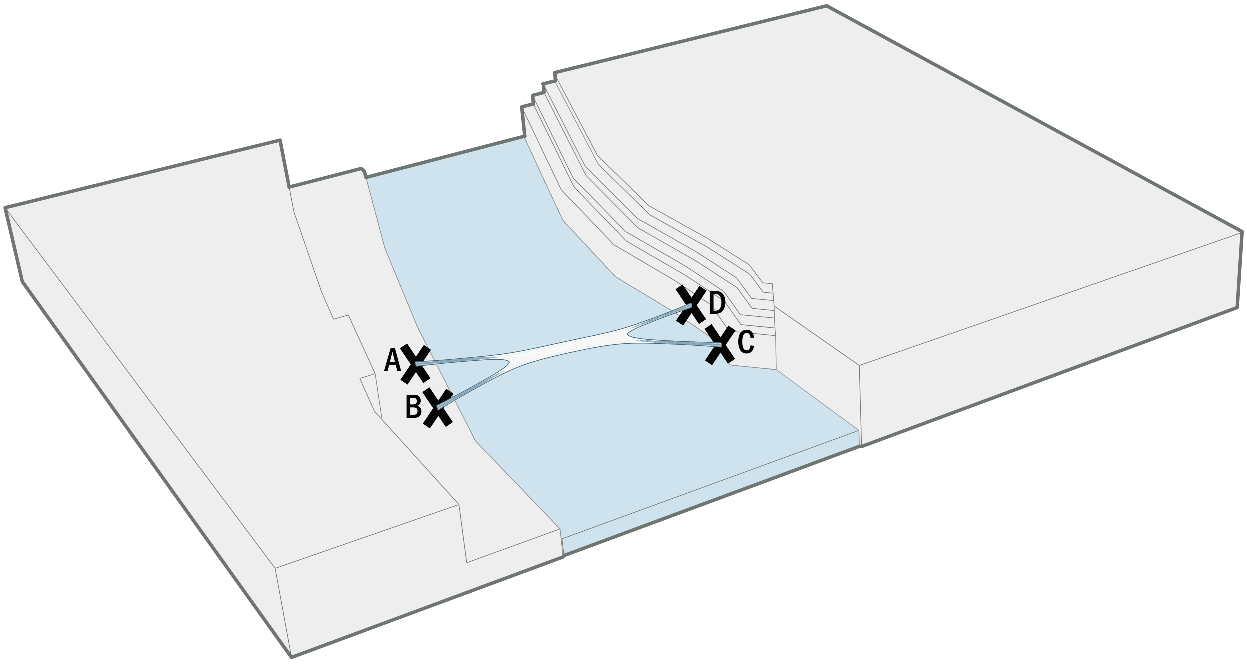
As it is schematized, with the light grey arrows, the idea of the street is thought like a double direction: this is a designer’s choice, in this case the necessity of a new bridge in this part of the city is connected with the traffic that stuck the historical bridge, Ponte Vittorio Emanuele I, so the homogeneity that will be created with the bridge “touching point element” between Corso Casale, eastern bank, and Corso San Maurizio, western bank.

Going ahead, the before called “designer’s choice” can be interpreted in three ways

- every idea that the designer insert in the form-finding processes is binding and is mathematically a parameter, in this first case all the parameters set are connected with the geography of the project’s place, but it will not be always like here

- a different choice of the designer changes the formal aspect of the object but with these methods it is possible to change idea every moment during the planning; taking for instances that the street has have two cars’ ways and the way for the tram, in that case the street is bigger in terms of walkable surface and weight, so all the other steps of the algorithms will change their results maintain their set-up because what is changed are only the inputs that arrive.





FIRST METHOD STRUCURAL FORM-FINDING

In this chapter, the sixth, there are two paragraphs. Every paragraph describes a form-finding method: in this thesis, and for extension in the project of the bridge, are used both. The methods are used in two different algorithms that are interconnected; at the same time, they are two part of the same infrastructure but they can also be attributed to two different part of the infrastructure designed. Starting with the first method, called “Structural Form-Finding”, it refers to the structural membrane that is below the bridge’s decking.

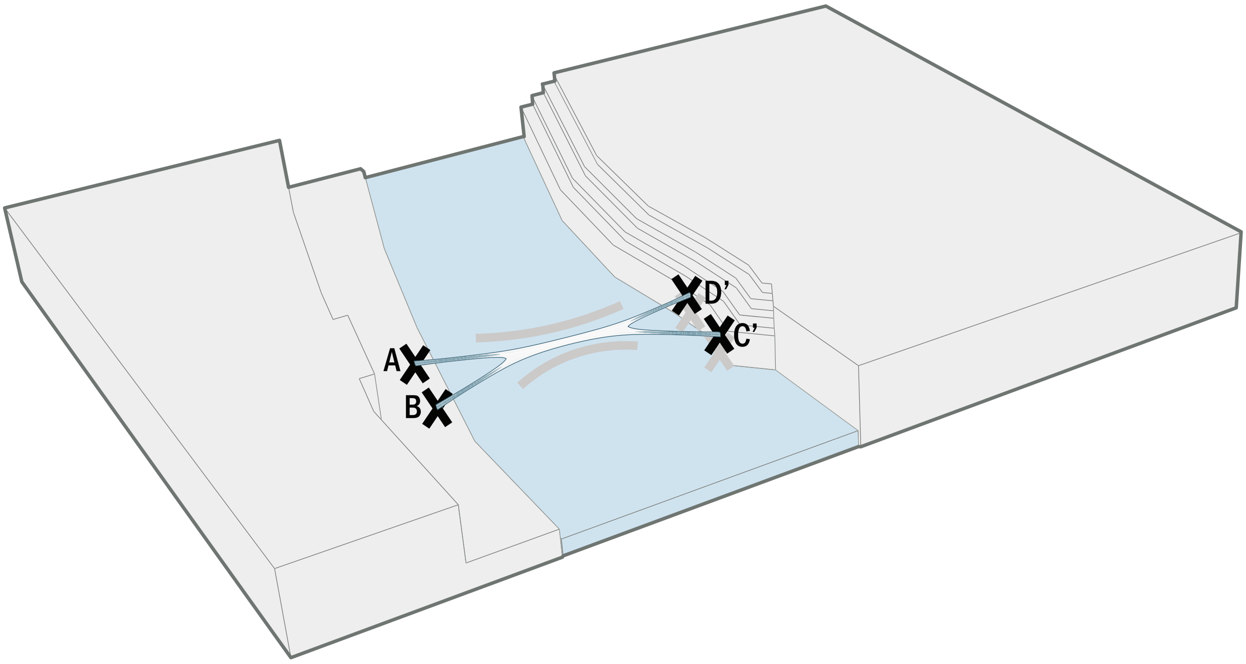
The structural principles that are the bases of the final algorithm are explained in the chapters four and five. As it is written in those chapters, the algorithm resulted is applicable everywhere because it is not strongly associate to the project’s plot. What renders the algorithm unique for the Turin’s possible building site is the use of parameters that are linked with the characteristics of the place: for example, the geographical ones, from the wind force in that area to the morphology of the land, or standard conditions, for example historical obligations or the necessity of security devices.

In the scheme above we can see the application of the algorithm explained in the previous chapters. The membrane resulted is the most resistant against loads that can influence its stability. It is placed between the two banks using the level of the Murazzi like supports’ plane.

The supports are in the points A B C D. There are the four points where the membrane unloads the weight to the ground:

- the western bank is a pedestrian way, the area is a built and consolidated environment, the surface of the support is regular and at a slightly higher hydrographic level than the regular flow of the Po river

- the eastern bank is a natural environment; the area is not accessible on foot because the pendency doesn’t allow it.



The points A and B represent the positions of two supports that can be in the same plane thank to the conditions of the western bank. Their equidistance helps the symmetry of the entire membrane. Taking into account the conditions set, already explained in the previous chapters, it is impossible to have a perfectly symmetrical structural membrane but where possible it is good to adjust to a simulation that doesn't completely subvert the laws of physics.

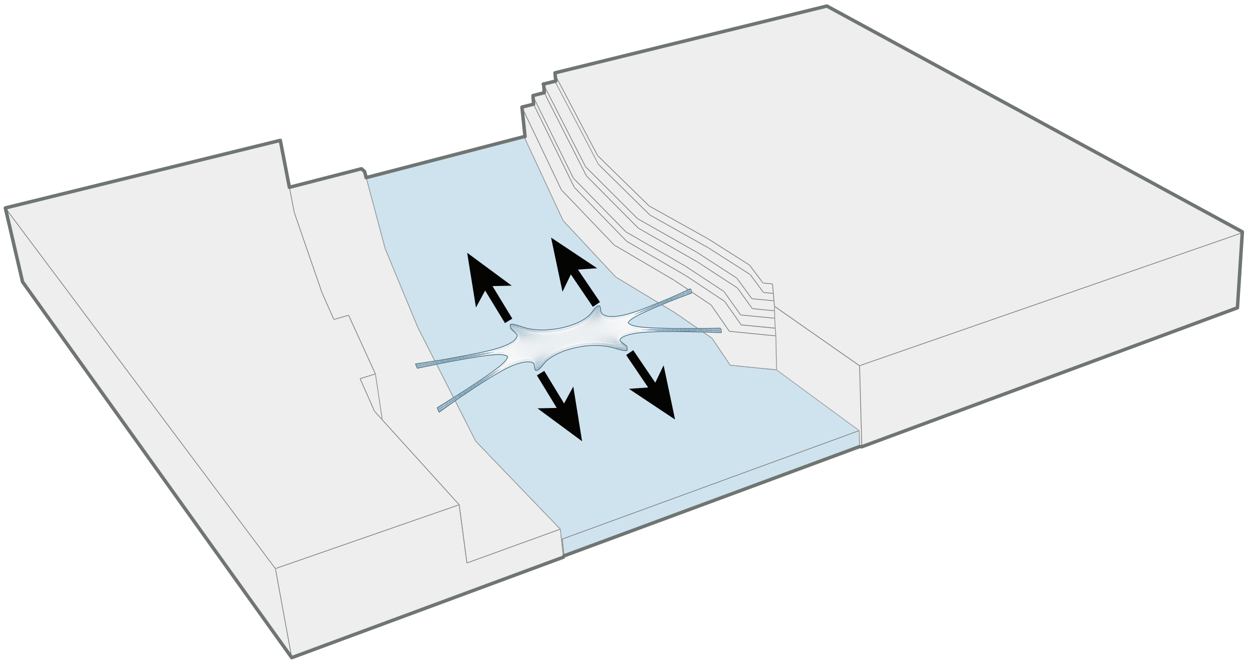
Different idea it is taken for the points C and D. Their situation, again connected with the geographical conditions, don't allow to attach regularly to the ground: the land is irregular and to set like reference plane the same of the first two points means to have the legs of the membrane or really different in length or with two different typologies of foundations. Both the consequences have structural complications.

So, as it is schematized above, the position of the points C and D are moved to C' and D'. The movement is done by the algorithm that intercepts two position that allow to have an equal length in membrane's legs of the eastern part. The result of the movement, as it right in a form-finding design approach, is unexpected and influence the shape of the entire membrane. Analyzing the partial result of the scheme above, there are some features that helped the structural resistance:

- the positions of C' and D' are higher the previous positions: the entire membrane is smaller in terms of surface allowing to minimize the use of material and the profile is more similar to an arch allowing to have similar resistance characteristics similar

- the positions of C' and D' are closer the positions of A and B: the reduction of the dimension of the entire span allows to have a thinner thickness of the entire membrane that is equal all along the slab with the consequent advantage to have a material continuity, same continuous steel reinforcements and similar concrete casts in place.

All the graphical elements colored in light



grey, in the scheme above, represent the distances in previous arrangement of the membrane to highlight the differences.

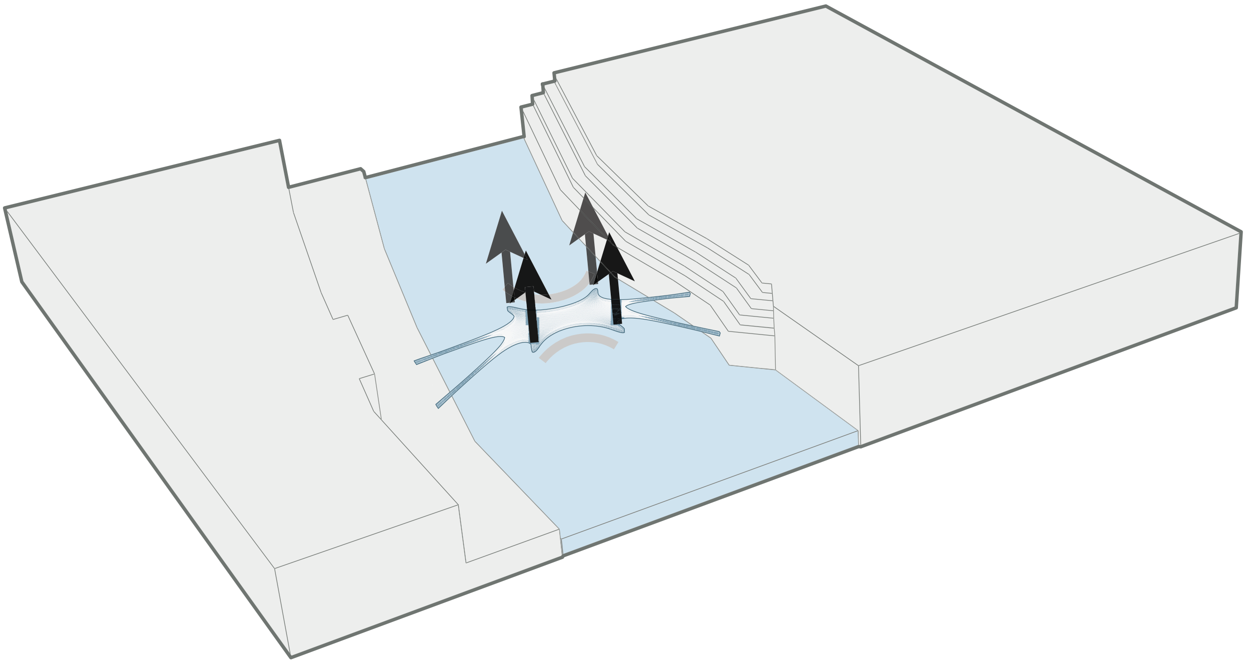
At this point the slab is a sculpture end in itself and the necessity are to identify portions of membrane where the decking can touch it. Analyzing the graphs of the membrane after compression analysis wit is evident that the best positions, excepted in the middle-slab in keystone, are between the basement's aches, shapes composed by the legs, and the keystone itself.

Then, looking the evolution of the membrane until now, the higher part is approximately flat with a pic in the middle of ideal axes, or in the keystone. This formal arrangement is perfect for a linear decking that touches and embodies the slab in a vast part covering the slab itself and with a compositional result with aesthetics lacunae. To increase the resistance possibilities and to use the expressive potentiality of a shell to set that the deformation of the membrane, during the simulation Kangaroo Physics in the algorithms, has to have a precise high.

To reach this high, found after calculation linked with the decking and explained in the following paragraph, the membrane modifies its general shape moving only the parts that are not bound, so the four points moved in the schemes above and in the following page. Before presented like the most resistant after the keystone.

The main thinking, that demonstrates reasonable this movement done by the algorithm, comes from Ponte sul Basento of Sergio Musmeci: looking a section taken perpendicular to the main axes of the entire bridge, it is clear the relation between concrete slab and the decking.

The membrane has a concave shape: it was conceived as a surface with uniform but not isotropic compression. Every part that touches the decking was selected with regular distance and intercepts the deck structure: a cross-section shaped caisson, beams and ribs in both direction transverse and longitudinal. In the longitudinal direction, the decking has a reticular structure pattern, but the structure is not visible because is covered by an extra-structure that had to continue above



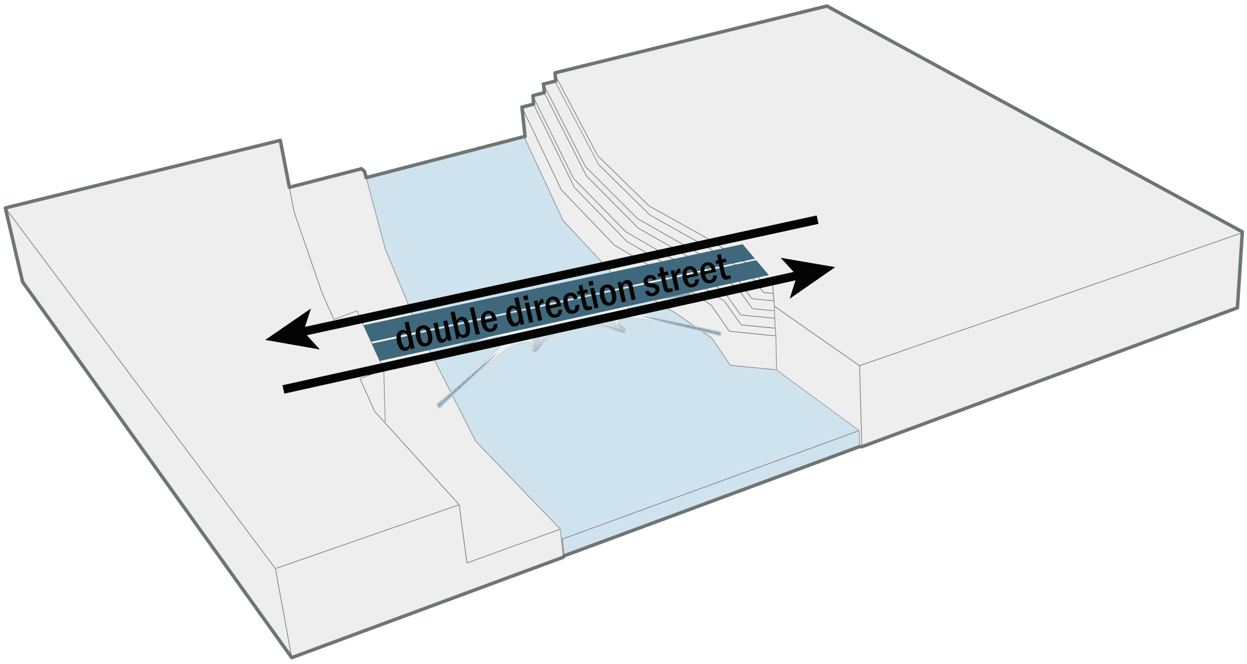
the street level to became the balusters.

Summary, the innovation of Musmeci's bridge is a sum of part that becomes a unique work where the relations with the part cooperates to a structural safety. This thesis tries to apply what Sergio Musmeci called "theory of minimal surfaces": producing a continuous shape that is at the same time structure. Here the theory is characterized by the envelope of a set of curves of equal value but of opposite sign, is achieved with a minimum use of material.

The material itself plays an important role in the structural efficiency: the properties of the concrete maintain a certain stress regime in the slab allowing a fluid design of the structure. In fact, the final shape, as it is schematized above, is the result of optimization and maximization which guarantees, so, maximum efficiency in terms of performance and use of the material itself. Although not required, the last thinking, in this paragraph, concerns the foundations. The scheme of this page shows how the last arrangement of the membrane has legs with pendency higher than in the previous versions.

The inclination of the membrane legs continues towards the ground so as to maintain the same inclination also for the foundation piles: most of the foundations of the bridges are on reinforced concrete piles, these are divided into piles built out of work and piles driven by beating. Whichever typology will be used, the foundation casting, having constant inclination to the membrane, will be continuous, homogenizing the structure wedged in the ground also from a material point of view.

The jet in place provides for appropriate formwork that are inserted into the holes in the ground made by drilling. In the event that the formwork is metal, once it is fixed it is abandoned in the ground to defend the fresh concrete from any erosion and washout, also giving a greater structural contribution.



SECOND METHOD POSITIONAL FORM-FINDING

Form-finding in Architecture, as we already know, makes the designer a decision-maker and a controller at the same time: in the case of the decking's project the there are different choices that influence the destiny of the project, but the structure remains a form-finding work. A new algorithm creates a shape thanks to the assigned parameters.

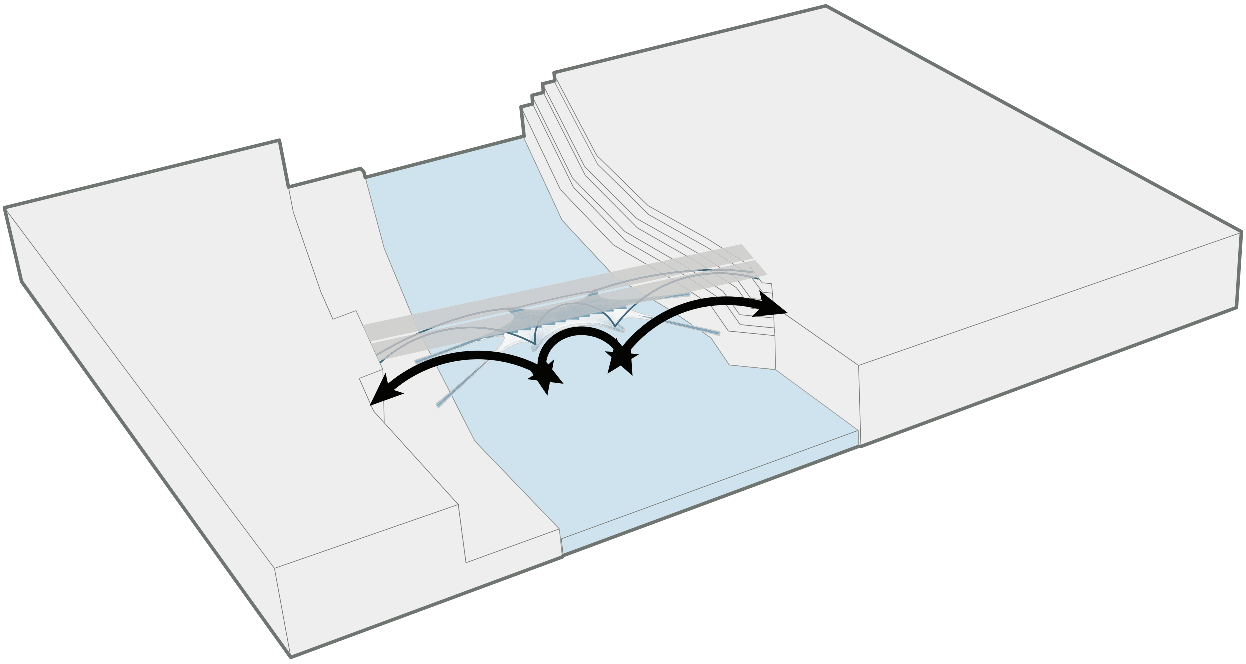
Looking the scheme above, it is reppreented the structural membrane, described in the chapter six and in the previous paragraph, with a schematic idea of the main function of the bridge's decking: a doubble driveway of 170 meters long, new road artery of the city of Turin that will connect two important city flow routes, two parts of the city, in both directions. The motor vehicles will cross the river 15 meters from the Murazzi level and will overcome a difference in height of about one meter between the two banks of the river, between the two anchor points of the entire deck structure. Precisely because of the numbers just mentioned, the structure of the decking must adapt to both the irregularity of the underlying reinforced concrete membrane and the road above, the latter being the result of the constraints imposed by the built and consolidated environment of the city.

The direction of the decking's road is the same of Corso San Maurizio: this choice allows to extending that road route of the city allows you to:

- preserve the existing road axis, a consolidated path within the city fabric and until now abruptly interrupted by the presence of the river, an insurmountable limit

- get to the east bank of the river occupying as little park as possible until it crosses Corso Casale, this operation minimizes the consumption of green land and does not cut into two Michelotti Park making it less practicable.

Going ahead to the following step, we can see how the algorithm works: set the direction



and dimentions of the upper road, it neds a support structure: if we consider the underlying membrane like simmetrical and we analyze half of it, there are two touching point in the membrand itself and an additional point on each bank of the river that can be used as anchor points. These four points are the ends of three arches that support the deck. Considering the road like two driveways, the algorithm is set to generate a structure for a pathway and a mirror structure for the other direction path. Even if the theory is the same the two structures have particular characteristics:

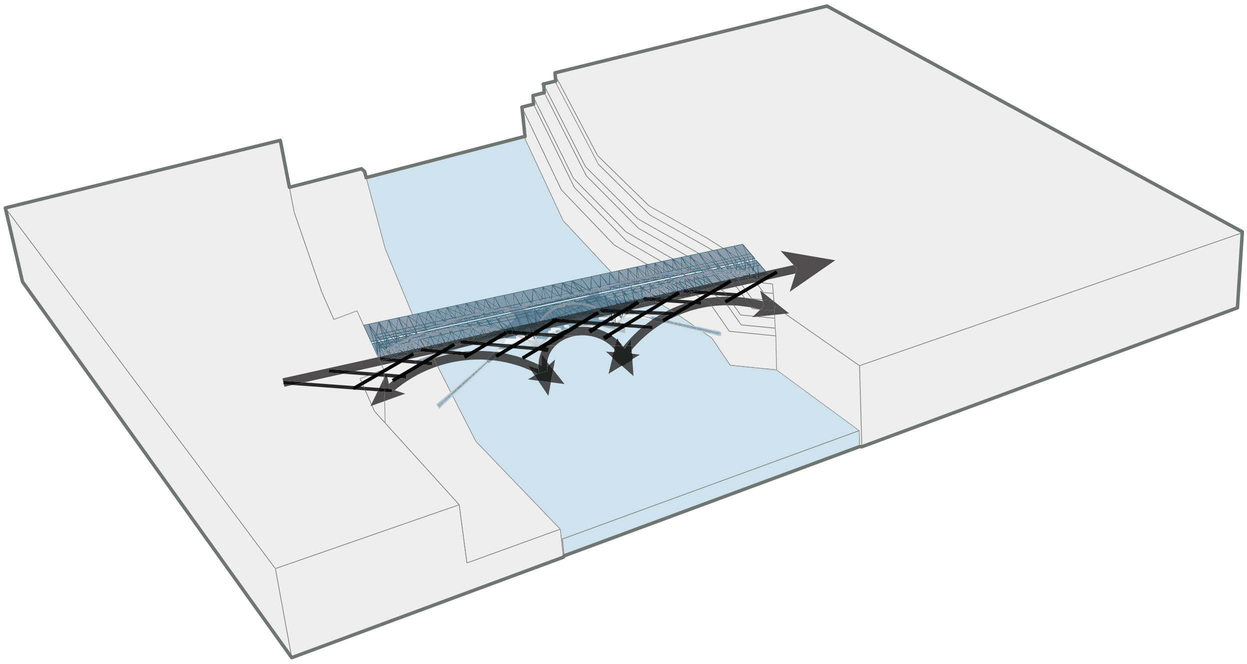
- they cannot be equal because the conditions of the underlying reinforced concrete membrane and the road above are different with a consequent different results at the decking level

- they are connected togheter, we wil see better in the last phase where the two parts have substructure in common, but anyway during all the process of generation they are linked also physically.

This type of arch is called “lowered” and is a legacy of the Italian tradition of the cloisters of the monasteries of the XVII century. The arch can be defined as lowered when the ratio between the arrow and the chain is less than 1, the center towards which the joints of the wedges tend is lower than the tax line. The application of this type of arch for bridges is linked to its ability to cover large spans at the expense of its height.

Its first and most famous application in the construction of bridges dates back to the reconstruction of the Ponte Vecchio in Florence in the XIV century: this type of arch was used to reduce the number of bridge crossings and consequently the encumbrance of the river bed in the event of a flood, decrease the piles in the river bed. In the project, developed in this thesis, the basic concept is the same: from the structure of the membrane to the deck up to the road, this is a composition of lowered arches which, rising more and more, decrease the lengths of the lights, resisting better the weights.

The arches between road and membrane creates a ventilated space in the middle, this space can be used and the connecting

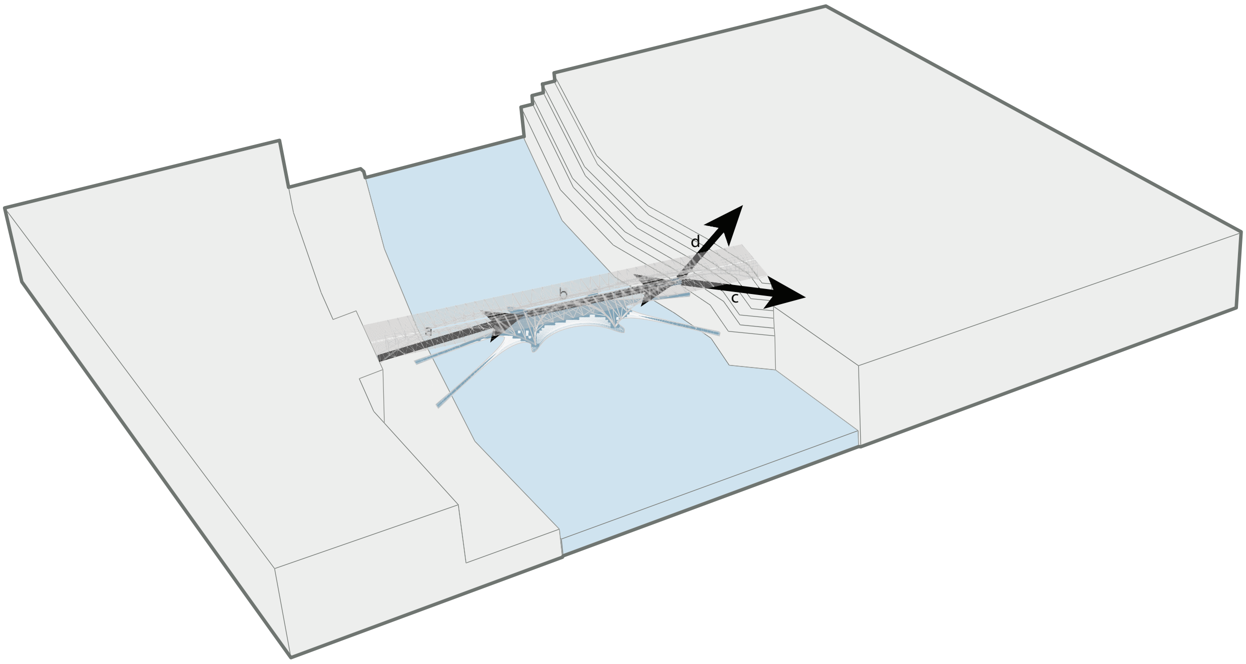


structures between the arches and the road above cannot be invasive but must allow the ventilation itself and the penetration of light.

So, the keystones of the arches touchs the central of three long beam tha support the road and the other two are connected with the arches with crossing inclined beams. All of these follow all the arches maintain an equal distance along the entire path. As the scheme above tries to describe, the concept generated by the algorithm is to manage lists of numbers in the road's main beams and in the arches: every main beam has a list of numbers, three lists, and the arches is another, one list, the principle of the trellis structure pattern needs to link al the lists in a single continuous truss.

The "reticular" structure is a simple structure because all the elements are subjected only to axial traction or compression stresses. In the bridge design the sloped beams connecting main road beams and structural arches are of two types: sloped in two directions and sloped in one direction only. The first type have a first inclination to intercept the subsurface arch and a second inclination to be incident obliquely, the second type of beams have the second inclination perpendicular to the main structures so as to cross the beams of the first type. If the deck had only orthogonal elements, second type, it would be a labile structure: the system could not sustain any shear stress, and therefore not even the torsion, managing to bear only pure axial stresses, traction and compression. Upon application of a shear situation acting on the structure, it collapses.

But, with the introduction of the first type of beams, diagonal elements, they prevent the deformation of the lattice because all the components also react to shear stress and the system does not collapse. Thanks to the trellis shape, if we load the same beam in bending it results that the shear stress can actually be considered as an axial traction or compression stress placed at 45 degrees. So such a system is much more effective compared to one made of all orthogonal beams to the main ones. A great application of these concepts comes from the aeronautical way: the biplanes are areas where the two wings are connected to each other by thin crossed tie rods, these can only be loaded by traction



and consequently there must be two more or less orthogonal, in order to keep the system stable under any load condition.

Continuing with the algorithm description, in this page the scheme shows the path obtained in the space between the two structures: starting from the landing in the ancient staircase of the Murazzi, the pedestrian path pases throught all the bridge and goes out in the park taking two directions:

- the start from the ancient staircase allows pedestrians to use three pedestrian levels: the city level, Lungo Po Luigi Cadorna, the new path obtained from the new bridge and the Murazzi pedestrian walkway

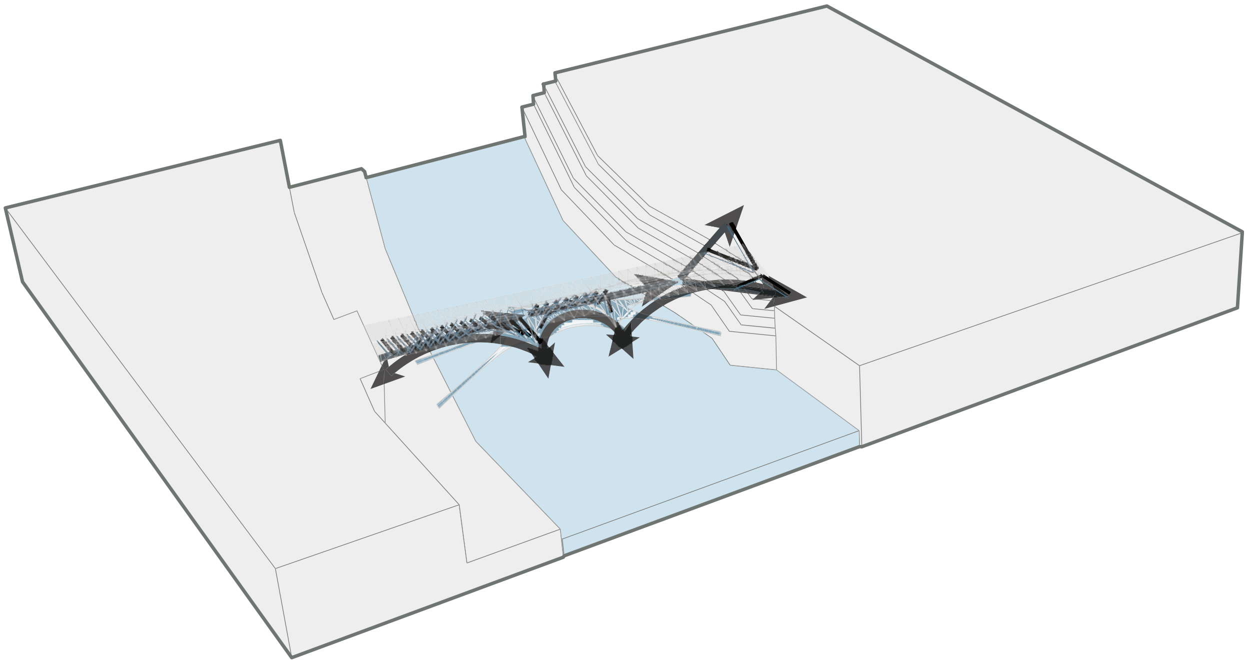
- the arrival in two parts of the park allows pedestrians to use the new walkway as a pedestrian crossing without crossing the road of the new bridge, to access the new paths of Parco Michelotti and faster access to Borgo Po and the area of the Gran Madre di Dio

- the new pedestrian walkway is not flat but starting from the ancient staircase it climbs towards the concavity of the membrane, from there it has a “donkey’s back” shape up to the bifurcation in the east part, here the two changes of direction change again inclination and rise up to reach the zero altitude of Michelotti Park.

The algorithm is set to garantee in all the space that are under the decking’s structures have the spaces and the heights that permit the passage of people and respect for distances. Then, all the slopes and slope changes all have inclinations not exceeding 8 percent, allowing any type of lost person to travel along the new pedestrian walkway.

Under the structual point of view, the new walkway has two types of structure:

- considering all the pathway as divided in three parts, taking as references the three arches, the first two, starting from the ancient staircase have an hanging reticular structure, the principle is the same of the support of the road, using the arches, but in this case it is hung, another characteristic is that the walkway doesn’t touch the



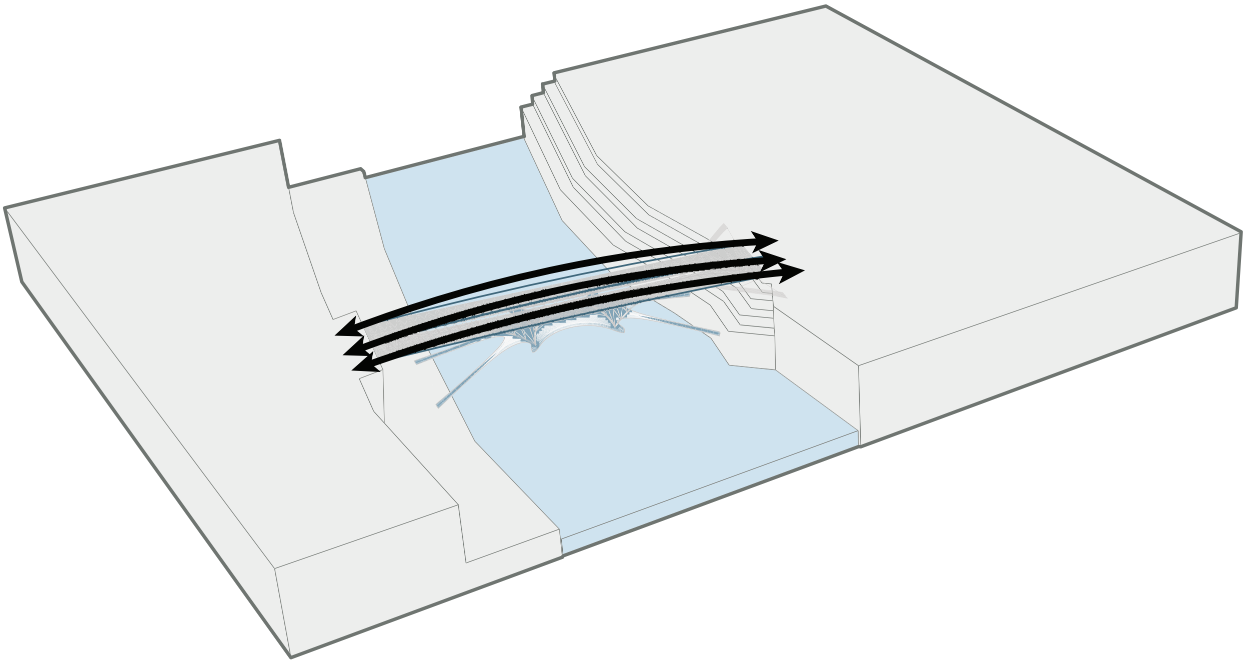
structural membrane and considering the all bridge system only the arches' ends touch the concrete

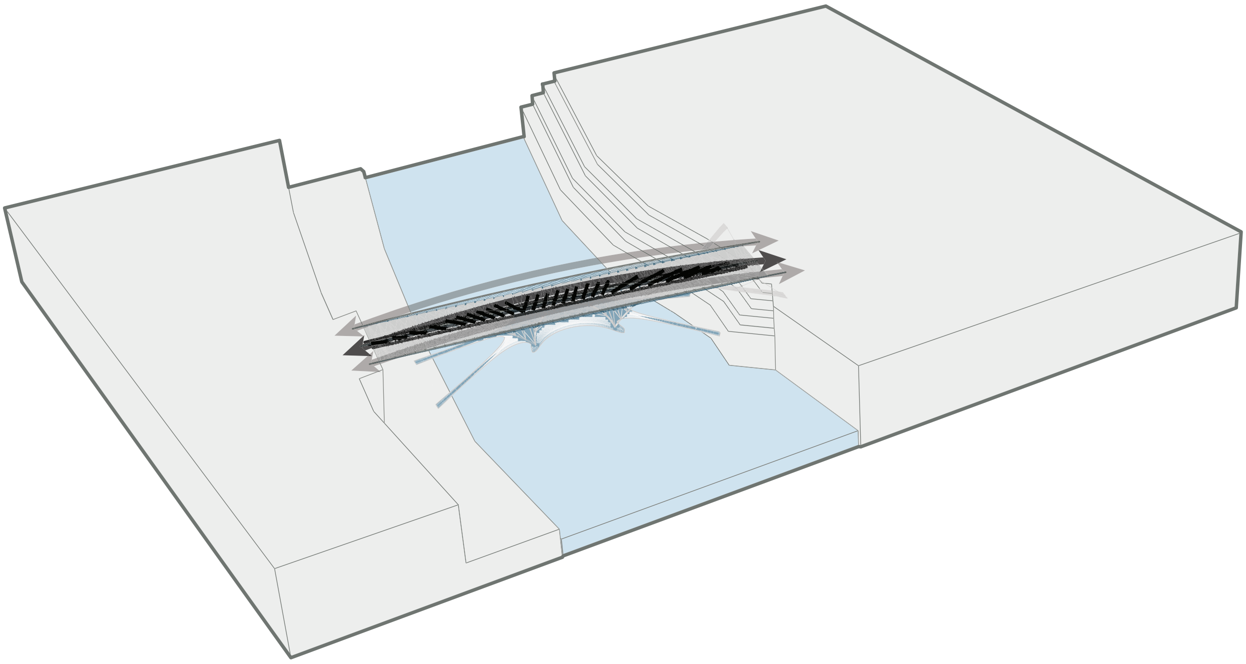
- the third part of the new path can't use the arch because the opening needs to go out, so, from the park's slope there are four inclined columns that intercept the bottom of the new walkway, these columns share with the end of the last arch the connection to the ground and also find the foundation plinth.

The structural reference of the structure of the walkway are the cabins of the cable cars of the ski resorts. A cableway is made up of a cable, which supports cabins or platforms, suspended and pulled by another cable, they are used particularly in mountainous regions for the ability to overcome gradients and changes in slope in a short time. The rope must support the weight of all the cabins and the people they contain, they are hung on the rope with a linear metal structure, this structure enters the cabin in its central part like a column and supports the bottom: the walls of the cabin do not being structural they can be lightened to a minimum, as in the case of the parapets of the new pedestrian walkway. Thin tuvature that is inserted inside the support columns of the bottom of the walkway.

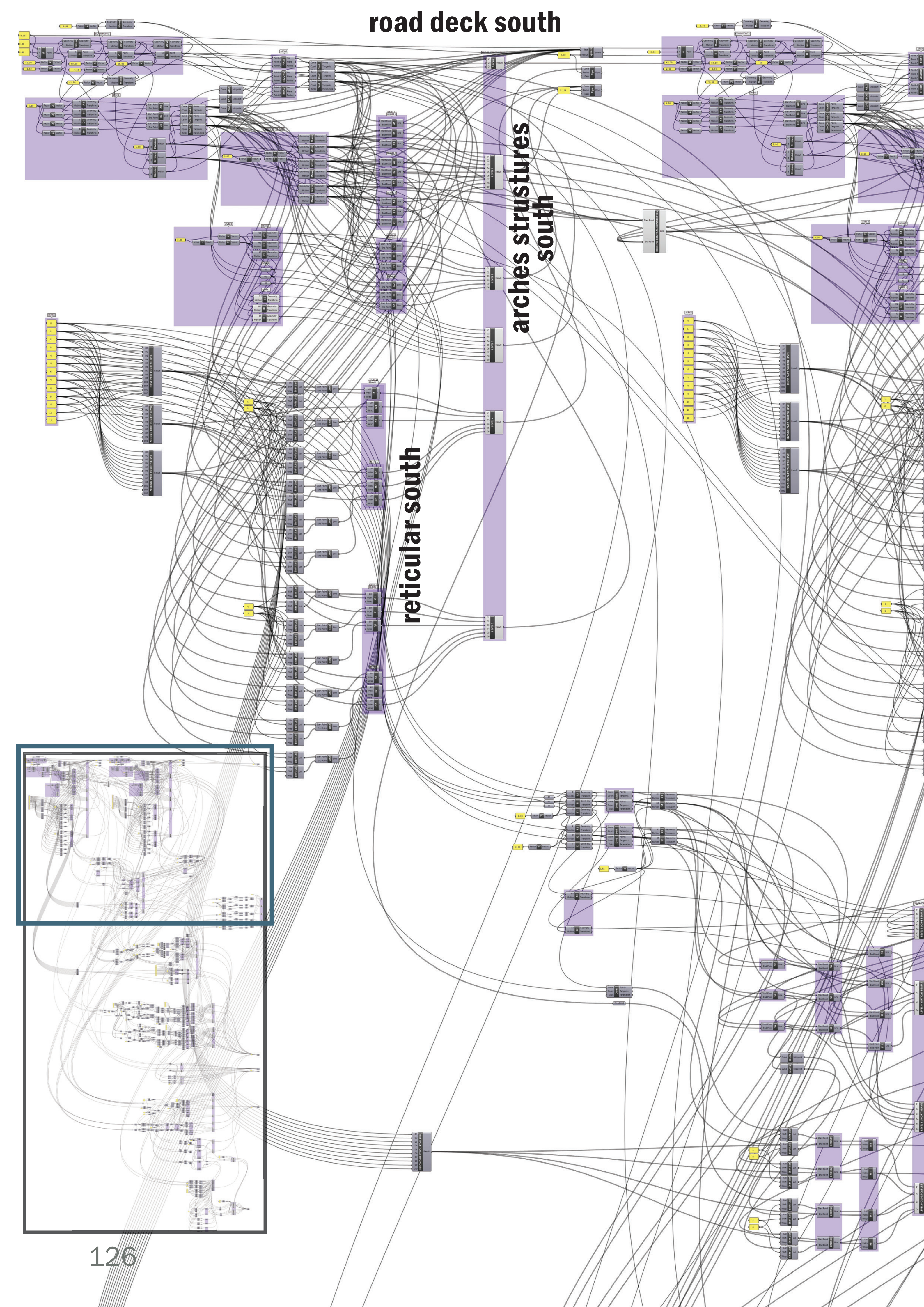
The final two diagrams on the next page show the third level of the entire bridge structure: they are three lowered arches that have a double function. The first function is purely compositional as arches and cross ribbed structures are the parapets and the traffic dividers of the bridge carriageway. The second function is structural: the three arches are anchored to the street levels of the city, both to the east and to the west, giving an aid to the concrete membrane to support the deck, lightening the general weight of the roadway supported by the central steel structure.

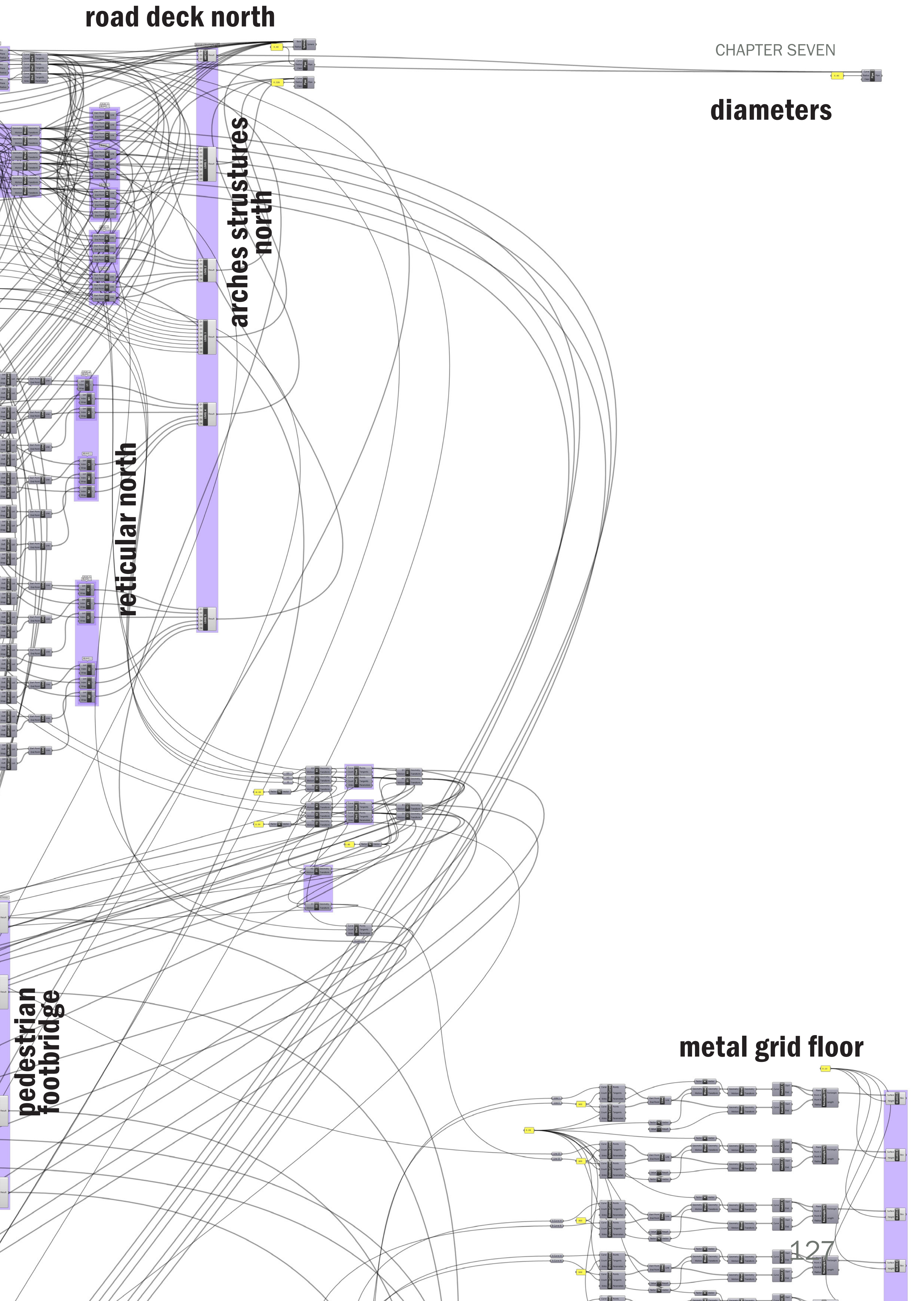
The arches represent the peak point of a series of structures which, in succession, cooperate with each other to fulfill their functions. Being part of the deck algorithm they are also generated by a form-finding and therefore have distances that are conducive to the safety of those who walk the bridge object of design.

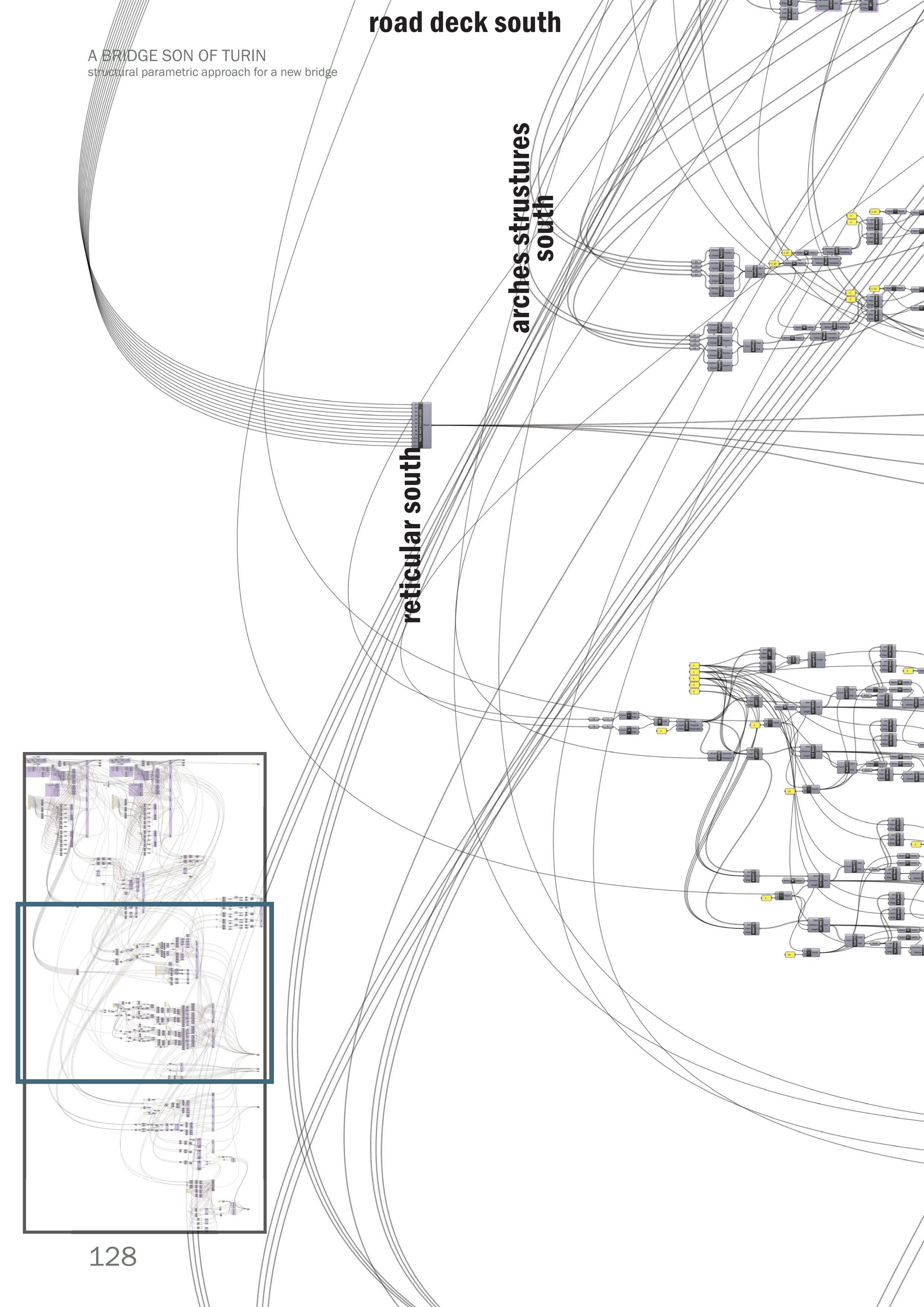


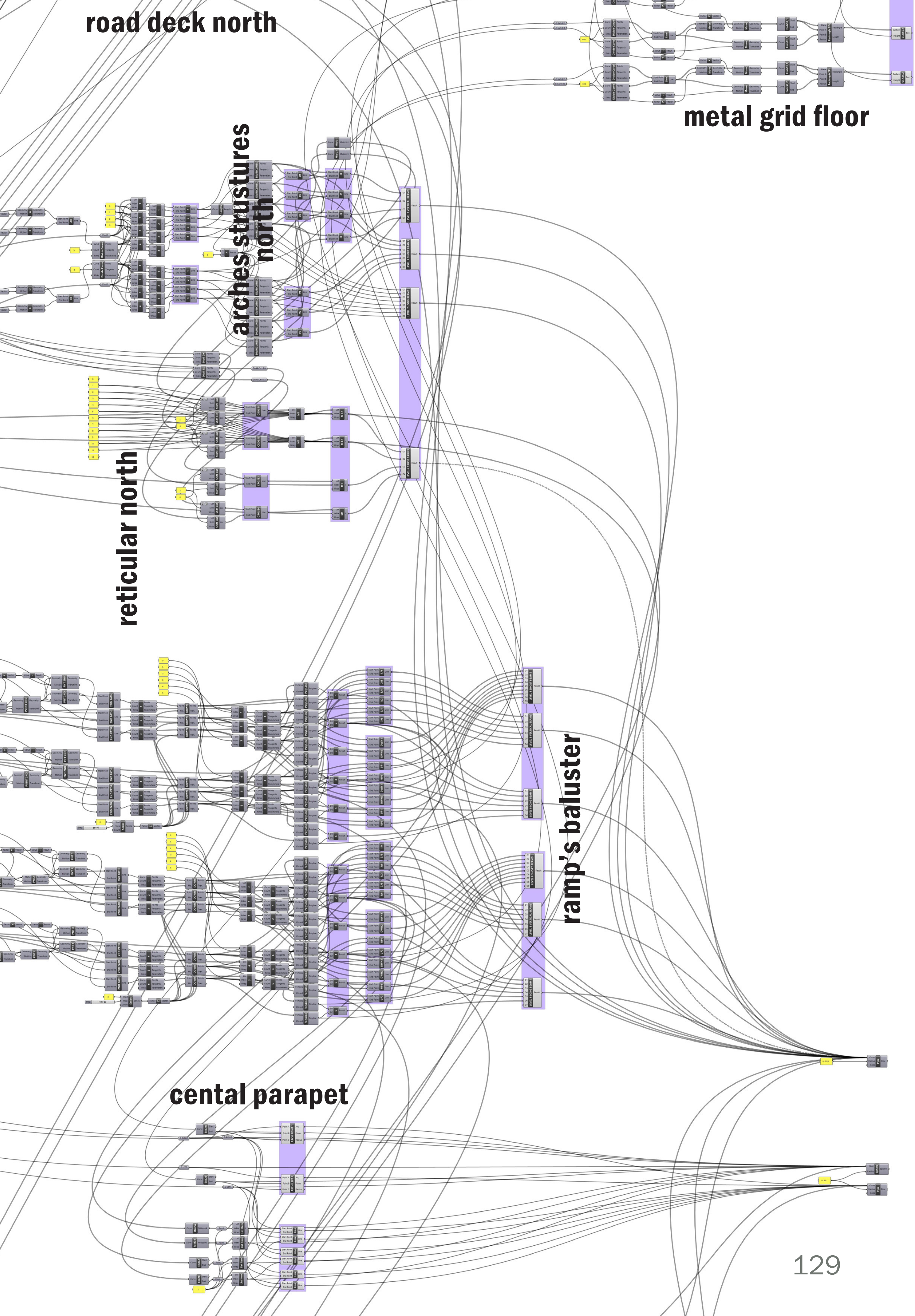


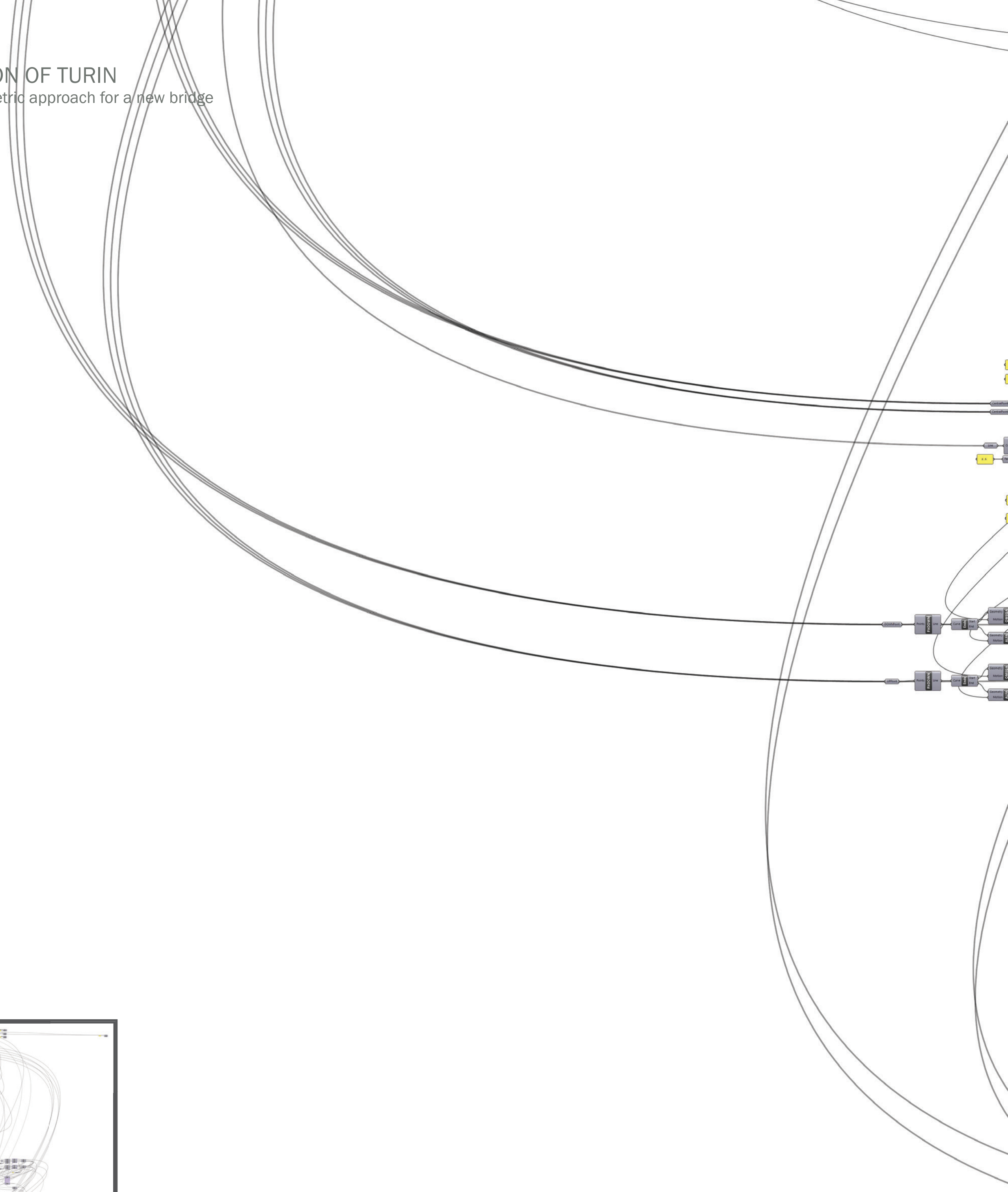
The material, the steel, used is the same as the deck in that, even if from the formal point of view the three arches are superior to everything, from the structural point of view they resume and hook to the beams that support the roadway.

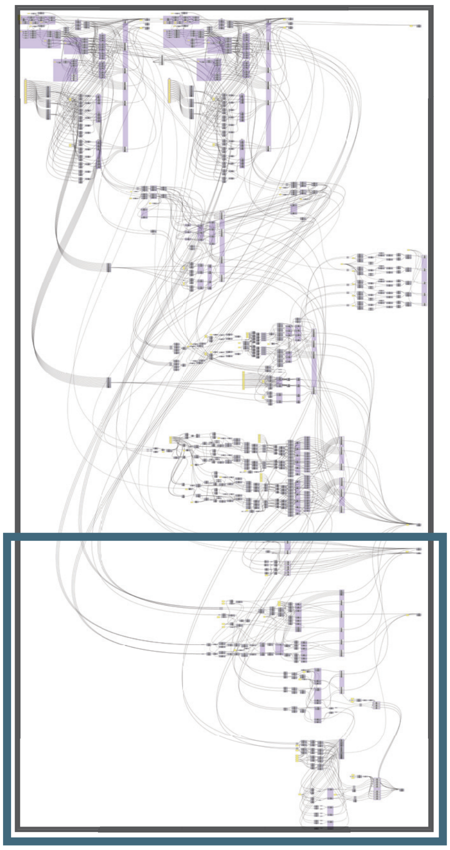

road deck south
arches strustures south
reticular south

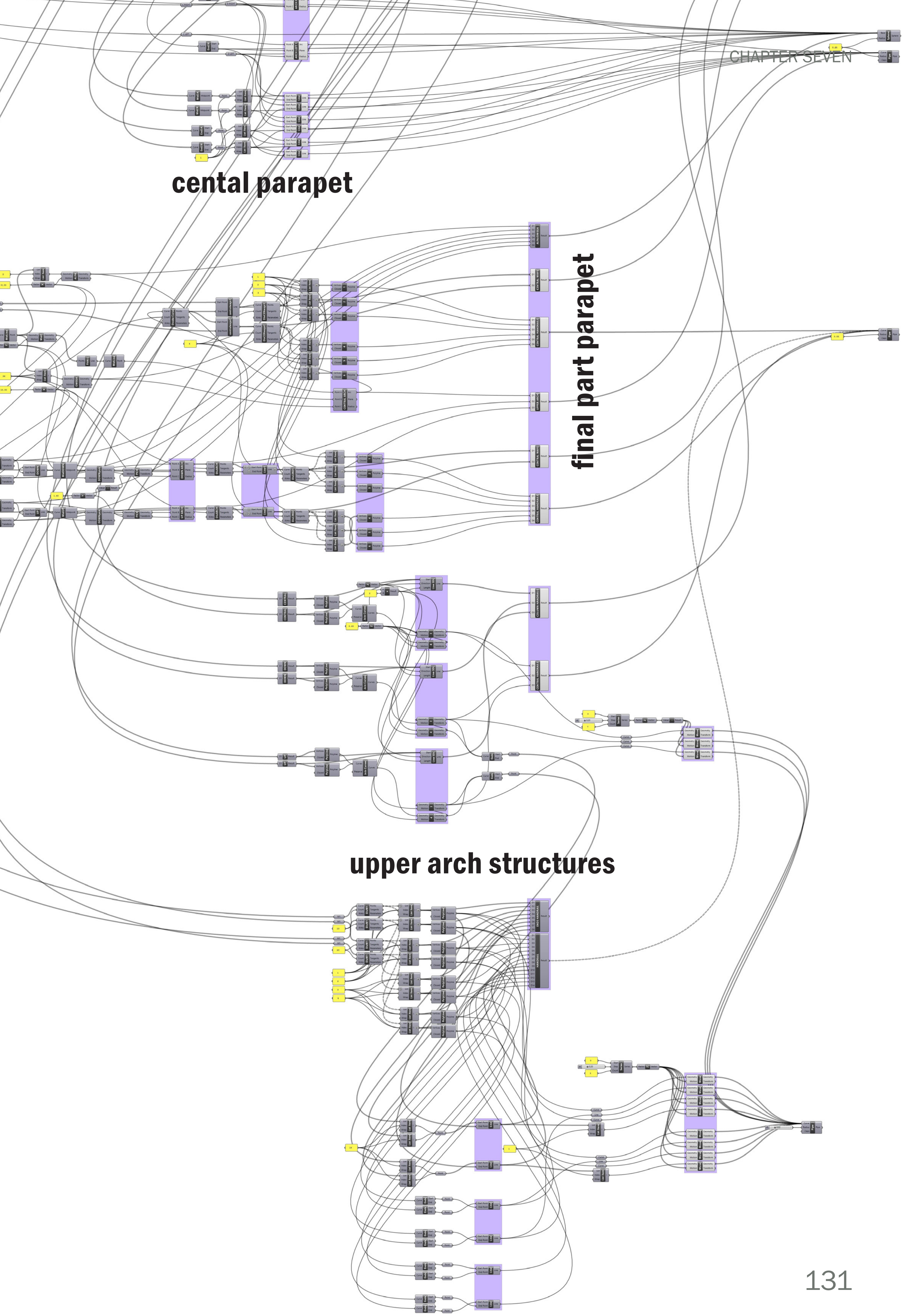

road deck north
diameters
arches strustures north
reticular north
pedestrian footbridge
metal grid floor

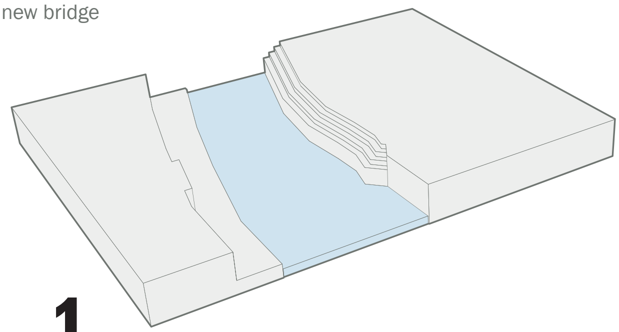

road deck south
arches strustures south
reticular south


road deck north
metal grid floor
arches strustures north
reticular north
ramp's baluster
cental parapet

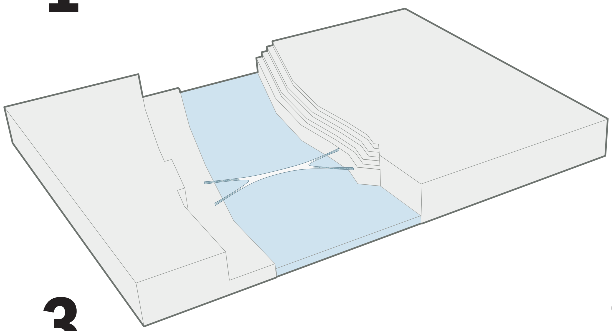




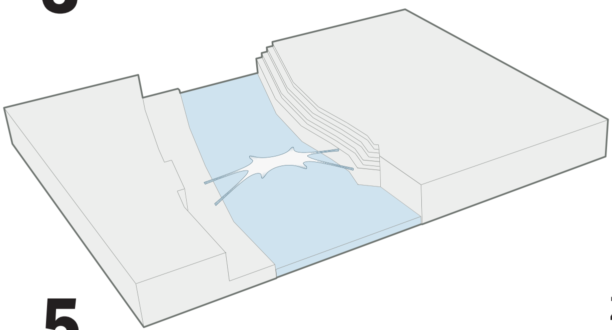

cental parapet
final part parapet
upper arch structures



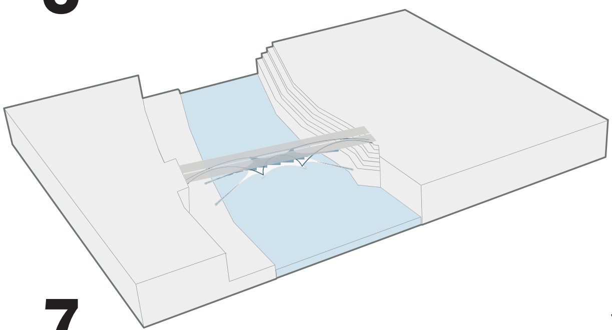
1 **ENVIROLMENT**



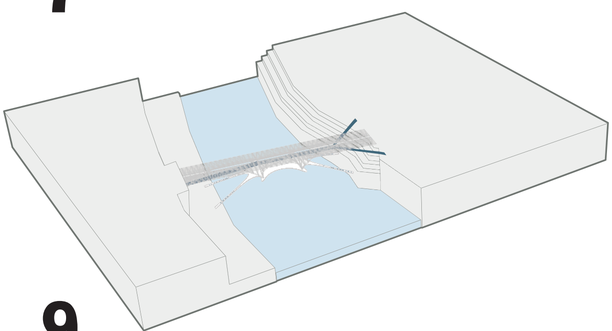
3 **GROUND ANCHORAGES**



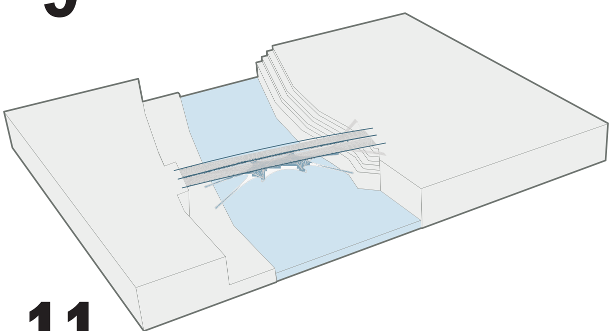
5 **Z AXIS DECK ANCHORS**



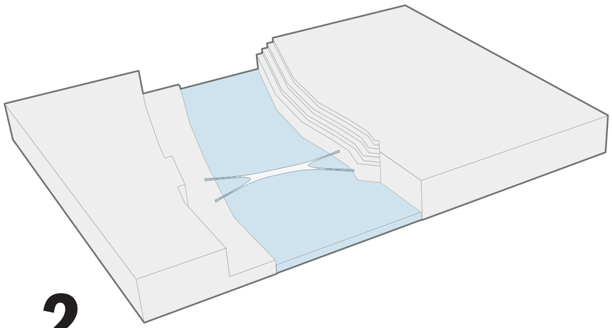
7 **STRUCTURAL ARCHES**



9 **PEDESTRIAN PATHWAY**

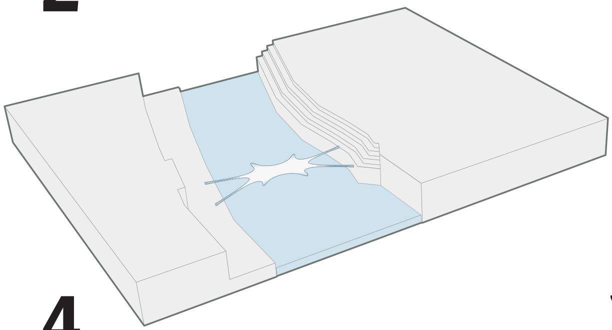


11 **EXTERNAL ARCHES**



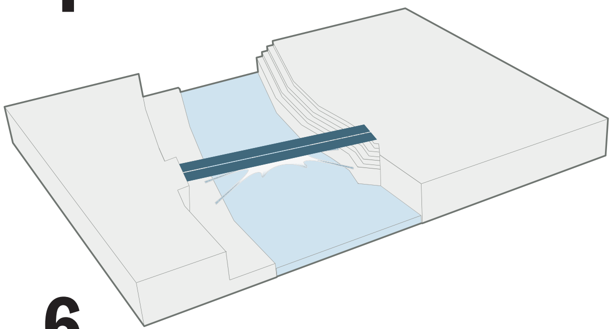
2

RAW ALGORITHM



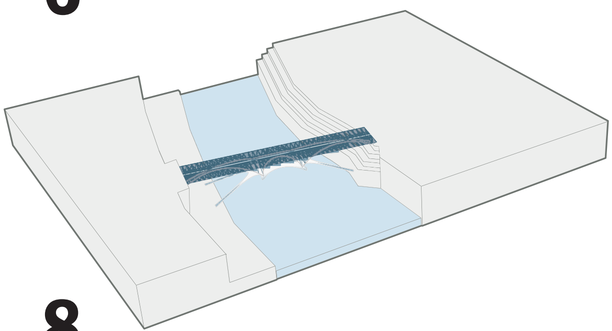
4

Y AXIS DECK ANCHORS



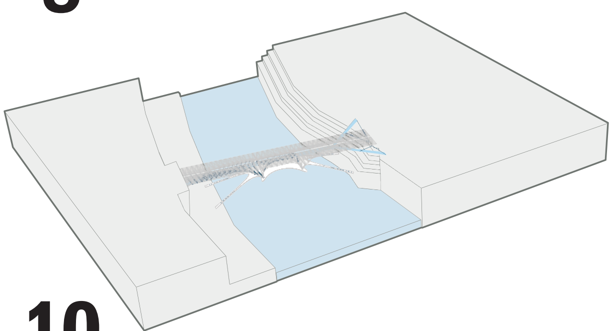
6

ROAD PLANE



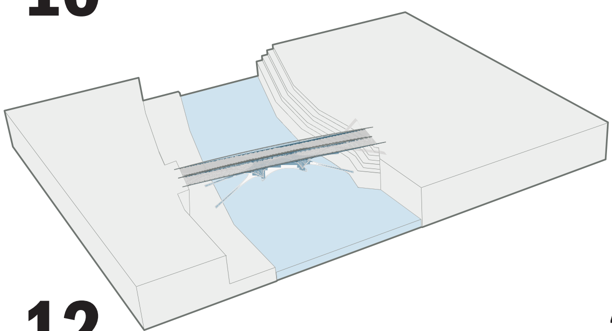
8

RETICULAR STRUCTURE



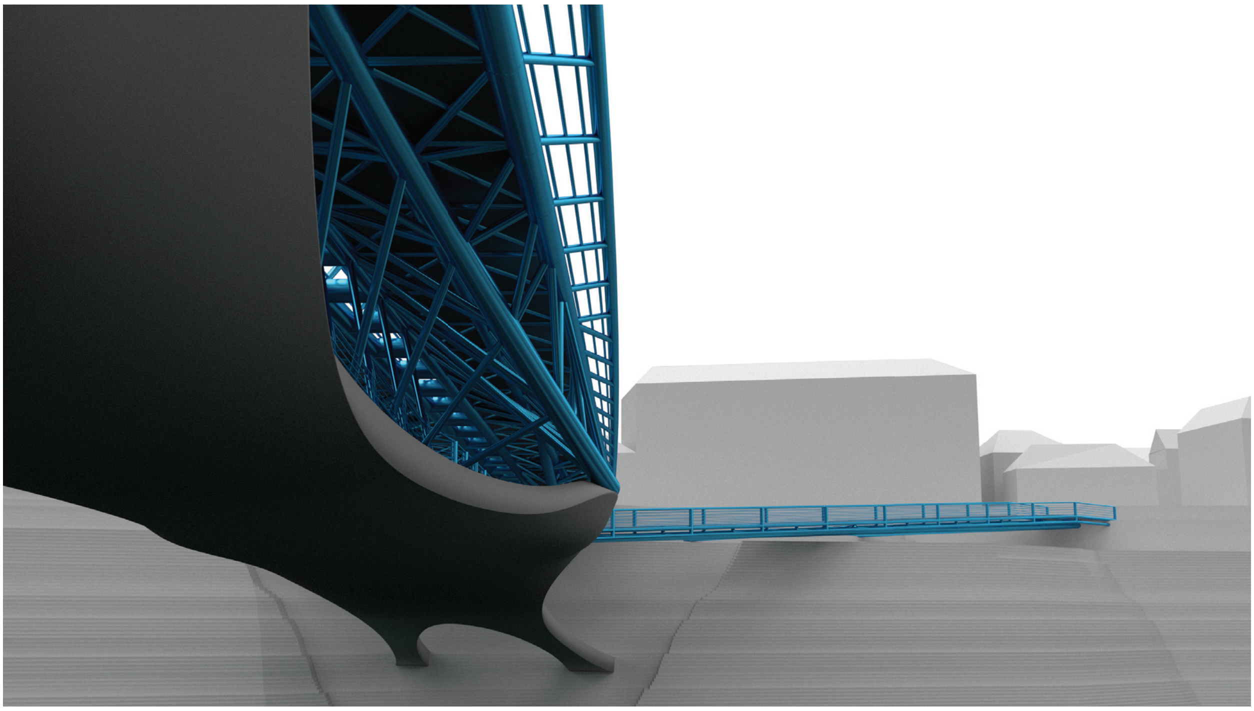
10

PATHWAY STRUCTURE



12

ARCHES' RETICULAR



THE NEW BRIDGE

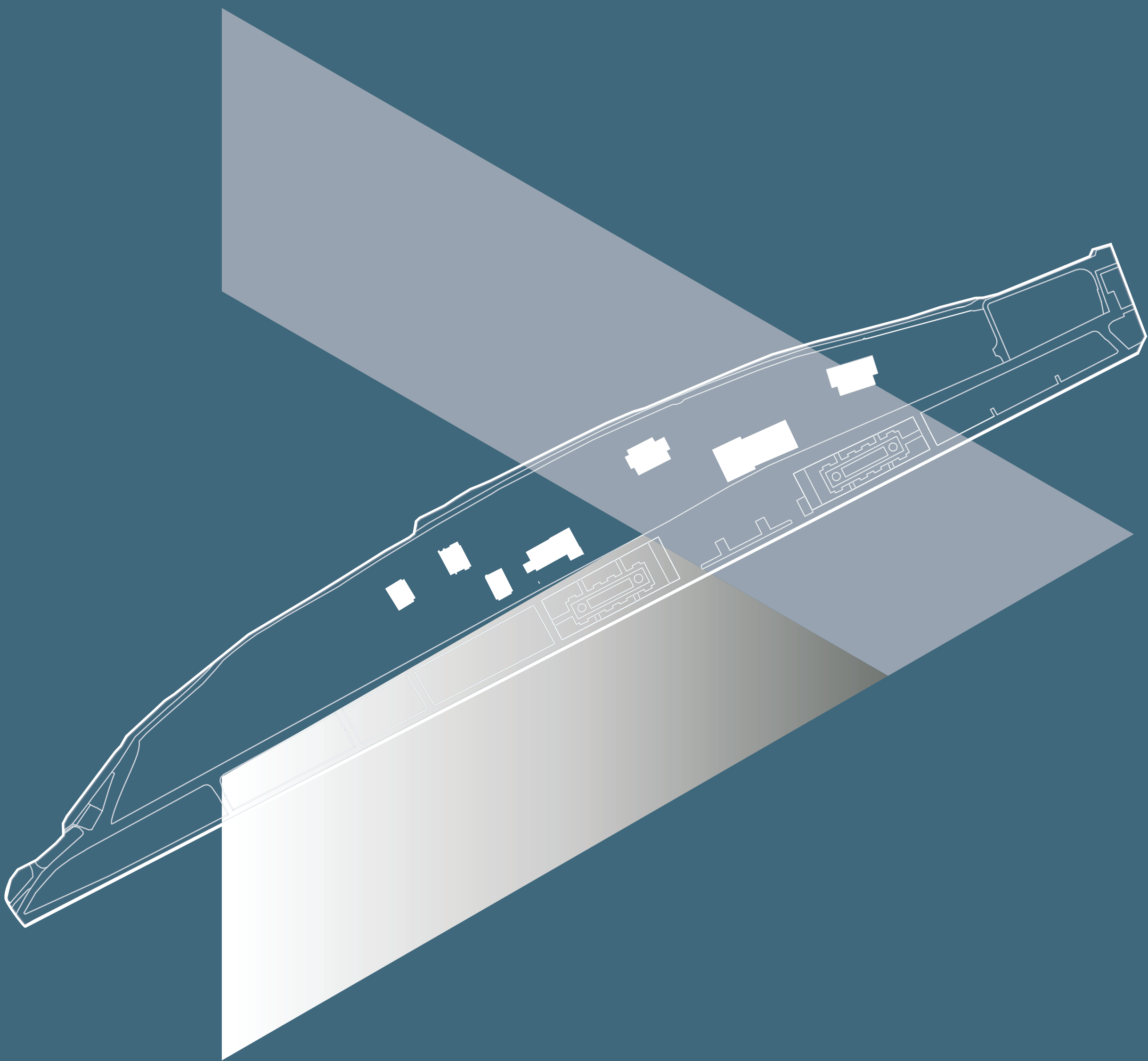
CHAPTER EIGHT

PARK ANALYSIS

La palla che lanciai giocando nel parco
Non è ancora scesa al suolo.

Dylan Thomas *(Twenty-Five Poems, 1936)*

The ball I threw while playing in the park. It hasn't hit the ground yet.



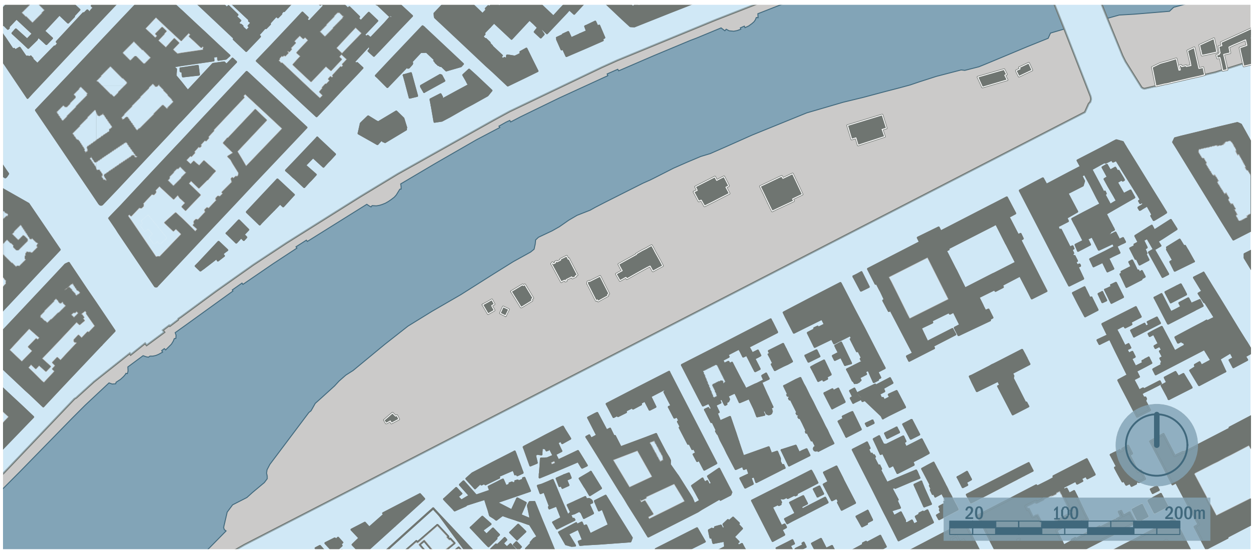
SITE OF THE PROJECT

The site of the tower project is in the green area of Turin inserted in the neighbourhood Borgo Po. The park has woodland characteristics that render it unique in the city centre area. Even if it is in the eastern side of the Po, the park is divided from the hills by an urban area. The municipal zoo was the main use of the area in the last century: after different projects never realized the area is abandoned.

SITE OF THE PROJECT

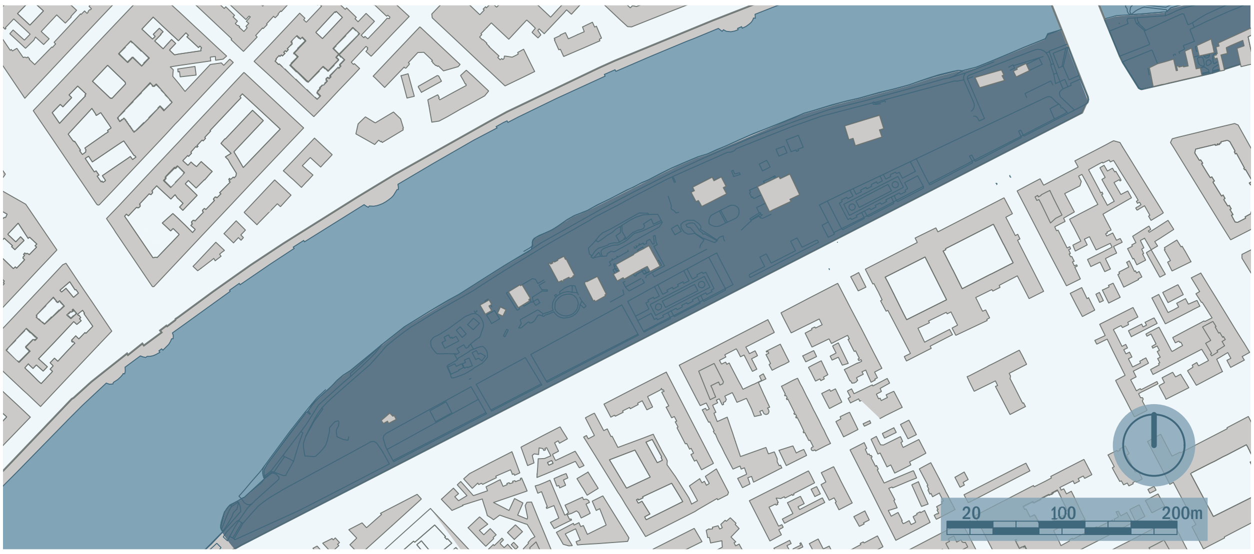
URBAN ANALYSIS PARK SITE

Plan of "*Fills and Voids*" shows that the site is enclosed between an urban area and the river. The project of the new tower interests some architectures present inside Parco Michelotti; these objects are the previous infrastructures of the zoo nowadays abandoned. The distribution inside the park respects the longer axis of the park occupying homogenously the entire area.



FILLS AND VOIDS

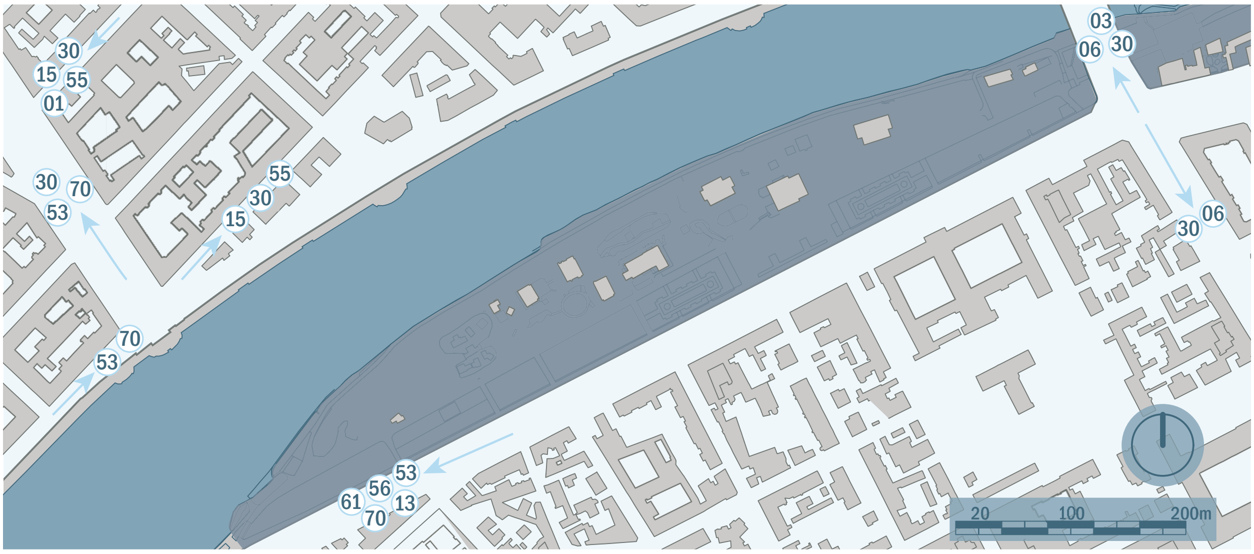
Plan of "*Green Areas*" shows that Parco Michelotti is a green area inside an urban context cut by the river. The park can be inserted in a bigger green area that follows all the path of the eastern side but at the same time its perimeter is clearly defined by the river, Corso Casale and two bridges: Ponte Vittorio Emanuele I and Ponte Regina Margherita, respectively from Piazza Vittorio Veneto and Corso Regina Margherita.



GREEN AREAS

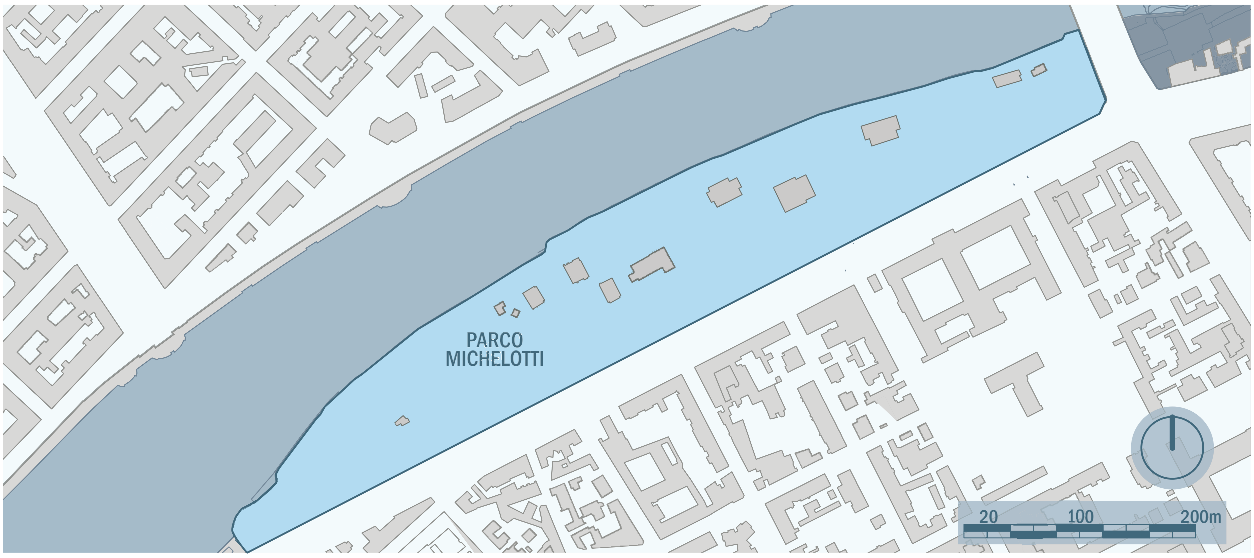
URBAN ANALYSIS PARK SITE

Plan of "*Mobility*" shows how many paths interested the area of the project. Corso Casale is well connected and cross the two bridges that connect the rest of the city. The western part of the city is more crowed of public transport lines, for instance Corso San Maurizio, but the project of the new bridge will make new mobility opportunities that can create a more organized net of lines.



MOBILITIES

Plan of "*Connections*" shows the direct nearness with different focus points of the city. Parco Michelotti is inserted in a central position in Turin, well connected with three important ways: Via Po, and Piazza Vittorio Veneto, Corso Regina Margherita and Corso Casale. Inside a middle position between the natural hills and the Po in a woodland atmosphere.

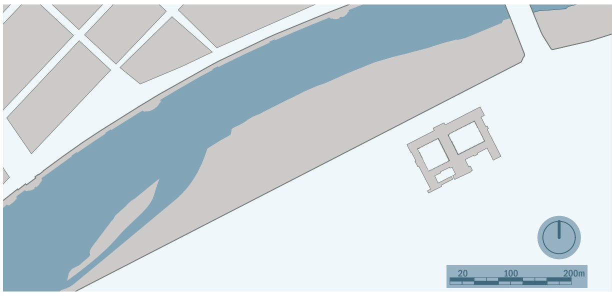


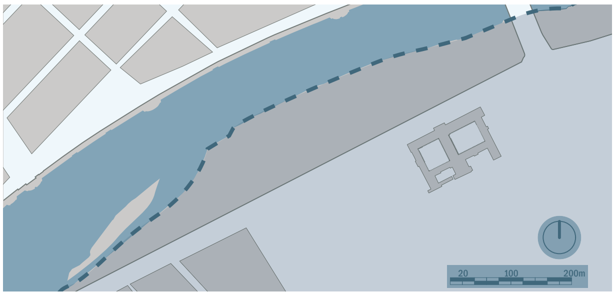
CONNECTIONS

HISTORICAL ANALYSIS PHASES

1800

1853





HISTORICAL DEVELOPMENT OF BORGO PO

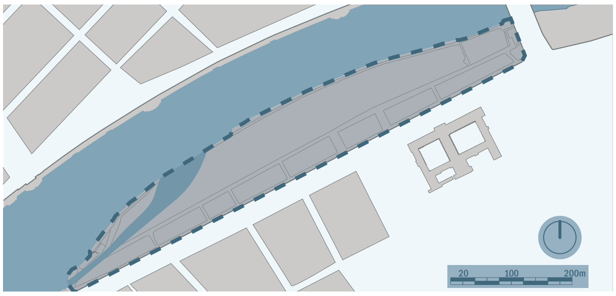
Borgo Po was a borgo that didn't take part in the normal day life of the city because it was sited outside the city walls. It was characterized by little restaurants and inns where travelers could pass the night close to the city center and without the payment of the city walls' taxes. At the beginning of the '800 there was the demolition of the city walls, the city was under the Napoleon's control and the new political arrangement led a new urbanization of Turin: the city has now the possibility to have open green areas along the two sides of the river Po and the possibility of expansion incorporating the small village that were over the city walls.

The 1827 was an important year because the construction of the square Vittorio Veneto and the church Gran Madre di Dio, these architectures were the first connection between the city, the river and the hill. Now the interest to incorporate also Borgo Po in the urban texture of the city was born.

In the 1853 Borgo Po became officially part of the city because the border of the Turin was moved over the Po and also to enter in Borgo Po it was necessary to pay the taxes that before were linked with the geographical position of the ancient city walls. This decision was connected with the presence of milling sites along the river, presence began in the '400 and multiplicated in terms of number of sites in the second half of the '800, the goals were firstly an economical advantage from the networks of the milling sites and in the second stage the possibility to develop Turin from an industrial point of view. This was the starting point for the enlargement plan of the 1886 that interested Borgo Po. The plan followed the typical regular texture of the Roman castrum and the main part of the new blocks had a residential aim.

HISTORICAL ANALYSIS PHASES

1901



1903

In the 1908 there was another urbanistic plan in the area, there was the shift of the industrial sites from the Po and the use of the river's flux to produce energy. Without the industrial sites and the closure for the ships of the Michelotti Canal, important for the milling sites, in the 1901 borgo Po is charactered by the prevalence of residential architectures sited between the hills and an elegant public park before the river. But initially, after the closure of the canal, the park was considered a wood, a forest, a natural element difficult to use like a park. Then the presence of the Michelotti Canal, also if closed, was a danger for the park's users and it limited the use of the area.

USE OF THE PARK DURING THE XIX CENTURY

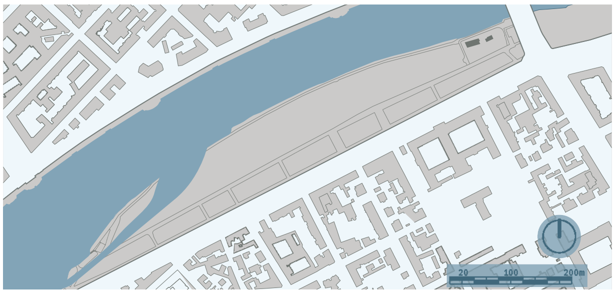
In the 1903 the park for the first time has commercial activities. Firstly there were a chalet, with a function of cafe, and a bowling alley with a total of 2500mq of occupied surface. Then there was the construction of a footbridge to overcome the Michelotti Canal. In that period the manager of the area was the Mr. Bosso. The granting decisions were finally revoked in the 1910, date of the contract's end after an extra time of two years, in that year the manager became the Mr. Fiandra that managed the park until the 1957.

The first idea of the new manager was to build beer shop in a Liberty style close to the previous chalet and a stage for cultural and artistic performances, but these two projects remained in a prelaminar phase like the construction of an extension added to the chalet and in the place where had to be the stage there was temporary covers. At the end of the 1910 the association Tennis Sport Club Junior obtains a granting for 1500mq of park sited in line with Via dei Romani and it real-

HISTORICAL ANALYSIS PHASES

1918

1928



ized a wooden storage.

During the First World War the park was area of temporary military barracks, after the war the army paid the manager Mr. Fiandra that decided to realize a new theater. This theater was a project of the engineer Premoli and it was an architecture similar to the Beer shop that was expected in the park. This architecture began a lucky season for the park's activities, the flux of people increased and Mr. Fiandra had to build an extra part of bowling alley and a residence of the guardian in the 1929, and in the 1931 a new level in the wooden building of tennis club.

The shape of Parco Michelotti during the Fascism was this one. A park between the Po and the neighborhood Borgo Po, crossed by a canal with various activities like the renting of ships, the bowling alley and refreshment places.

In the 1935 the canal was suppressed and in a small time there was an improved of the hygienic conditions that were represented by swamp smell and a big presence of mosquitos. The cover of the canal has given to Borgo Po a new space, called Parco Michelotti, sited between Corso Casale and the Po, with an increase of trees that harmonized the place.

This period was an important phase in the urbanistic shape of the city, Via Roma was in a rebuilding period and all the ruins of the ancient buildings that composed the street were used to delete the Michelotti Canal.

In the 1937 Mr. Fiandra had the renewal of the granting motivated by the Municipality for mainly two reasons, firstly the need to have time to cover the big initial investment and then reason the clear success in terms of people that used the park.

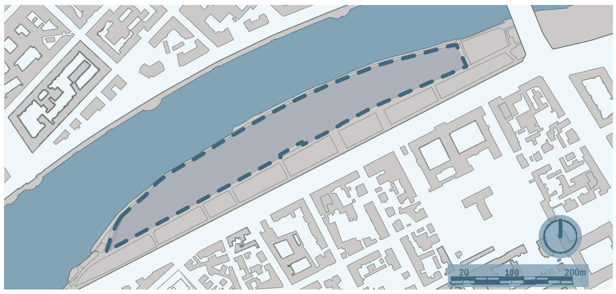
HISTORICAL ANALYSIS PHASES

1935

During the Second World War the park was bombed and the result was a critique situation that meets the strong will of Mr. Fiandra to rebuild everything re-establishing the conditions before the war. In the 1948 an association, called S.I.S. (societá di incremento sportivo), had the granting to build a wooden construction for social goals, but at the end the association realized a Beer shop and another bowling alley. In the same year Federcarni, national association of butchers, asked and obtain the permission to build its seat in Turin from the Municipality, nowadays this building is the library Geisser.

In the 1955 the company Molinar sent the request for the creation of a zoological garden. It was the first time in the history of the city that activities present in a public park are not re-confirmed and improved but replaced with a new function not more public.

1955
25th February



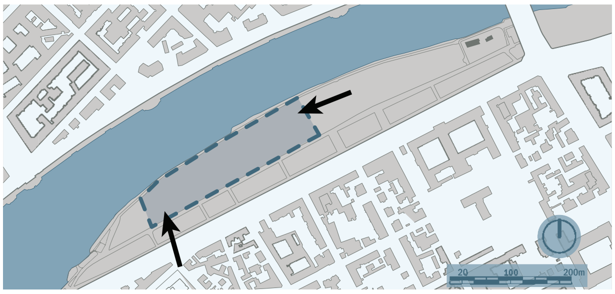
THE ZOOLOGICAL GARDEN

In the 1928 the company Molinar organized an animal exibition in the Parco del Valentino, the istallations are very big, close to the medieval castle the organization staff install an aquarium. The installations were to become permanent and during the Second World War they were all bombed.

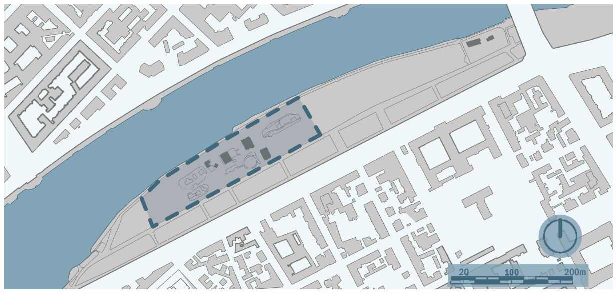
After the war the company Molinar organized events to promote the constraction of a permanent zoological garden in the city. The people approved the initiatives and from the 1945 different projects for a future zoo were presented to the Municipality, the projects were planned in the parks, options were Parco del Valentino, Parco della Pellerina, Monte dei Cappuccini, Parco Gizburg and Parco MIchelotti. The last one was choosen by the superintendence because the place hadn't infrastructures. So, the municipality allows to construct the zoological park the 25th

HISTORICAL ANALYSIS PHASES

1955
18th March



1955
20th October

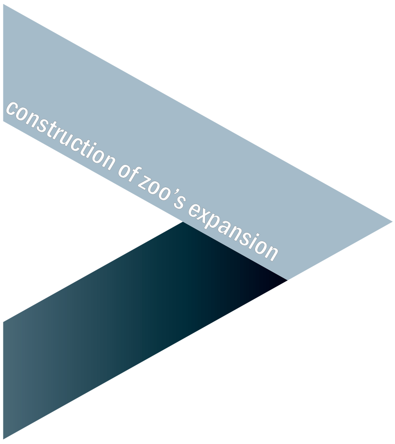


February 1955, from this date the company Molinar obtained a concession for thirty years for the management of 24 500 mq of the park. The contracts kept in the archives testify that the municipality was responsible for the construction of the fences for the sewer, electricity and water systems.

A part of the population of Turin, after a first phase of enthusiasm, begin to be afraid about the presence of wild animals in the city center, the main reasons were the nauseating smell and un pleaseant sounds. The company Molinar clarified that the project will contemplate not a traditional zoo but a zoological park. It will be two main functions: refuge and sorting center for exotic animal. Their permanance in Turin wuold be temporary, or they will be sell or transfered to the north Europe zoo and the period passed in Italy needs to don't have a thermal shock in the movement from the original country to the final destination. This policy was adopted to have a vast range of animals that after a period of time change to improved the number of visitors and researchers.

The building site started the 18th March 1955, the prevition was the opening the following July. The project had expected two entrances: the first parallely to the Via Felice Romani and the second one close to the Fiandra theater. The fence of the project had to be metallic in order to be transparent the view from outside with a double goal: on one side the animals live in a natural location without visible obstacles, on the other side to see the animals by the people that use the park like an advertisement. The first designer of the zoo was the engineer Manfredi, the first infrastructures realized were the home of the felids, it was made up of eight cages and the roof was made up of eight glass blocks to favor natural lighting, and the monkey house made up of twelve cages and a pit dug to make them play with each other.

HISTORICAL ANALYSIS **PHASES**

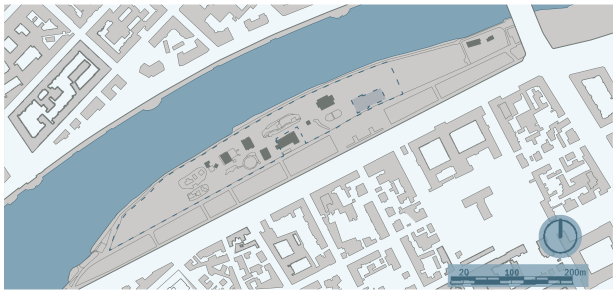


1957

The inauguration day of the zoo was the 20th October 1955, the following days the park aroused great interest from the population who occupied it with a constant flow of visits. Mr. Fiandra, feeling the success of the new zoological park, allowsto the company Molinar to occupy the rest of the park to increase the surface, the goal was the constrution of new structures for other types of animals and to give them more space. So, in 1957 the theater was demilished and replaced by the houses of giraffes and elephants. The entrance became only one and was moved to a central position, parallel to Corso Casale, and in front of the new entry was built a large car parking.

The zoological garden of Parco Michelotti attracted the attention also out of the city with the consequent increasement of visitors, the zoo was different compared to the previous examples: mainly constructed outside the

1958



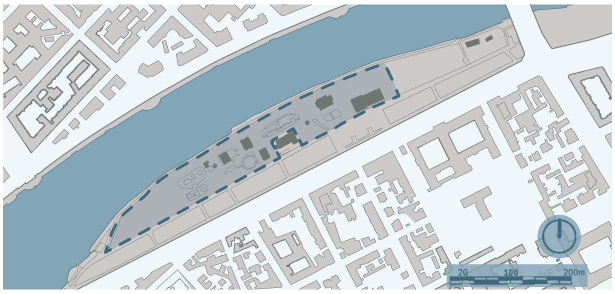
city, or in vast area in not urbanized spaces of the city, completely managed by private companies owners of the ground too, the first consequence was the high price of the ticket.

The press often advertises the “new zoo of Turin” provoking the interest of the people: the success pushes the company Molinar to ask to the Municipality to expand the again the surface of the zoo. The new project had the goal to transform the zoological park to a more cultural center with the addiction of a reptile-aquarium, a library and a confernce room. The 20th March 1957 the construction of the zoo’s expantion started, the expectation was to finish the works in seventy days, it is index of the confidence in the business.

The 29th January 1958 the company Molinar exposed to the Major of Turin, Amedeo Peyron, the project of the new reptile-aquarium, designed by the architect Enzo Venturel-

HISTORICAL ANALYSIS PHASES

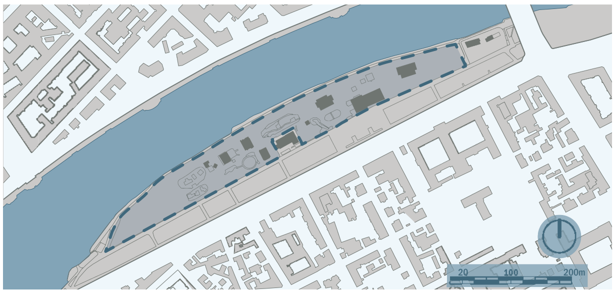
1960



Ii. The construction begin shortly and continued until the inauguration day the 28th May 1960.

The visitor of the reptile-aquarium had to feel the underwater life, in plan the shape was a “T” and the walkable floor was lowered of 2 meters compared to the ground level. The building measures 22,60 meters of width and 49,80 meters of length, the higher point is the external porch 9,50 meters high. The main elevation had a stained glass window as large as the width of the building, outside covered by a indentation that simulated the teeth of a crocodile and had the fuction of sunscreen. From the main mall started three ramps one went down to the exibition of the sea animals, and the other two went up to the reptile cages. Venturelli had designed a tecnological building where the atmospheres, the lights and the temperatures simulated conditions of the original places of the animals. These conditions were optimal also for the growing of plants native of the animals’ places. The visitors could look the animal behind large stained glass window that had dimentions from the floor to the ceiling to allows a complete view of inside the cages. The lights inside the building simulated real light, every morning there was sunrise and every evening the tamonto, the windows never condensed and the water was continuously filtered and exchanged. In the reptile part the floor was 90 centimeters higher than the animal habitats, the heating of the tropical reptiles was radial to the floor and the lighting was allowed through the mechanical opening and closing of large skylights placed above the cages. Externally the building stands out for its size and position: it was much larger than the other animal houses, it was entirely white in contrast with the wooded vegetation of the park and was located near the metal fence.

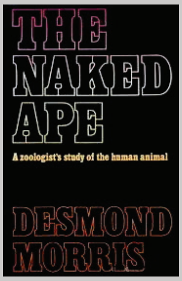
1961



The interest in this new type of zoo estab-

HISTORICAL ANALYSIS **PHASES**

1969



1984

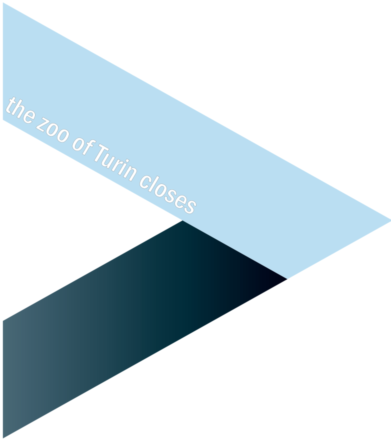
lished itself over the years, becoming a model, even the national press dedicated articles and the number of visitors grew. A consequence of all this media exposure was the need to hire far more staff. In 1960 the Molinar company asked the superintendence to be able to build residential buildings inside the park in order to have permanent people inside the zoo. So, in the 1961 started there was the second expansion of the zoological garden. In addition to housing for employees, four other buildings were also built in the same year to house hippopotamus, rhinos, tigers and lions. This was the zoo's maximum expansion, the completion of the project. The zoo was a series of structures, the animals were the object of scientific study and tourist attractions, but the main target of visitors were young people so even the company choices over the years had been directed towards descriptions and easy to understand educational paths.

Despite the trend, in 1968 the director of the zoo, Arduino Terni, asked to the Municipality the possibility to extend the northern part of Parco Michelotti, the last area of the park not yet incorporated in the activities of the zoological garden. In 1965 the Municipality allowed to ocupy 1100 mq, expanding the activities in the northern part of Parco MIchelotti but not with the condition that the company Molinar asked.

THE CLOSURE OF THE ZOO

Desmond Morris, director of the Zoo of London, pubblished "The Naked Ape"in the 1969. This book summarizes the conditions of European zoos showing their limits and room for improvement. The author's experience in zoos led him to redefine a new type of zoological garden by proposing a radical combination in zoo structures, in some cases Moris also hypothesized the closure. At

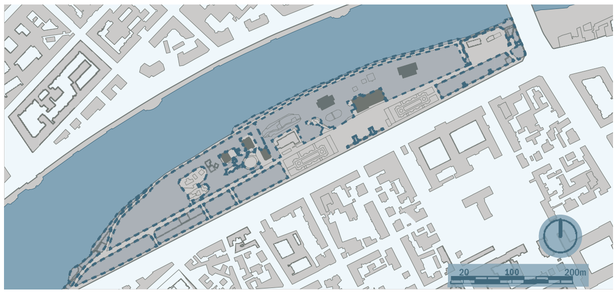
HISTORICAL ANALYSIS PHASES



1987
1st April

the end of the 1960s, the Turin zoo, despite the positive revenues, was in a condition where the structures needed modernization and Morris's new ideas began to spread even among ordinary people. The municipality suggested to the zoo management to move the whole complex to the Stupinigi area so that the new rules related to zoos could be applied. The municipality proposed a redevelopment project for the Michelotti Park with fountains and public greenery, but the Molinar company never presented a definitive plan for a zoo in Stupinigi. In the meantime, the local press held a contradictory position towards the presence of a zoo in Turin. Morris's ideas had spread across Europe, committees were born to promote zoo closures. So in this situation of apparent transition the Turin zoo began to sell some species, reduced the staff and occupied some structures with local animals more adaptable to the climatic conditions.

1991



In the 1984, the committee Cavoretto-Borgo Po was born that put forward ideas for the re-appropriation of the park by the neighborhood with the subsequent conversion into a public park. The Mayor Giorgio Cardelli was in favor of moving the zoo and converting the park into a public area, in line with the ideas of the various committees against the zoo. In the autumn of 1985 a special commission was appointed of the municipality which had to take decisions regarding the Turin zoo: from the first meetings, the desire to dismantle the zoo from Parco Michelotti and its displacement to the Stupinigi area immediately emerged, so as to constitute a new type of structure that did not have exotic animals and could have larger spaces.

But, although the special commission had clear ideas, the works lasted longer than had been planned and the closure of the zoo was postponed to 31st March 1987, exceeding the expiry date of the concession by one

HISTORICAL ANALYSIS PHASES

1992

1995

year. On 1st April 1987 the Turin zoo closed, the Molinar company was suspended from any public office and exonerated from having to dismantle the structures, the animals were largely sold and the older ones continued to live in Parco Michelotti cared for by a community.

In December 1987, an agreement between the Department of Biology of the University of Turin and the Faculty of Architecture of the Politecnico di Torino presented a redevelopment project for the area: use of some structures for scientific purposes, the demolition of others and the return of the rest of the park, embellished with fountains and flower beds, in the Borgo Po district. The project involved the reopening of the canal closed in 1935, the extension of the reptile house, which was to become an aquarium of the Po species, the monkey house attached to the library. All of this has never been achieved due to lack of funds, investors and bureaucratic problems.

In the summers of 1989 and 1990, demonstrations were organized by artists who confronted each other on the theme of captivity among the abandoned structures of the park. In the summer of 1991, despite the deterioration, the park had become a place for entertainment and meeting place and the opening of a place called “Ippopotamo”. After the zoo was closed, all the activities proposed and implemented in the park did not take long enough to become permanent. In 1991 the municipality promoted a large project linked to the whole city of Turin called “Torino città d’acque” where at the center were the relations between the Turin river parks and the parts of the city linked to public parks.

In the PRG of 1992 the “Torino città d’acque” project appears again: the large project involved the construction of a large river

HISTORICAL ANALYSIS **PHASES**

2007

park connecting all the estistenti along the river with strategic points in areas that, such as Parco MIchelotti, were points of direct contact between cities, hill and river. The project envisaged a restructuring of all the abandoned structures in the existing parks and their use also through a river transport system that would cover the entire urban stretch of the Po. 1935, a widening of the road on Corso Casale, an underpass at the Gran Madre di Dio, the construction of a new bridge to extend Corso San Maurizio.

In 1995 an area for children, called Parco Giò, was built in the southern part of the park, in correspondence with the Ponte Vittorio Emanuele I, using some existing structures of the old zoo and others were built. Today these structures are also abandoned, although, unlike those still existing in the zoo, they are accessible.

2021

LA CITTA' IL FIUME LA COLLINA

The park, in ever increasing conditions of abandonment, has always been an object of interest for the population of Turin. In 2007, a great opportunity was represented by the "La città, il fiume, la collina" competition for ideas, the municipality asked for redevelopment projects for the whole part of the city that from Piazza Vittorio Veneto included the Gran Madre di Dio, the banks of the river and Parco Michelotti.

The historical, environmental and architectural values of the area must be preserved, they need a renewal of the viability at all levels, hills, river and urban fabric must be part of a functioning complex for the city. The competition therefore aims to improve the pedestrian and cycling viability of the river banks, to enhance and protect the historical and architectural environmental landscape heritage, to increase the usability of the flat part of the city for those coming from the north and east of the city, to improve urban mobility in pre-hill areas.

The competition announcement explains in detail what needs to be done with Michelotti Park: as regards the abandoned structures of a significant historical nature, they must be preserved and adapted for temporary events, the urban destination must be changed in the park, becoming public green paths must be redefined inside, the reptile house, the work of the architect Venturelli, must undergo a functional recovery that meets the needs of the city with multipurpose and multifunctional rooms, the park must become an attractive place, and this competition also includes the design of a new bridge which crosses the river extending Corso San Maurizio. The competition had a winner but the various administrations that followed each other were unable to carry out the projects.

Since the failure of the competition that this degree thesis tries to simulate again, several targeted projects have followed one another without ever seeing the problem as a whole. from the point of view of events the last dates back to 2011 and was an exhibition on dinosaurs promoted by the DNArt foundation, the last building works were the demolition of some structures costing 150,000 euros of public money and the last project for the conversion of the reptile house in the theater it was approved by the municipality in 2004 but was never built, the cost would have been 8 million euros.

The park is located in the heart of the city, it is abandoned and inaccessible, but as now Turin would need to give back to its citizens one of its symbol parks, one of its green lungs, a place of social gathering.


2


3

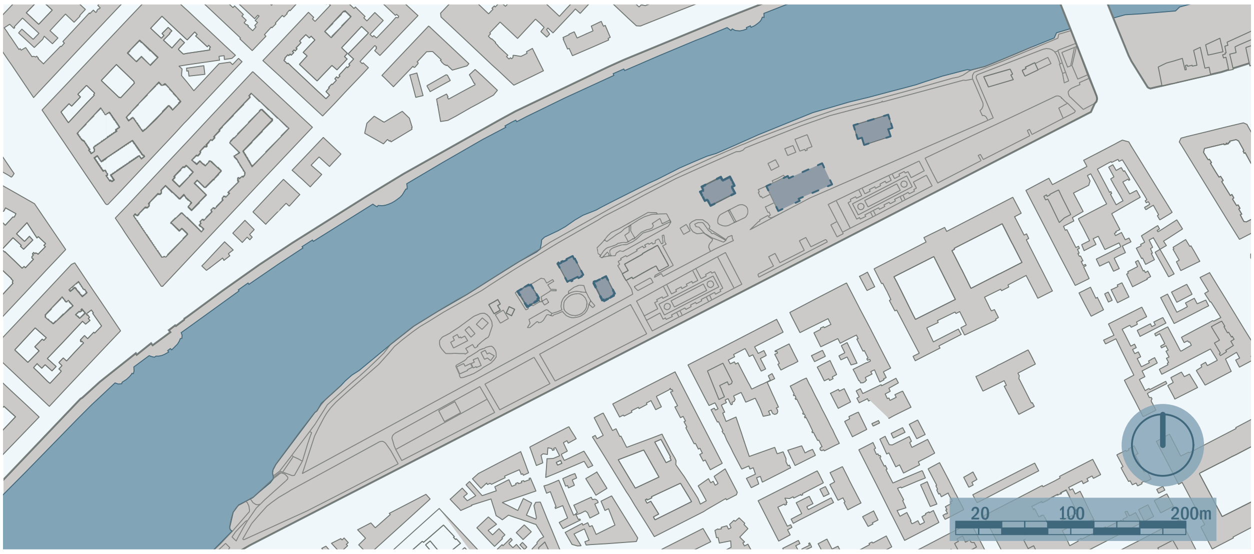

4

5

6

7

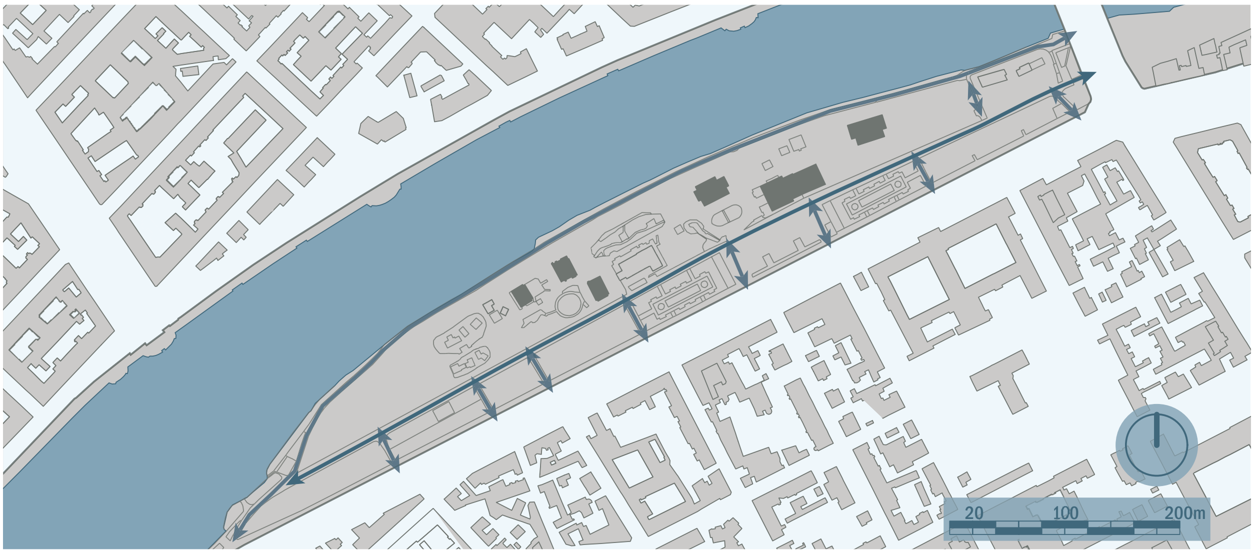
HISTORICAL ANALYSIS STATE OF THE ART



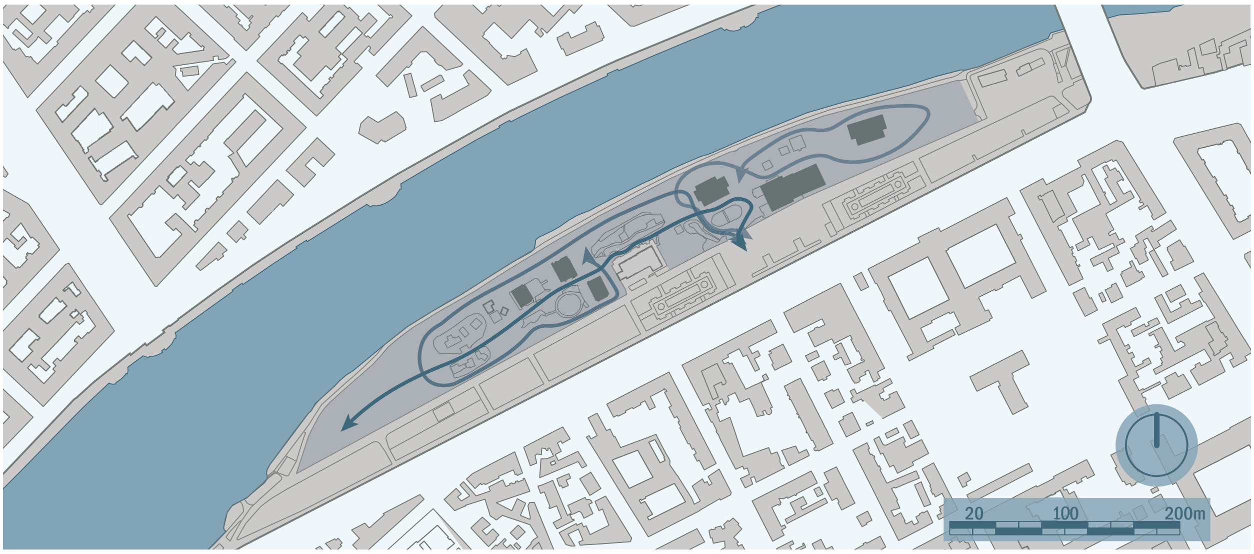
EXISTING EX ZOO INFRASTRUCTURES

EX ZOO AREA

HISTORICAL ANALYSIS STATE OF THE ART



PATHS OUTSIDE THE EX ZOO AREA



PATHS INSIDE THE EX ZOO AREA

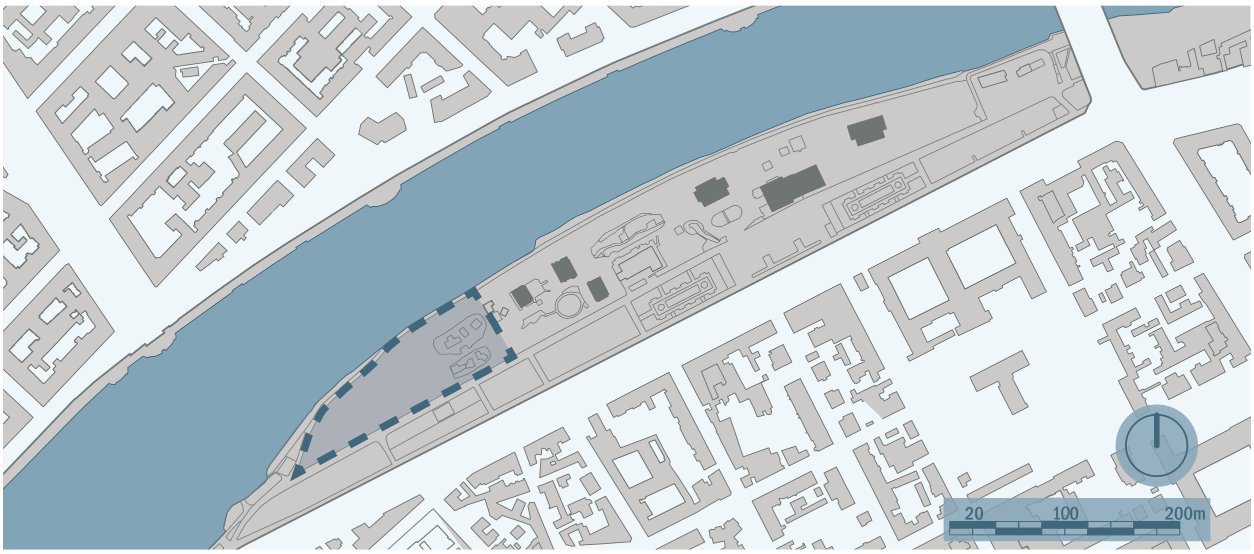
HISTORICAL ANALYSIS STATE OF THE ART

EXISTING FOUNTAINS

EXISTING CAR PARKING

HISTORICAL ANALYSIS STATE OF THE ART

GREEN AREAS INSIDE THE PARK



USABLE AREAS OF THE PARK

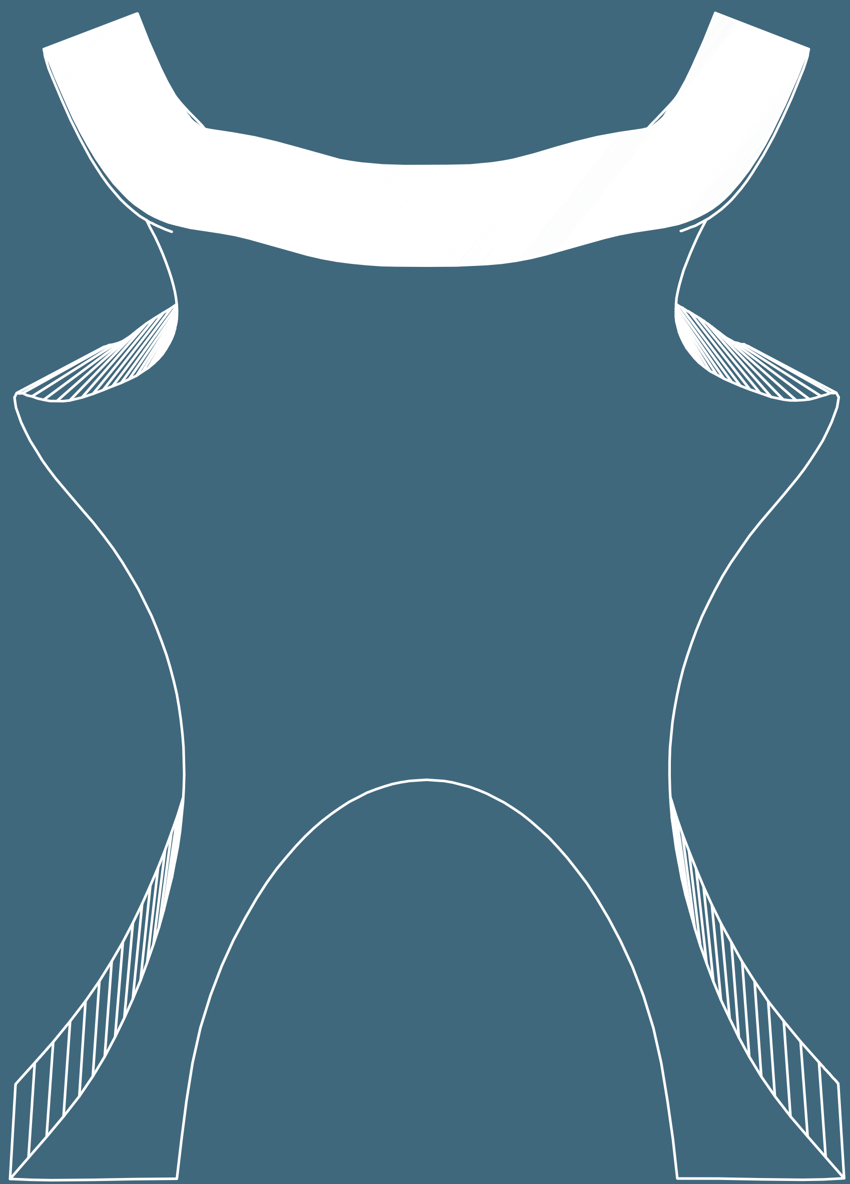
CHAPTER NINE

STATIC ANALYSIS

Ogni volta che scopriamo nuove tecniche spesso ci atteniamo stupidamente alle vecchie forme. Un nuovo materiale, come il cemento, crea da sé le sue forme. Una struttura è architettonicamente valida quando è corretta.

Pier Luigi Nervi *(Ernest O. Hauser, Un creatore del nostro tempo, 1962)*

When we discover new techniques we often foolishly stick to the old methods. A new material, such as concrete, creates its forms by itself. A structure is architecturally solid when it is correct.



The realization of this chapter comes after a long and difficult reflection. Its purpose is to understand, through FEM procedures and structural static analyzes, the behavior of the structural membrane in reinforced concrete, the load-bearing structure of the bridge deck, the subject of the degree thesis. The designer must therefore interpret the real behavior of the structure and model it, according to the principles of construction science, with structural elements, constraints and applied loads. The model generated by the algorithm and explained by Grasshopper's CAD tools cannot itself be a model for FEM systems, therefore it is necessary to have a structural model that can be analyzed and solved to determine the maximum stresses that can develop during the nominal life of the structure.

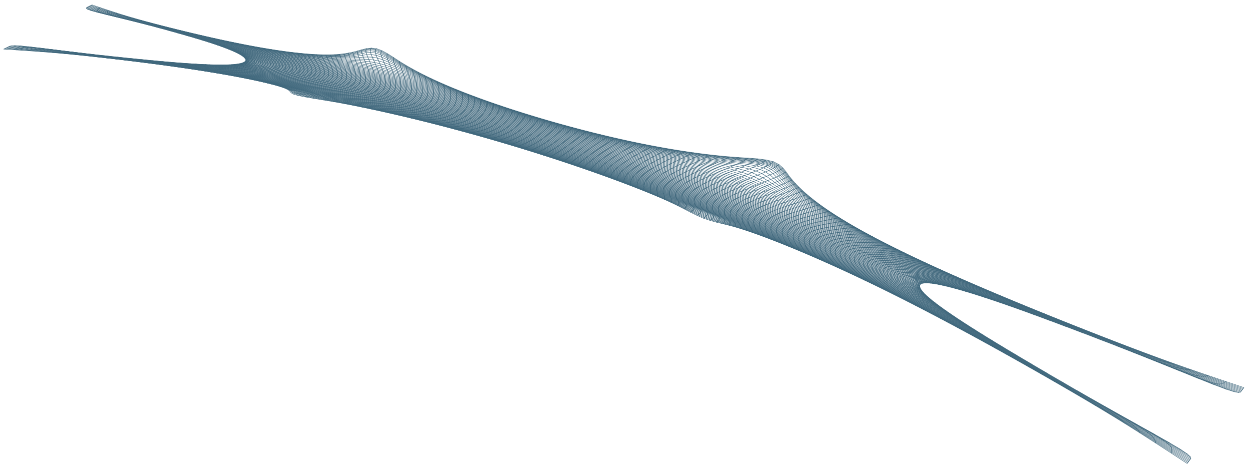
The program from the model, both analytically and graphically, makes explicit values that, at a later time, will be interpreted in such a way as to carry out a structural design. It is therefore necessary to verify that the maximum stresses determined by the resolution of the model are compatible with the capacities of the structural elements, taking onto the geometric configuration of the sections and the mechanical properties of the material constituting the structure. The generative algorithm generates a shape, a polyhedral mesh, which even if viewable in Rhinoceros is not properly feasible, therefore requires approximations that infinitesimally modifying the shape of the membrane making it physically achievable and therefore reusable in FEM processes, programmed to simulate real behavior of the object. A second phase of the structural design process is the passage from the CAD, Rhinoceros and SolidWorks programs, and then to the FEM program. Ansys is a structural analysis software that allows you to solve complex structural engineering problems, another problem arose: what kind of finite element to use. The most common options are two:

- the beam element, a structure composed or decomposable into rods to which the properties can be attributed to each rod by transforming each element into small simulated beams; this element is ideal for linear structures but since the mesh is very complex and composed of many nodes: on the one hand the model would not be too much compared to reality because the continuous material of the membrane is not physically decomposable into rods and secondly the large number of mesh lines complicates the structural model to such a high level that there would be complications to attachments between the various members requiring constraints

- the shell element, a structure composed or decomposable into surfaces to which simulated three-dimensional physical properties can be attributed; this element is ideal for structures that undergo applications of forces from various levels: on the one hand the irregular and complex shape of the membrane would be very well approximated by virtue of the increasingly smaller dimensions of the small surfaces, but secondly the shell element, precisely because it must resist a complex equilibrium, it stiffens a lot making the thickness irregular

- the brick element, a structure with a very irregular shape is broken down into many interlocking solids, each object has simulated physical properties; the brick element with a minimum of five tetrahedes in the membrane thickness accurately simulates objects with a regular thickness of complex shape not only on the surface but also internally on the fibrous level.

FIRST CALCULATION STEPS



grasshopper's mesh

from MESH to CLOUD OF POINTS

EXPORT Grasshopper 6
IMPORT Rhinoceros 6

TRANSFORMATION
from Mesh to Cloud of Points

METHOD Grasshopper's algorithm

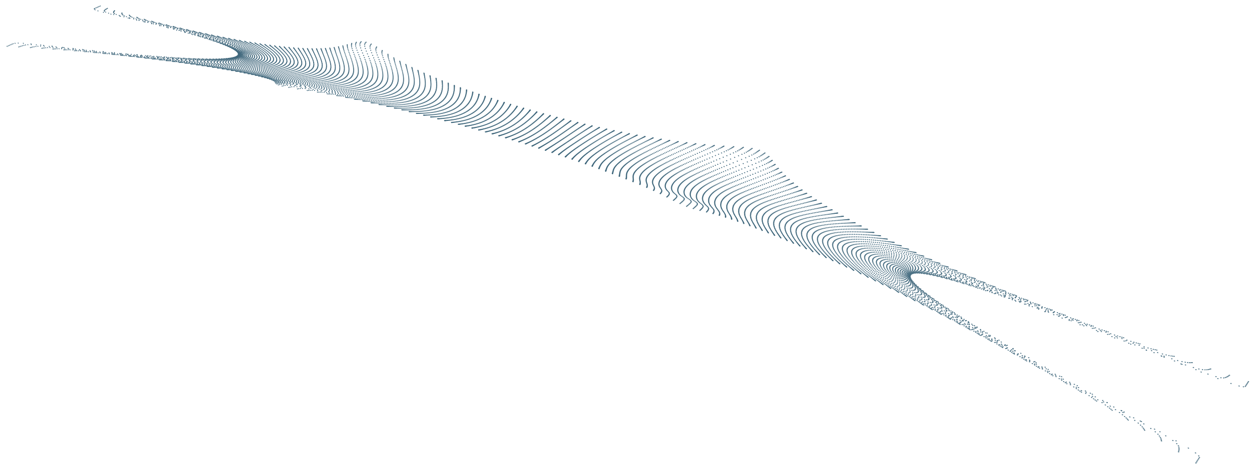
MESH 25202 curves
CLOUD 12601 points

Starting from the mesh created by the generative algorithm, explained from the theoretical point of view in chapters four and five and from the practical point of view six and seven, FEM programs need finite elements to be able to process structures.

In the case of this thesis the mesh is a polyhedral mesh: it is a subdivision of a solid into smaller solids of a polyhedral shape, to apply the method of analysis to the finite elements, which allows to study the behavior of a solid when subjected to of the stresses, the behavior of the solid is approximated with that of the polyhedra that compose it, allowing the theory to be applied to more complex shapes. A mesh, in essence, is not a graphical representation but a mathematical-analytical composition. So, in order to pass from a mathematical element to a graphic one, it is necessary to define a method that graphically approximates mathematics: in this case the geometry of the points is used. The point, by definition, is a geometric element that has no dimensions but defines positions by redefining a trend. A set of points creates a cloud of points: it is the result of the survey of the mesh creating a three-dimensional model of the object, known the coordinates of each point derived from mathematics.

From the Grasshopper it is possible to create an algorithm that associates a "mesh" component the membrane, graphically visible in Rhinoceros, the component is set as the input of the "deconstruction mesh" component, which, in turn, processes between the various outputs the vertices. These, in turn are divided into mathematical sets. The set that defines a continuous trend is exported to Rhinocero like a clod of points.

FIRST CALCULATION STEPS



cloud of points

from CLOUD POINTS to CONTINUOS SURFACE

EXPORT	Rhinoceros 6
IMPORT	Rhinoceros 7

TRANSFORMATION
from Cloud of Points to Continuos Surface

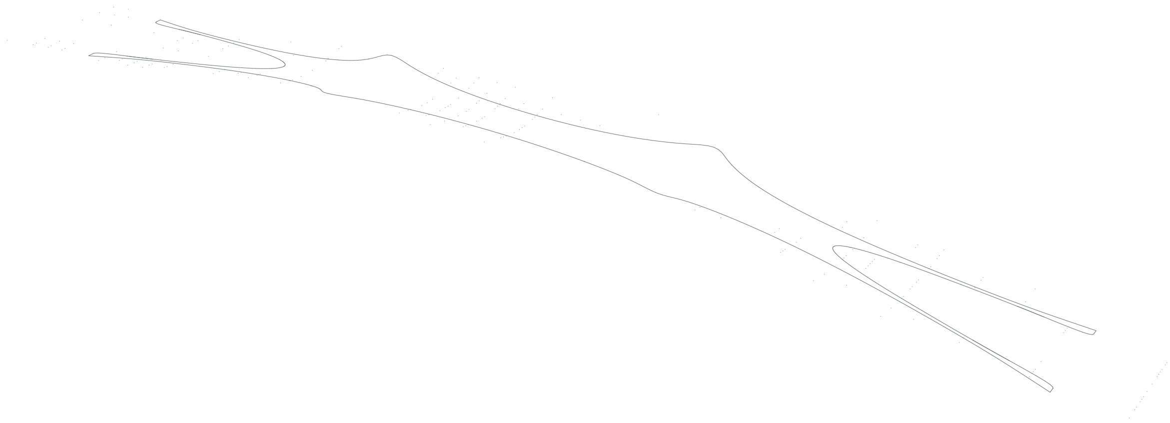
METHOD	patch

CLOUD	12601 points
SURFACE	25000 faces

Starting from the cloud of points, generated by the deconstruction algorithm, it is necessary to define a geometry having dimensions. The points are taken as the basis for defining a surface, type of geometry. FEM programs can process “beam” elements or “shell” elements, since the membrane is an object of continuous material, for design choices, in this thesis the goal is to have an elaborable shell. Since the initial mesh is very complex, composed of many 3D faces all oriented differently, the generated point cloud is composed of points with very variable distances in all three dimensions. The surface, by definition, however, is a geometric shape without thickness, having only two dimensions, these are given by the U direction and by the V direction. In the case of this thesis, being the curved surface it falls into the category of “abstract surface” or “differentiable variety”, that is a generalization of the concept of surface generated by curves, therefore the program to generate it from points makes use of the tools of infinitesimal calculus. The geometry that is defined at the end of this phase is tangential to all the points of the cloud, therefore continuous and respectful of the real variables in the three-dimensional Euclidean space.

From Rhinoceros 6, the cloud of points is exported to Rhinoceros 7, the “patch” command of the seventh one, in addition to creating a surface by passing it through the selected points defining the U and V directions, from points generates curves according to the two directions, in turn the curves generates a deformed surface using a parameter “stiffness”, it establishes the deformation allowing the new surface to the plane that best fits dimensionally.

FIRST CALCULATION STEPS



continuos surface

from CONTINUOS SURFACE to SILHOUETTE

EXPORT Rhinoceros 7
IMPORT Rhinoceros 7

TRANSFORMATION
from Continuos Surface to Silhouette

METHOD projectsilhouette

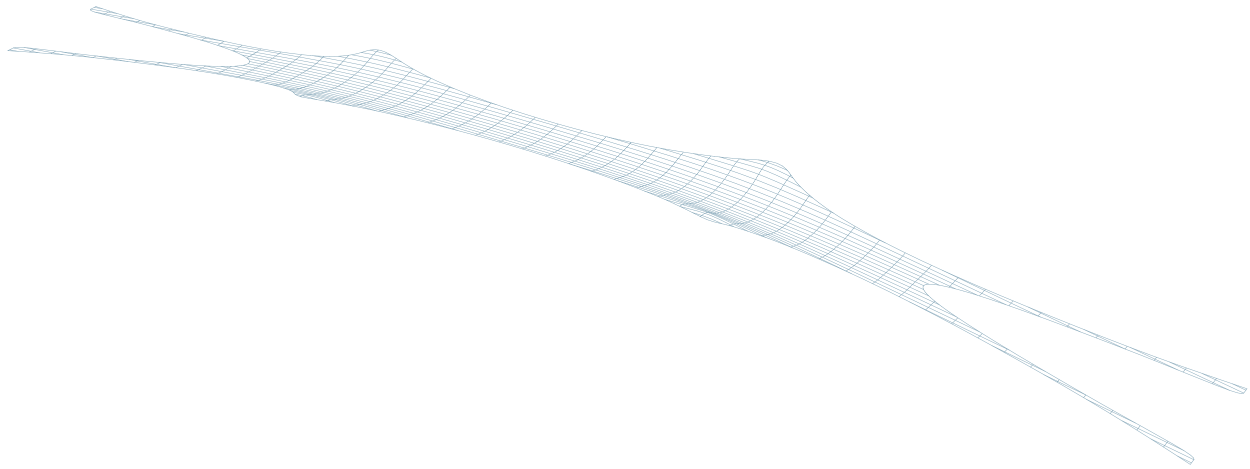
SURFACE IN 25000 faces
SURFACE OUT 2500 faces

Starting from the surface created by the sampled points, it, as can be seen in the drawing above, does not have the shape of the initial mesh. Since the membrane has an irregular shape, its borders cannot be defined with a point cloud, so the previous step generated an approximation. This approximation is not yet sufficient for a FEM calculation, as the physical characteristics are not adequately approximable.

Now, the initial mesh, generated by Graahopper, and the continuous surface are compared. The goal is to project the mesh outline onto the surface. In summary, its surface was generated by the points retrieved from the mesh, therefore, the two objects have a similar shape but infinitesimally different because the mesh is a mathematical function while the surface has a CAD approximation of all the curvatures. The goal is, therefore, to create a mold, a trace of the mathematical outline of the mesh on the surface: the result will be a continuous surface with single lines along its curvatures.

Placed mesh and surface on the Euclidean plane of Rhinoceros in two different layers, the command “projectsilhouette” creates contour curves that represent the projection on the surface of the mesh. The result is a model, the visible edges are perceived where the surface goes undercut and begins to be visible on the surface itself. The set of the visible edges are called “silhouette”. The approximation of the silhoutte, compared with the continuous surface, is satisfactory to be the basis of an object that can be used as a shell to simulate reality in a finite element program.

FIRST CALCULATION STEPS



cutted surface

from a .3DM FILE to a .IGS FILE

EXPORT Rhinoceros 7
IMPORT SolidWorks 19

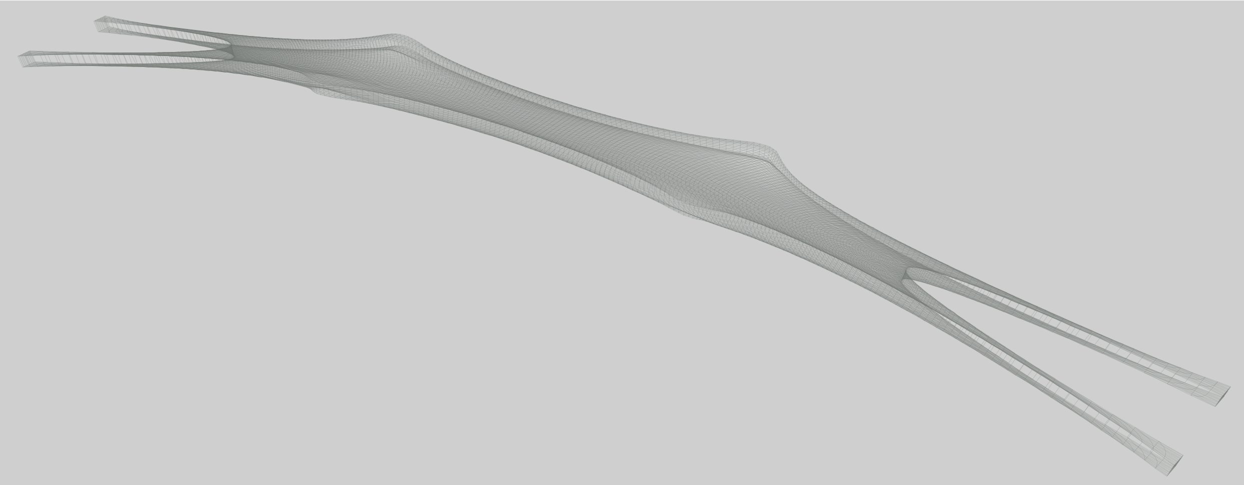
TRANSFORMATION
from a .3dm file to a .igs file

METHOD split

SURFACE 2500 lines
SOLID 1 block

Starting from the silhouette, resulting from the projection of the initial mesh onto the continuous surface of the point cloud, the surface itself is broken down into two parts: the silhouette, after joining all the contours into a polyline, generates a cutting line. This cut creates two of its edges that have the same curves but different borders. The “split” command divides the objects into various parts using cutting objects: the polyline, created by small lines generated by the shape of the mesh, is transformed into an isocurve. The isocurve divides the continuous surface object into various parts through its own isoparametric curves: the parametric soul of the isocurve serves to adapt the curve itself to the curved surface. From the isocurve the program generates a cutting plane that is perpendicular to the curved surface at every point where the same surface touches the isocurve.After cutting, we obtain two different surfaces: one of the two is the transformation of the parametric mesh of the Grasshopper algorithm into a surface geometric element. Again, it is fair to point out that the two have very similar but infinitesimally different shapes due to CAD approximations. At this point the surface obtained can be exported in formats readable with the SolidWorks program, the most precise is IGES, with the domain .igs, and from Rhinoceros it can already be transformed into a SolidWorks surface in such a way as to create an element with characteristics identical to a native element of the exporter. SolidWorks is a three-dimensional parametric design and design software, it is software that is mainly used in mechanical engineering, the approximation of mechanical components, by virtue of their small size, must have a very high degree in order to perform simulations.

FIRST CALCULATION STEPS



solidworks' solid

from a SURFACE to a SOLID ELEMENT

EXPORT SolidWorks 19
IMPORT SolidWorks 19

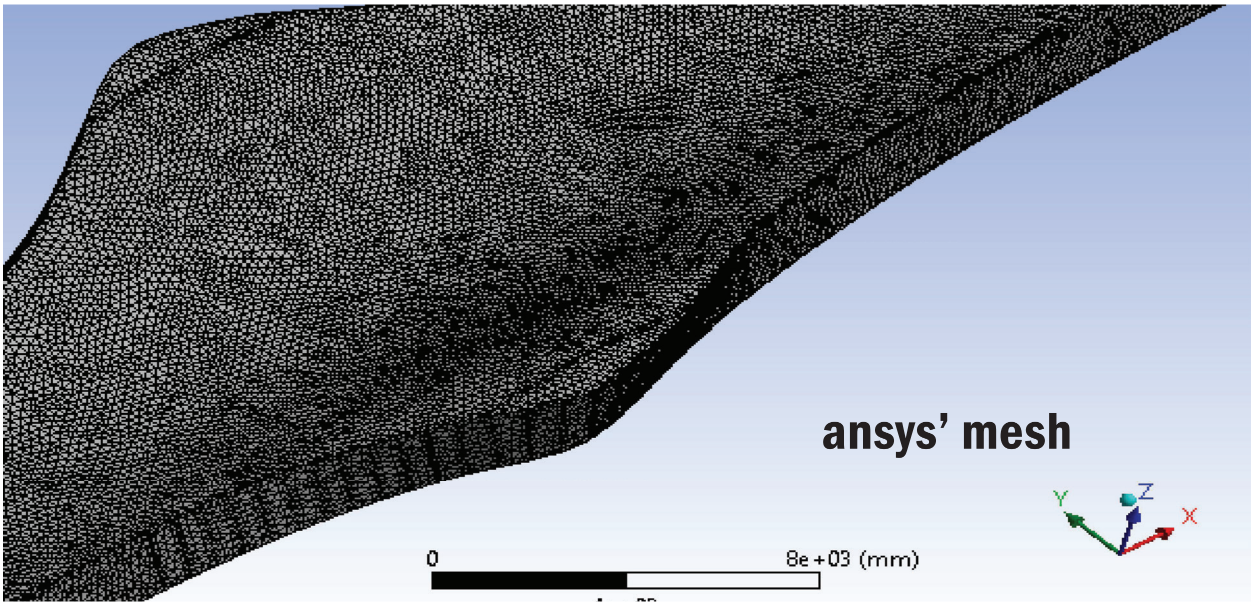
TRANSFORMATION
from a Surface to Solid Element

METHOD import/extrude

SOLID 1 block

Starting from the surface imported from Rhinoceros and generated from the contours of the initial mesh, imported into SolidWorks it is extruded in order to create a solid element. The thickness is set equal to 1.80 meters, value that was generated by the generative agorithm. The program, used for mechanization and so with an almost real approximation doesn't allow to make a linear extrusion because the curved surfaces do not permit it. Returning to the point cloud, each point cannot be moved by a fixed measure with a direction perpendicular to the face where it is located because each point is part of three 3D faces at the same time and each face has a different inclination. So each point of a surface is translated by a fixed view with respect to the perpendicular to the curve in which the point is located, this movement therefore generates its overlapping surfaces and the space between the two is densely filled to generate a solid, but the two surfaces they are not the same: one is smaller than the other. So, one of the two can maintain the dimensions derived from the transformations generated with Rhinoceros, while the other must undergo a further approximation in some parts, the example is the fold of a sheet where the edges have regular thicknesses while the two surfaces have different dimensions due to the external expansion occurred during bending. The method of tangents, called the Newton-Raphson method, is a method for the approximate calculation: starting from a curve y=f(x), insidean interval (a; b), the tangent to the curve, from any point, can start from one of the two points that have as abscissa in the curve and assume, an approximate value of the root x_t, the abscissa of the point where the tangent intersects the axis x inside (a; b).

FIRST CALCULATION STEPS



from a SOLID ELEMENT to MESH FEM

EXPORT SolidWorks 19
IMPORT Ansys 19

TRANSFORMATION
from a .3dm file to a .x_t file

METHOD remesh

NODES 1108907 nodes
ELEMENTS 651023 elements

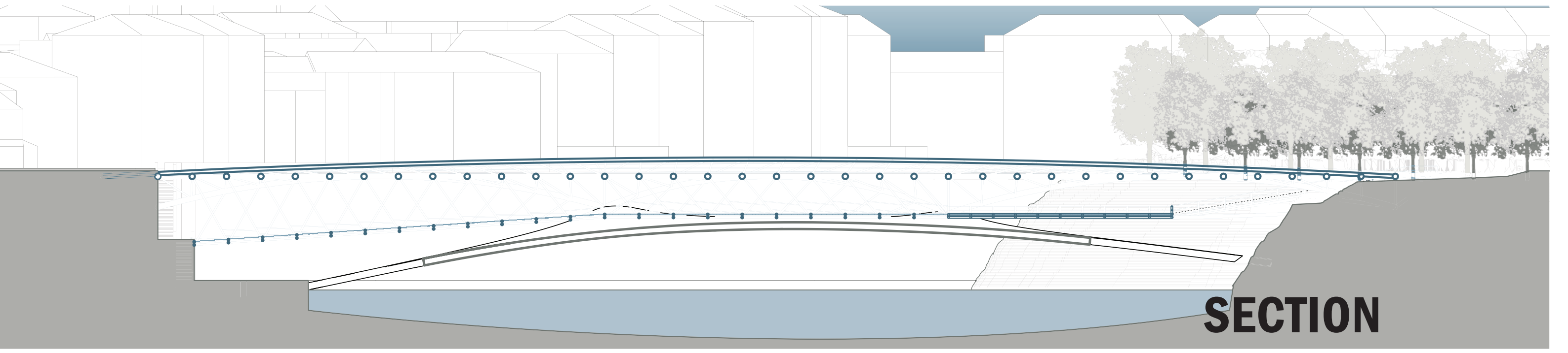
The solid element is the third approximation of the initial mesh: the various transformations and, by virtue of each, the consequent approximation of shape, have led the object to be a solid that can be exported to a FEM program. Ansys was chosen for the calculation analysis in this thesis: it is a high-precision structural simulation tool and was chosen mainly because it starts from the solid that is imported from SolidWorks and generates a mesh, which can be defined more or less high, make a more or less dense grid. From the mesh that is created by following the solid, every face, visible in the image, is a solid precisely a tetrahedron, al the little solids are brick element. Thus, returning to the initial geometry undergoing approximations, now we go to further improve the approximations as a mesh becomes capillary on the surfaces of the solid and is a real rendering of the initial mesh generated with Grasshopper.

At this point we begin to use the program as a real FEM program, define the material of the various bricks and set the material characteristics related to the NTC 2018; then constraints are placed and forces are applied.

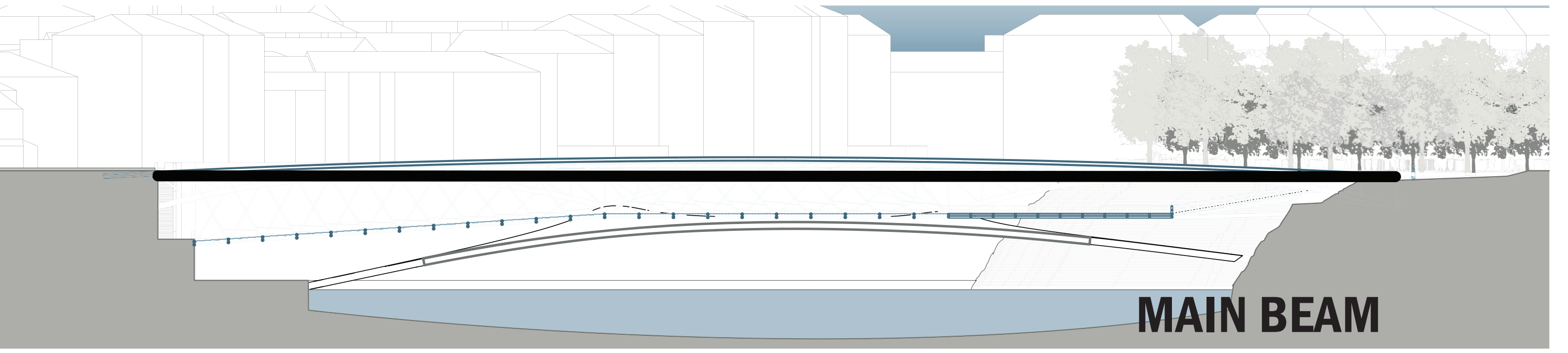
Set the concrete material and related performance standards related to the regulations. The interlocking constraints are placed at the four feet of the membrane, in such a way as to simulate the continuity of the material even in the foundation by following the trend of the curves of the arch, which by virtue of its being lowered arch will have perhaps pushed towards the ground. And we position the forces in the four points of support of the steel arches of the overlying structure of the platform.

FIRST CALCULATION ACKNOWLEDGE

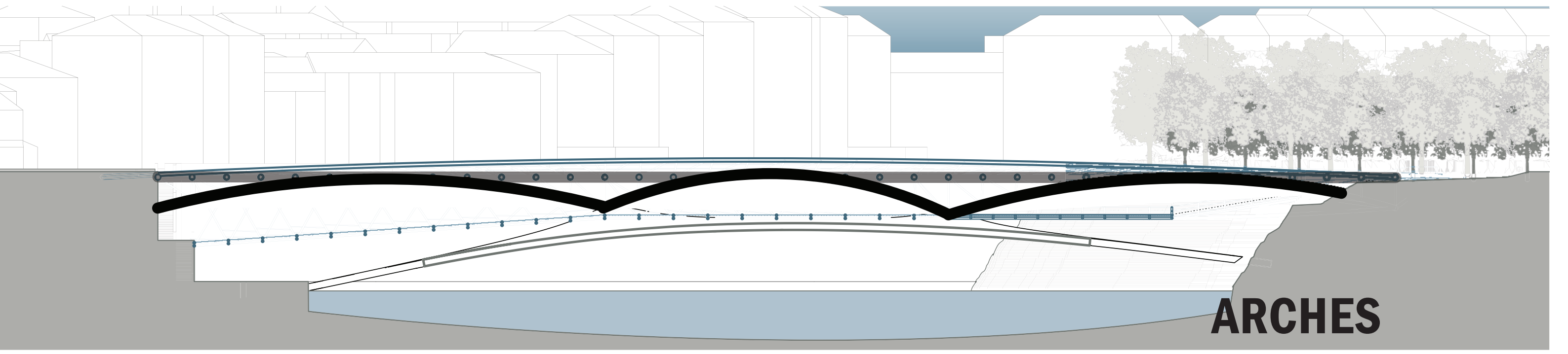
Before approaching the structural static analysis with Ansys, it is necessary to define a static diagram of the concrete membrane, basic component of the entire structure of the bridge project and main subject of the degree thesis. Considering the following schemes, it can be seen starting from the first that the project envisages a bridge composed of a reinforced concrete membrane resting on two different altimetric levels. Above it there are three arches, lowered and inclined, which unload their weight on the banks of the river, in turn different from each other, and in two points of the membrane. Finally, above them there is another lowered arch which rests on the road ledges, relieving the weight of the entire structure on the structure.



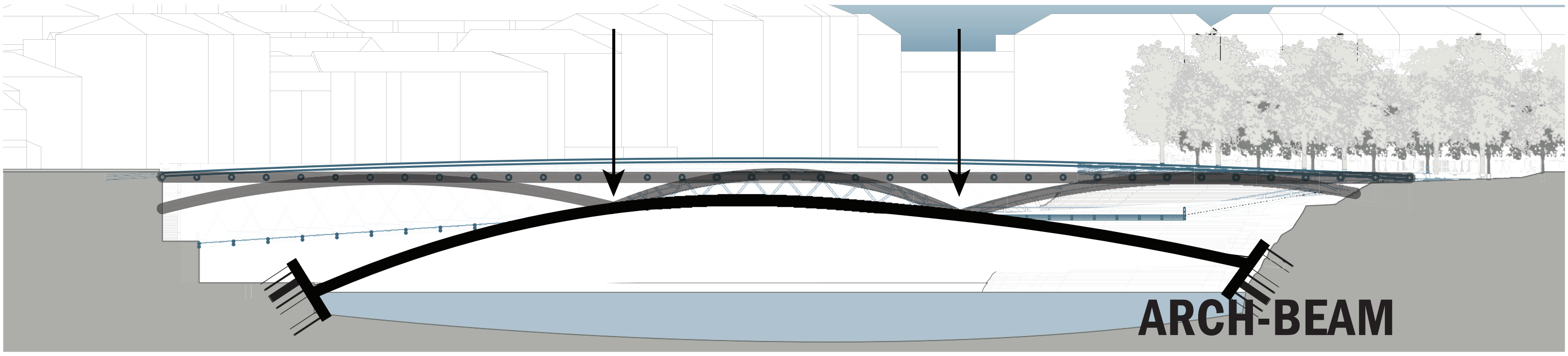
The schemes show the long elevation of the bridge, but it is also known from previous chapters that the concrete membrane unloads the weight on the ground on four points and receives the weight of the deck on four other points. Which are points of support for the terminals of six arches which support six



staff support beams by compression most of the weight of the gangway which hangs from them. Above all, the lowered arches that act as parapets are three. The structural part that bears the most weight in the entire static system of the bridge is the concrete membrane: as shown in the following diagrams, it has rregular sections. In correspondence with the supports of the arches, it can be simplified as a broken line that changes di-



FIRST CALCULATION **ACKNOWLEDGE**



rection precisely at the points of contact with the different structure. But, the material is continuous, a parameter imposed on the generative algorithm, and therefore cooperating as a single mass despite the asymmetry both in the distribution of the loads and in the ground connection. Then, in its central section the structure arches exactly following the trace of a lowered arch, its static scheme can be approximated to an arch with two fixed supports at the bases. The interlock is a triple constraint, which imposes three constraint equations and eliminates all three degrees of freedom: the rotation around the interlocking axis and the translation along the normal to the interlocking plane and the d plane joint itself

The scheme is justified by two design conditions:

- since the membrane can be approximated to a lowered arch, its property is a strong thrust to the bases, this in turn implies high resistance supplies

- the foundations to counteract the thrust that acts in the ground with continuous direction with respect to the inclination of the membrane feet must be countered with opposite forces, therefore the concrete of the feet will continue inside the ground by putting the steel bars in common, the system is typical of an built-in support constraint.

<u>LOADS' ANALYSIS</u>

considering

CONCRETE WEIGHT	2,26e+004 N/m^3
STEEL WEIGHT	7,35e+004 N/m^3

<u>permanent structural loads (G1)</u>

ARCH 1	65 m * 0,40 m	*4
ARCH 2	49 m * 0,40 m	*2
	= 143,20 m^3	
BEAM	170 m * 0,40 m	*6
	= 408,00 m^3	

TOTAL VOLUME	551,20 m^3
TOTAL WEIGHT	3,92e+007 N

<u>permanent no-structural loads (G2)</u>

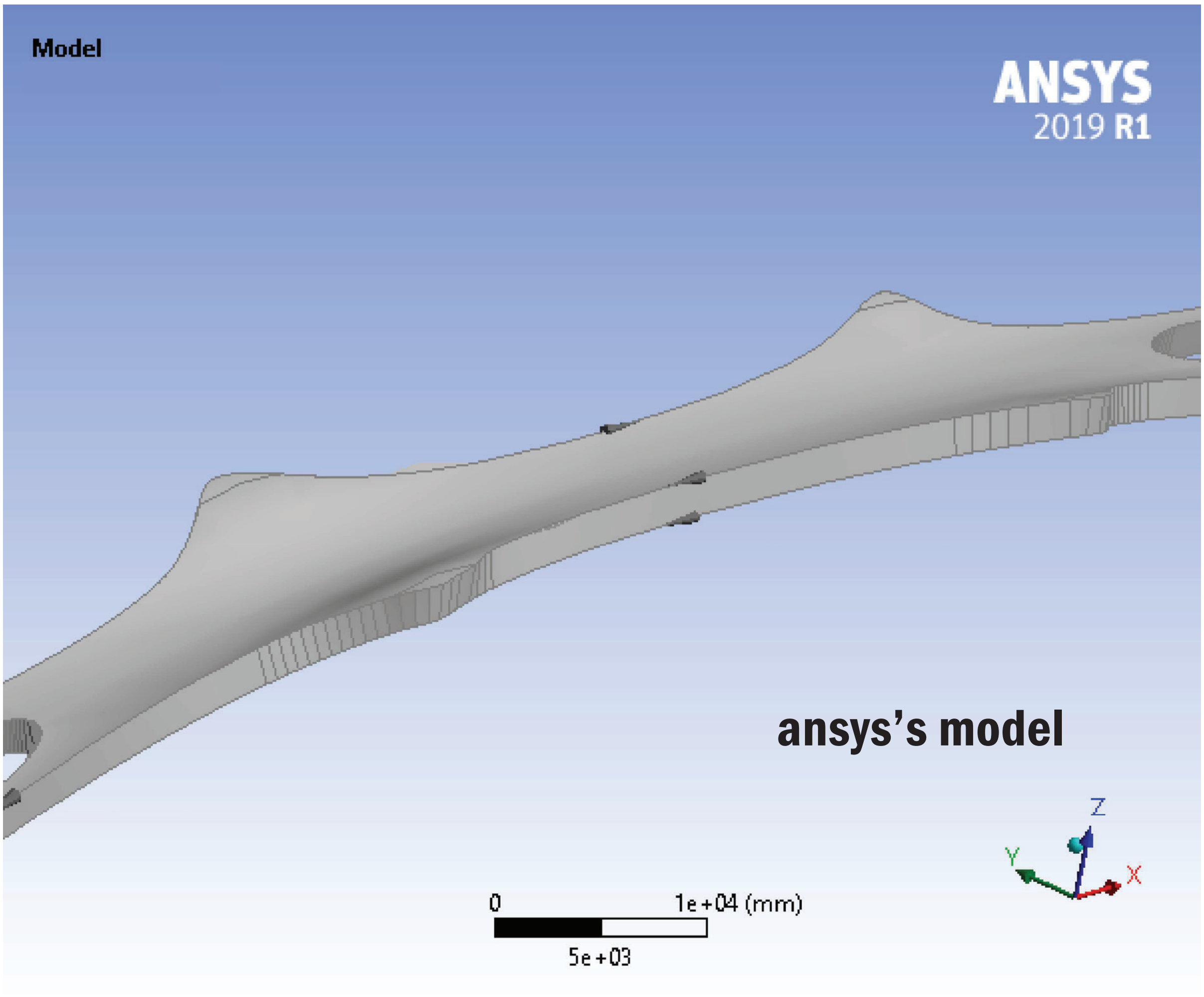
SLAB	170 m * 0,40 m	*2

TOTAL VOLUME	816 m^3
TOTAL WEIGHT	1,86e+007 N

TOTAL PERMANENT WEIGHT (G1+G2)
= 5,78e+007 N
= 6,00e+007 N

So, dividing the load on the four support points and on the two banks it results that each point load has a magnitude equal to
= 1,00e+007 N

FIRST CALCULATION SETTINGS



GEOMETRY PROPERTIES

VOLUME 1,6373e+012 mm³
MASS 3765,8 t
NODES 1108907
ELEMENTS 651023
CENTROID Y 4001,1 mm
CENTROID Z 8340,9 mm

MOMENT OF INERTIA Ip1
5,3777e+010 t*mm²

MOMENT OF INERTIA Ip2
3,9209e+012 t*mm²

MOMENT OF INERTIA Ip3
3,9388e+012 t*mm²

MATERIAL concrete C40/50

MESH PROPERTIES

ELEMENT SIZE50 mm

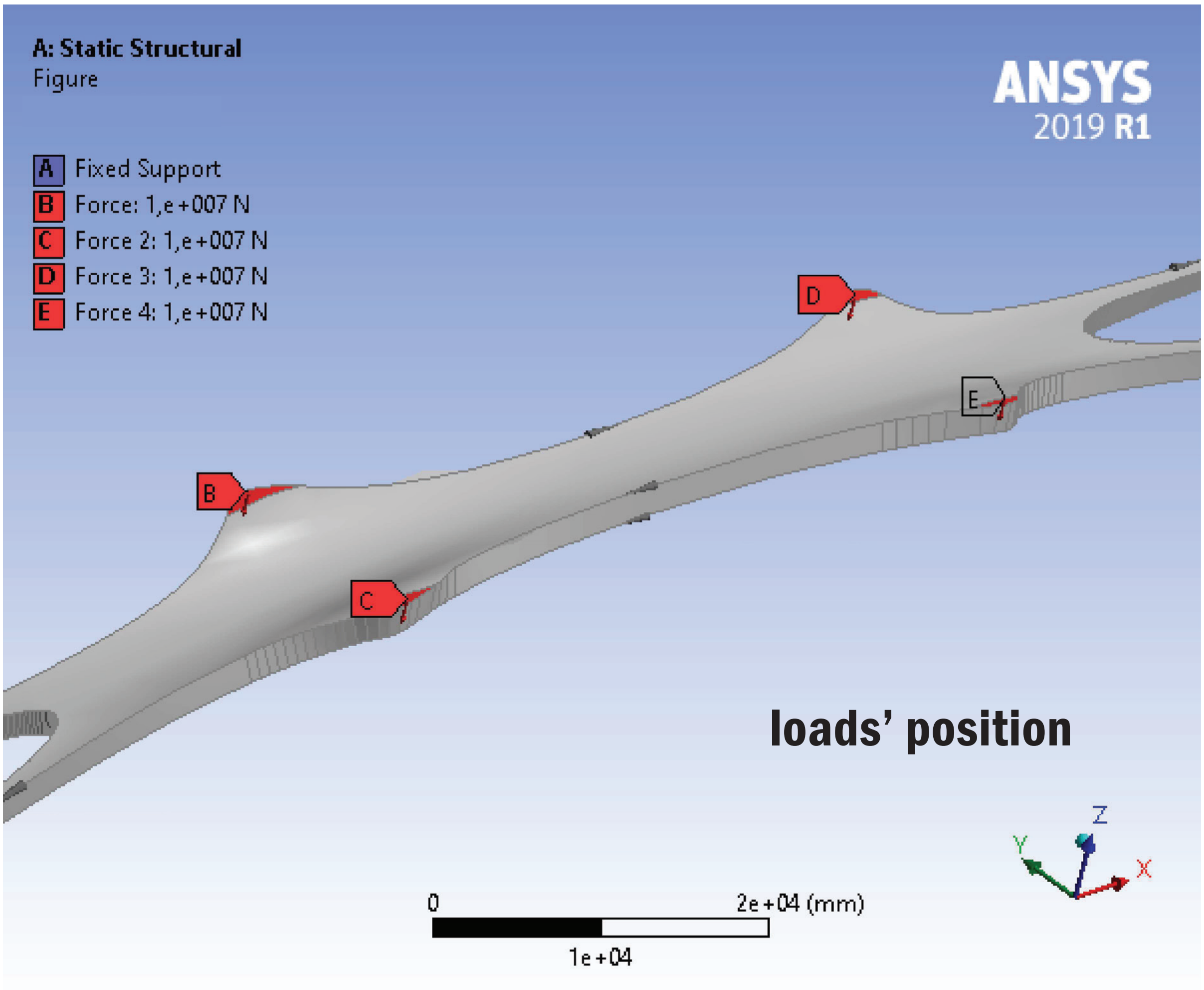
AVAREAGE SURFACE AREA
1,408e+007 mm²

MINIMUM EDGE LENGTH
32,275 mm

TRANSITION RATIO 0.272
MAXIMUM LAYER 5
GROWTH RATE 1,2

NODES 1108907
ELEMENTS 651023

FIRST CALCULATION **SETTINGS**



LOADS

FORCE 1	-1,e+007 N
FORCE 2	-1,e+007 N
FORCE 3	-1,e+007 N
FORCE 4	-1,e+007 N

ISOTROPIC THERMAL CONDUCTIVITY
7,2e-004 W mm^{-1} C^{-1}

COMPRESSIVE ULTIMATE STRENGTH
49 MPa

TENSILE ULTIMATE STRENGTH
5 MPa

MATERIAL DATA
[concrete C40/50]

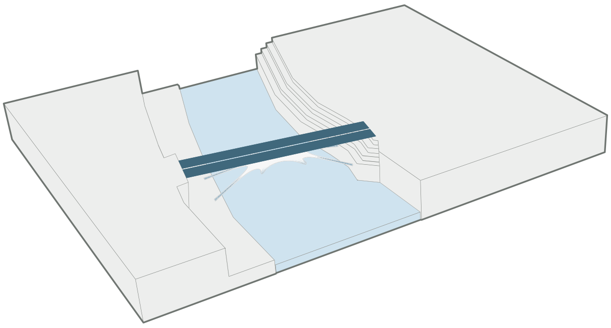
COEFICIENT THERMAL EXPANSION
1,4e-005 C^{-1}

DENSITY	2,3e-009 t*mm^{-3}
YOUNG MODULUS	35347,1 MPa
POISSON RATIO	0,20
BULK MODULUS	22389 MPa
SHEAR MODULUS	16792 MPa

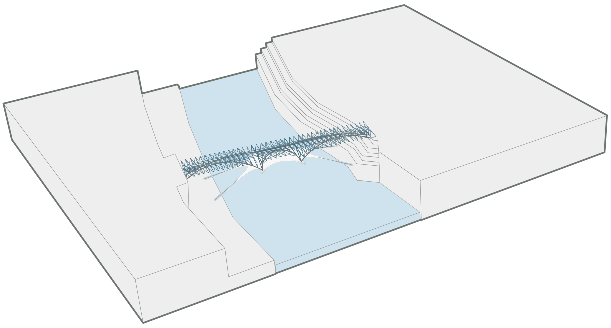
HEAT CONSTANT PRESSURE
7,8e+008 mJ t^{-1} C^{-1}

HOMOGENIZATION COEFFICIENT
5,21

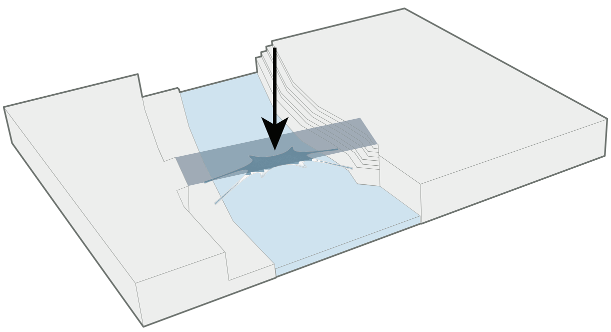
FIRST CALCULATION SETTINGS



MEMBRANE + ROAD'S SURFACES



MEMBRANE + DECK'S STRUCTURES



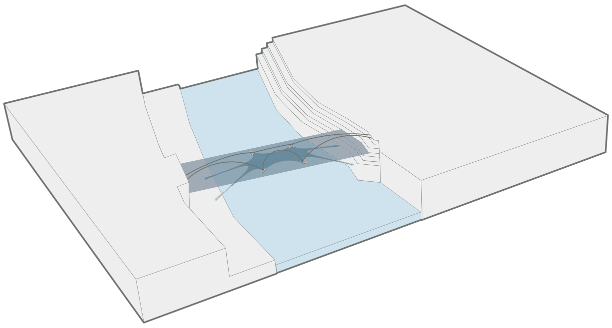
SURFACE PARALLEL TO THE RIVER'S PLANE

Placing in a scheme, which can be seen on the left, the membrane, the structure that supports the superstructure of the slab, and the plans of the streets, one can see their correspondence. In reality, due to the difference in height between the two banks of the river, the roads are not in two perfectly horizontal planes but are slightly curved towards the center. But, by approximating this curvature to a plane parallel to the plane of the river, two geometric places are determined: the membrane, approximated according to the passages previously described, and the surfaces of the roads.

Considering then, the structure of the bridge deck as six lowered inclined arches and six beams that connect the two banks of the river. All the weight of the superstructure, as well as on the sides, unloads the weight on the arches through a reticular system whose beginning and end are the beams and the arches themselves. Therefore, the only points of contact between the superstructure of the deck and the underlying membrane are the ends of the arches. Also to be considered is the pedestrian walkway which, although not present in the diagram on the left, never touches the membrane but weighs on the beams and arches which, in turn, weigh on the membrane.

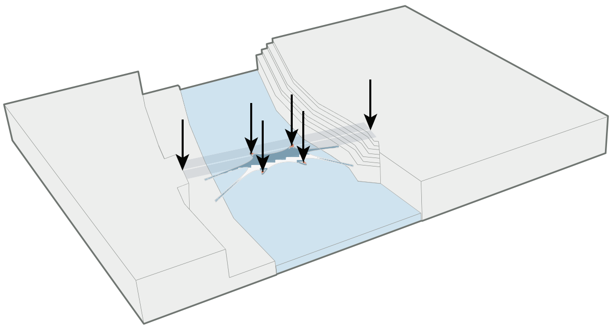
Returning to the approximation of the first diagram on this page and integrating it to the second, a surface is defined which, parallel to the river level, weighs on the concrete membrane. The arrow shown has a magnitude of 5,78e + 007 N which is approximated by excess to 6,00e + 007 N and corresponds to the sum between G1 and G2. Which correspond respectively to structural permanent loads and non-structural permanent loads. Already described on the previous pages considering all the deck's components.

FIRST CALCULATION SETTINGS



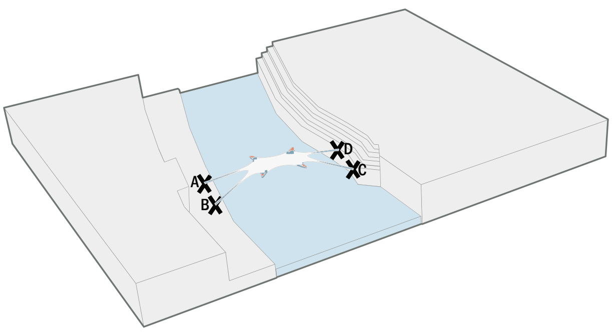
STRUCTURE + LOADS POSITIONING AREAS

Considering, in turn, the arches, a structural part that weighs on the membrane, and the surface, theorized in the previous diagram, the areas on which the loads will be applied are defined. Since the terminal parts of the arches, acting on the membrane, are not punctual in their contact with the membrane itself, they will influence well localized portions of the membrane which can be obtained through the correspondence of the surface with the concrete structure. Considering that the membrane is not perfectly symmetrical, the areas corrispondenti are different from each other even if very similar to two by two.



MEMBRANE + ITS DISTRIBUTED LOADS

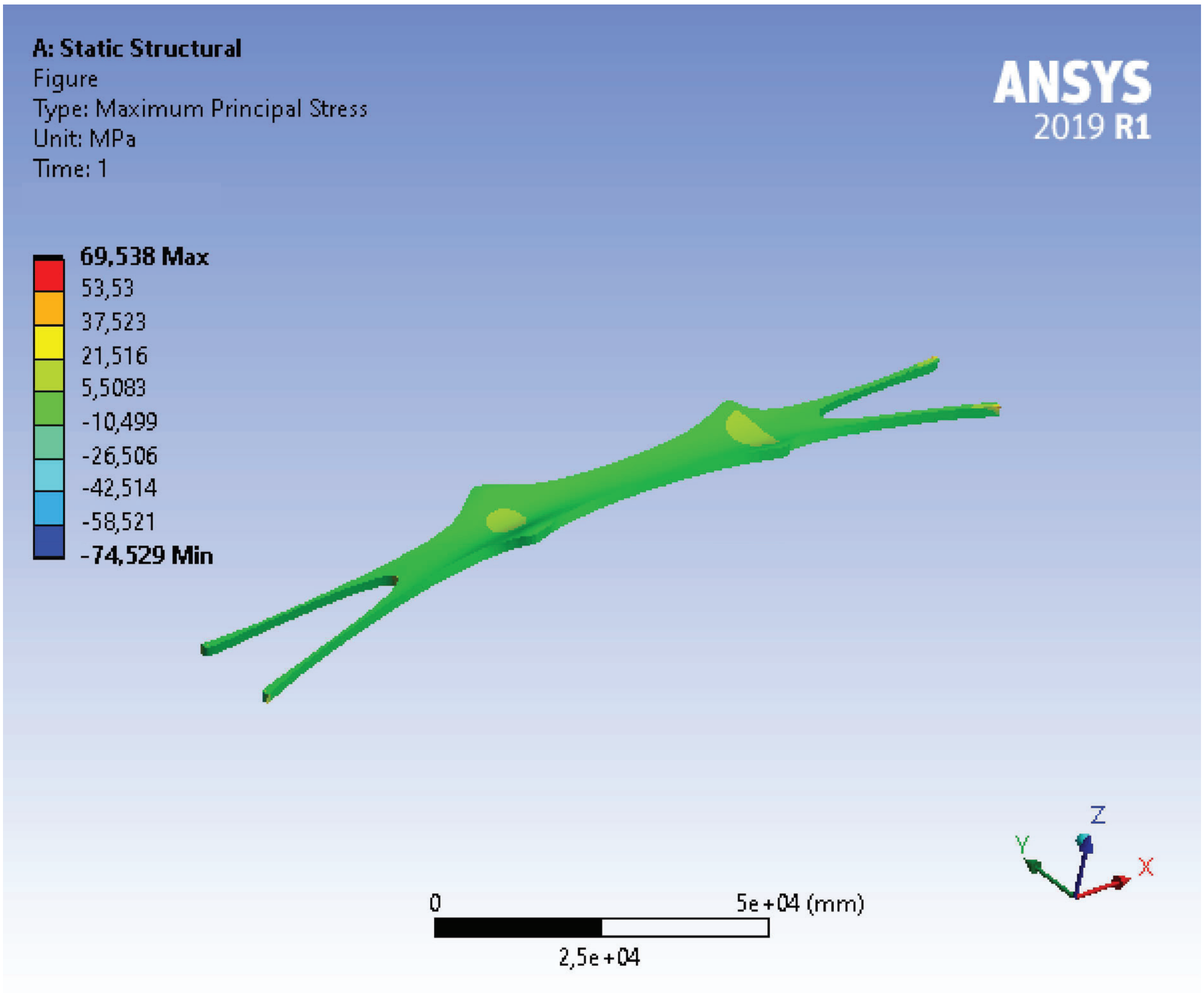
At this point, the positions of the loads are defined. The total load, equal to 6.00e + 007 N, is divided into six parts, each with a magnitude of 1.0e + 007 N, which are the four areas obtained on the surface of the membrane and the two banks of the river. But, each arrow, represented in the diagram on the left, represents a uniformly distributed load on the small surface. Furthermore, since the membrane is being studied through the static structural analysis, all the subsequent calculation will be made considering the loads acting on the structural membrane.



MEMBRANE + POSITIONS OF ITS INTERLOCKS

The last step is the definition of the anchor points on the ground. Since the membrane is a hybrid structure which cannot be properly defined as an arch, it is inconvenient to approximate it to an arch with three hinges. So, this four-foot curved beam touches the ground at four points and these are four interlocking constraints. The definition of the same was previously theorized also considering the foundations of the structure itself: in continuity of form and material. Also in this case, as in the application of loads, the constraints are not precisely located but arranged in the surface areas of the feet.

FIRST CALCULATION RESULTS



FIRST STATIC STRUCTURAL ANALYSIS

The membrane is almost completely in compression with values that increase in correspondence with the transverse centerline between the points where the forces have been applied.

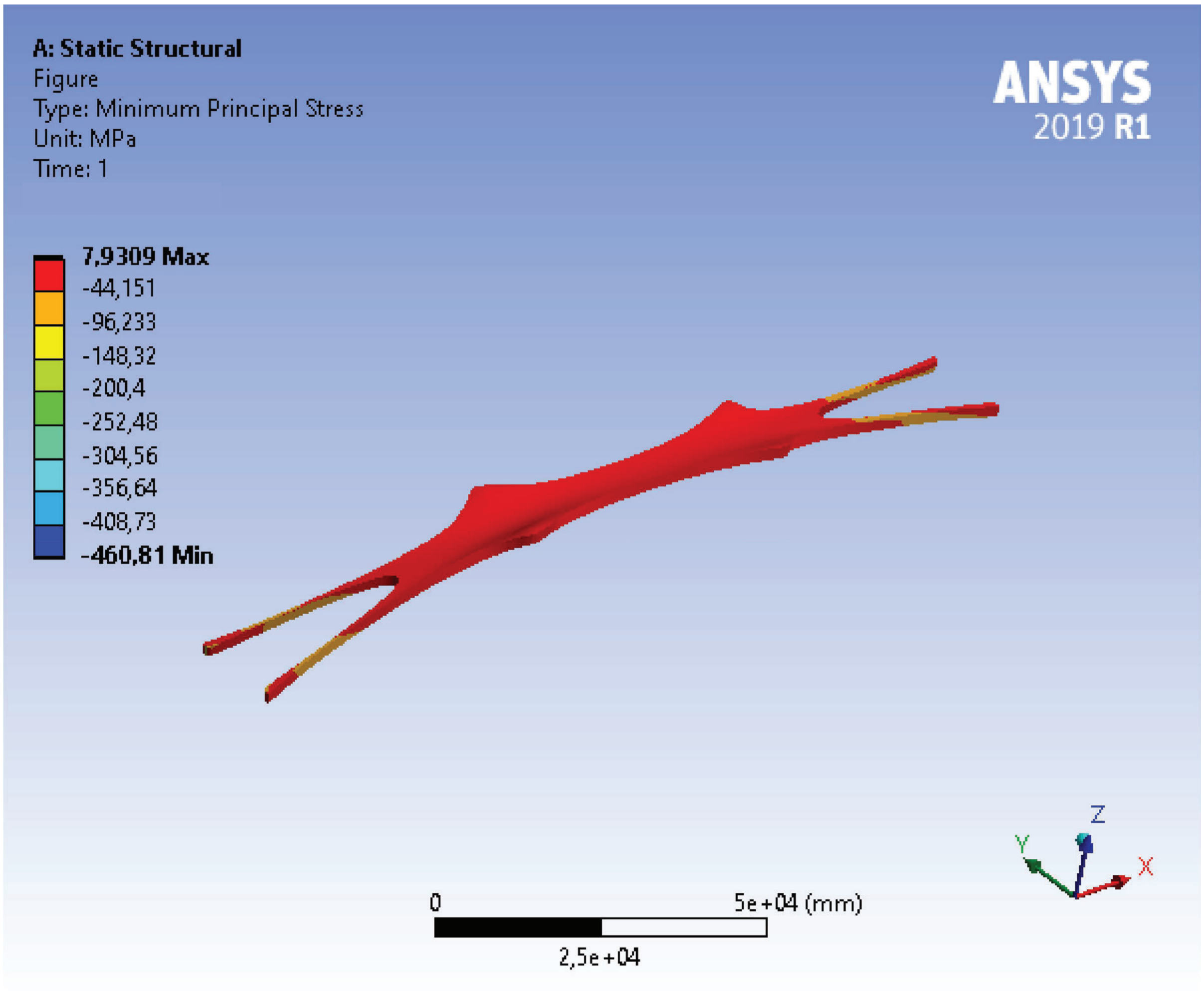
The structure reacts almost homogeneously to compression, which is a positive thing as it is one of the principles that define the generative algorithm, the least exciting data are the very high values of stress. The possibility that the structure will go into crisis by reaching the limit value is high.

MAXIMUM PRINCIPAL STRESS
solutions

MINIMUM	-74,529 MPa
MAXIMUM	69,538 MPa
AVERAGE	0,79285 MPa

MOST DIFFUSED
-10,499 MPa < x < 5,5083 MPa

FIRST CALCULATION **RESULTS**



MINIMUM PRINCIPAL STRESS
solutions

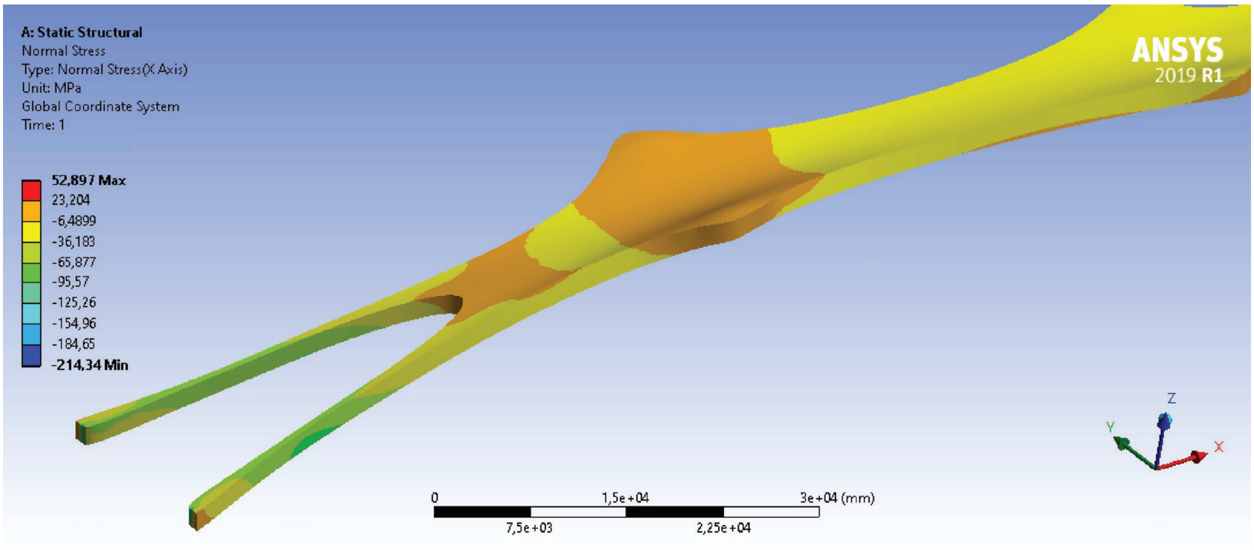
MINIMUM	-460,81 MPa
MAXIMUM	7,9309 MPa
AVERAGE	-24,35 MPa

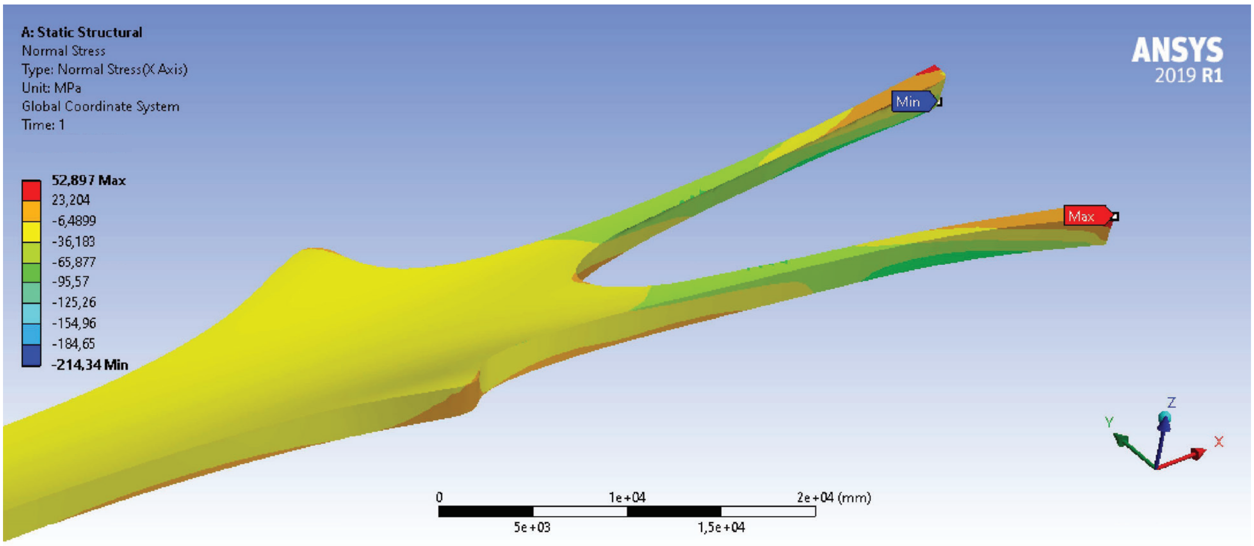
MOST DIFFUSED
-44,151 MPa < x < 7,9309 MPa

The membrane is vastly in compression, but has tension values at mid-foot height tornadoes then pure compression in the ground attacks.

The values of stess are high, the least exciting data in this case are the voltage distributions, the changes in such targeted and dimmetric positions give resistance discontinuities by locating possible failures.

FIRST CALCULATION **RESULTS**





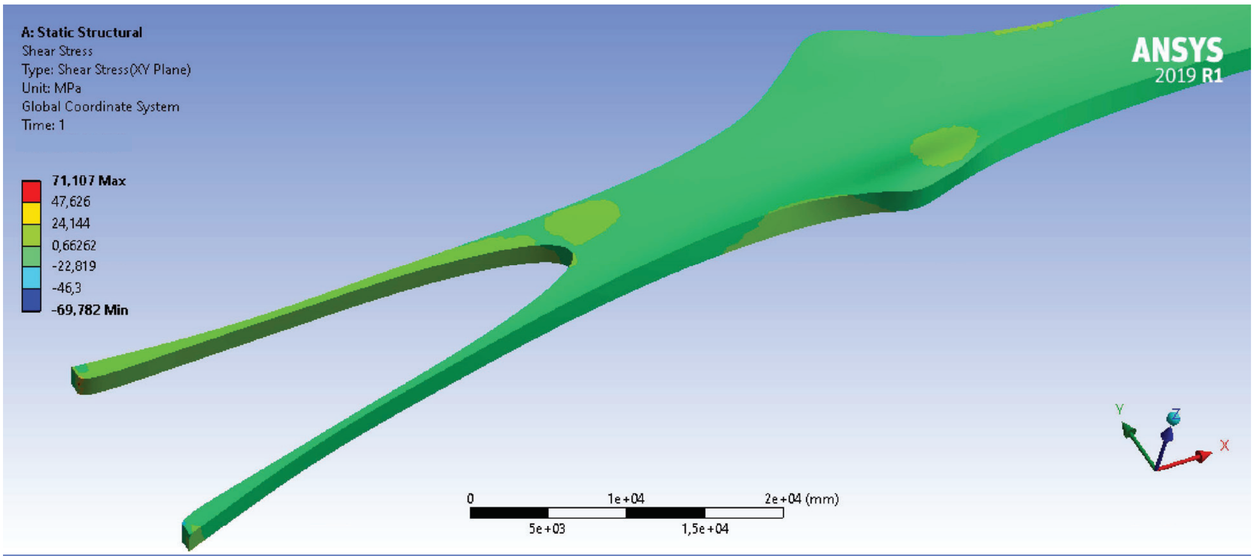
NORMAL STRESS
solutions

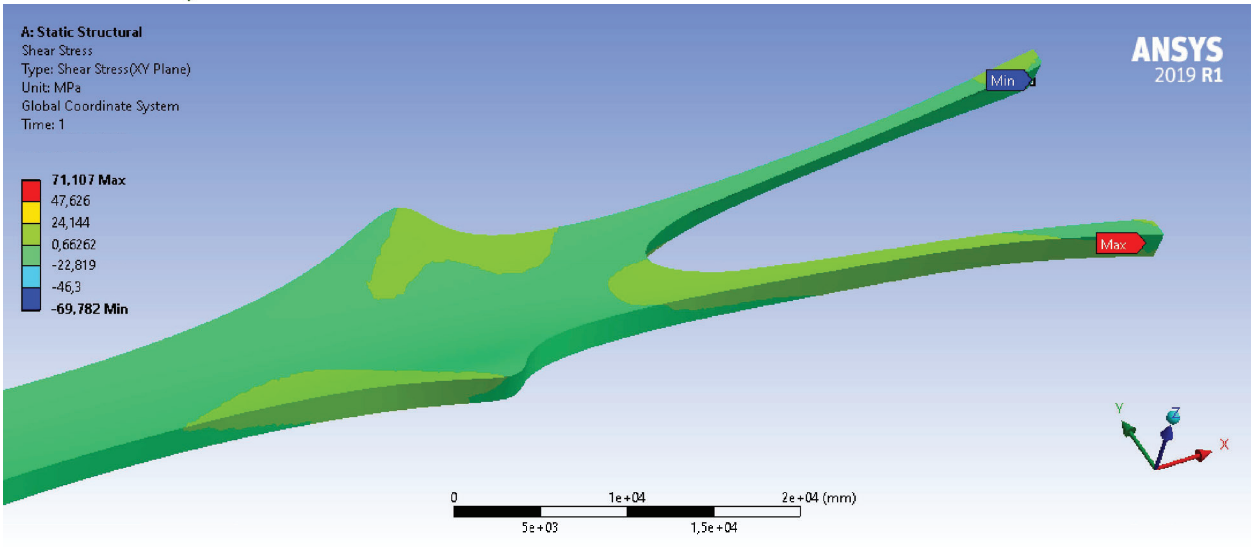
MINIMUM -214,34 MPa
MAXIMUM 52,897 MPa
AVERAGE -13,694 MPa

MOST DIFFUSED
-95,57 MPa < x < 23,204 MPa

The diagram shows a reaction to normal stress where a range of values is fairly distributed throughout the membrane, leaving out areas of the feet, again in a symmetrical and localized way.

FIRST CALCULATION RESULTS





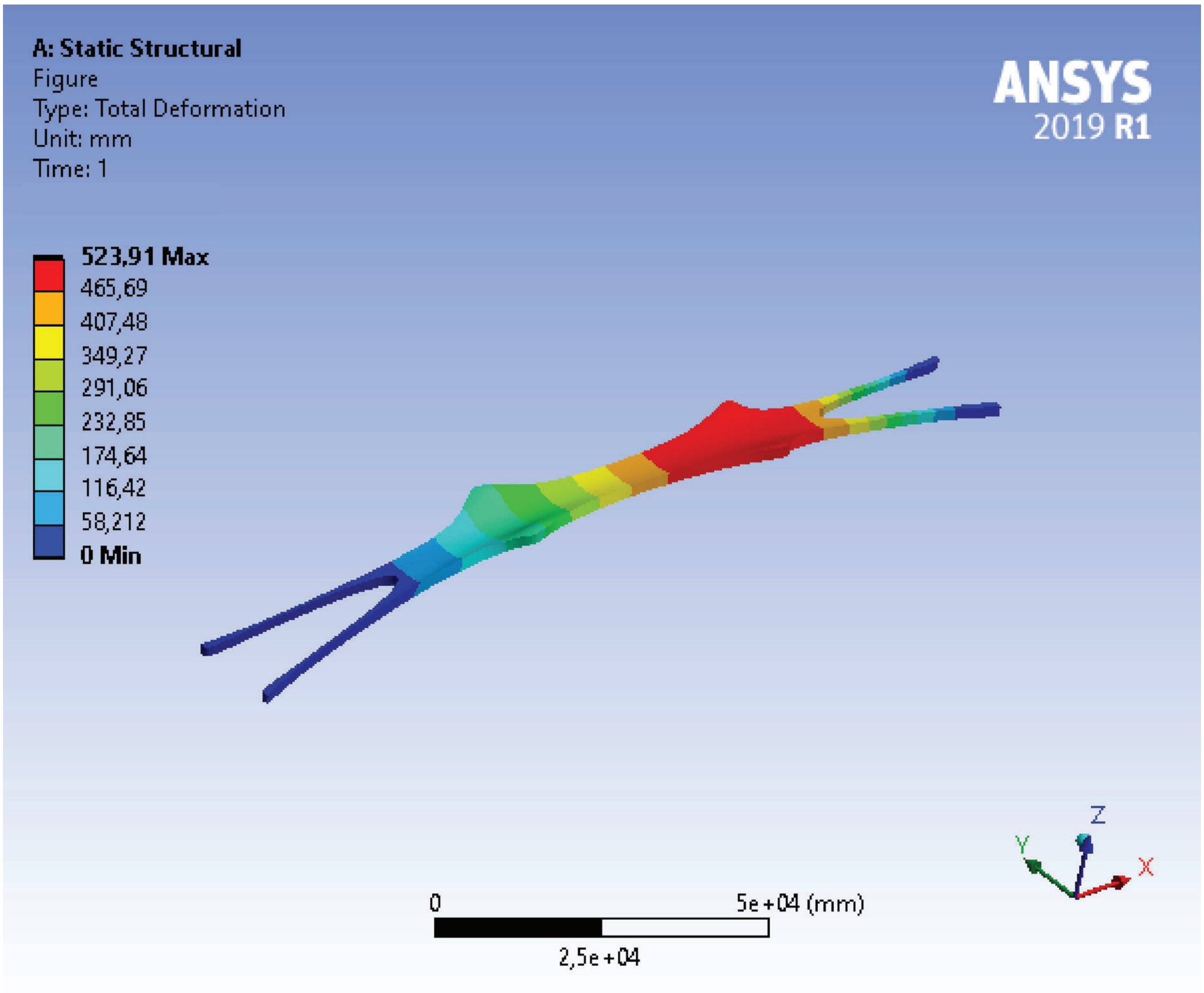
SHEAR STRESS
solutions

MINIMUM -69,782 MPa
MAXIMUM 71,107 MPa
AVERAGE -2,054e-002 MPa

MOST DIFFUSED
-22,819 MPa < x < 24,144 MPa

The diagram shows an almost constant shear stress reaction along the entire stressed structure, almost imperceptible where the sheet becomes negative.

FIRST CALCULATION **RESULTS**



TOTAL DEFORMATION
solutions

millimeters

MINIMUM	no moviment
MAXIMUM	523,91 mm
AVERAGE	255,15 mm

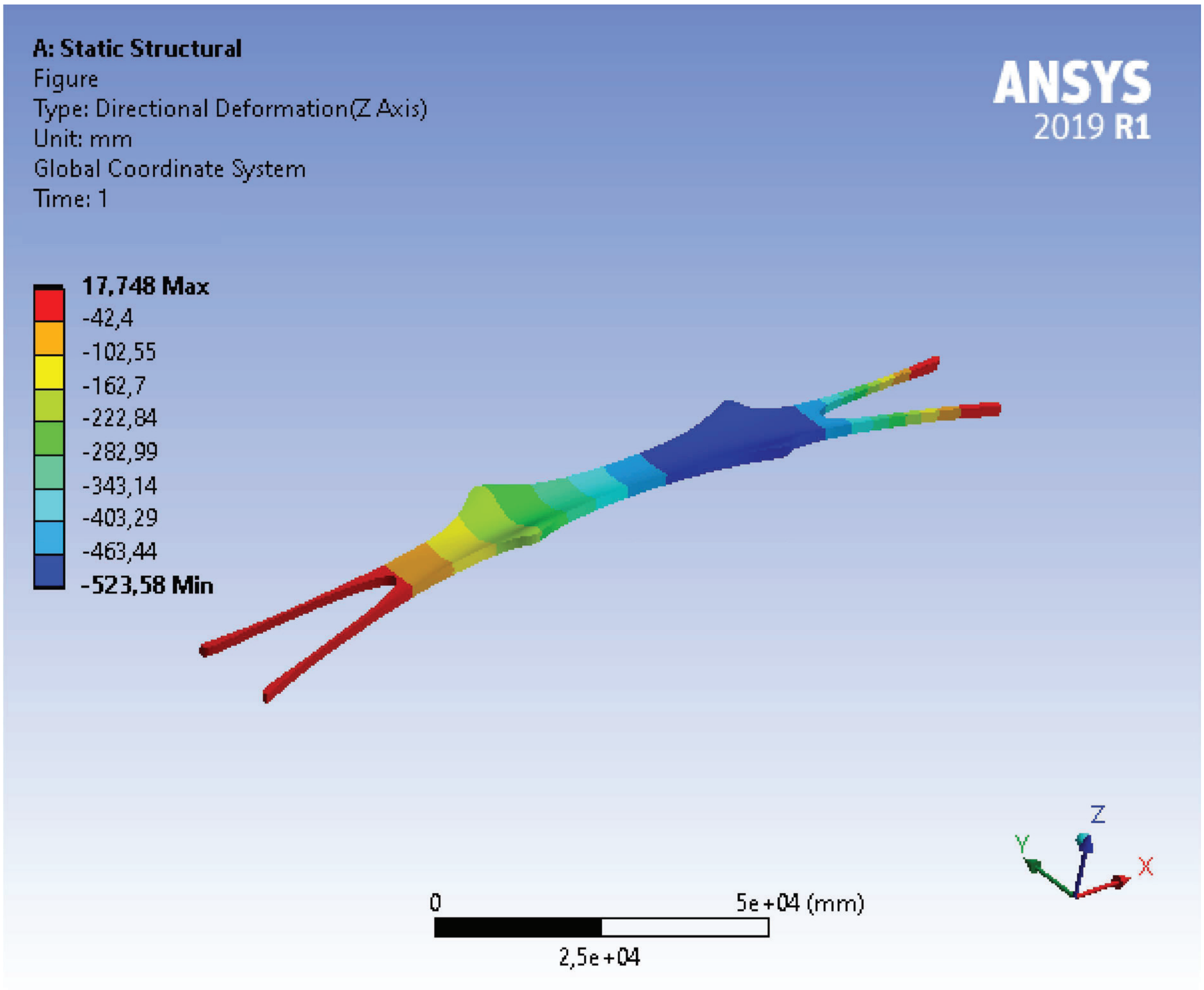
meters

MINIMUM	no moviment
MAXIMUM	0,52391 m
AVERAGE	0,25515 mm

The distribution of the colors, and therefore of the deformations of the structure, are reasonable: there is a greater value at the points of apprication of the forces that vanish the closer you get to the ground anchors.

Therefore, also by virtue of the generative parameters of the membrane, a lowering at the points of application of the forces and where the arch is lowered was expected. The least encouraging figure is the value of that lowering, equal to 523 mm, more than half a meter.

FIRST CALCULATION RESULTS



DIRECTIONAL Z DEFORMATION
solutions

millimeters	
MINIMUM	-523,58 mm
MAXIMUM	17,748 mm
AVERAGE	250,15 mm

meters	
MINIMUM	0,52358 m
MAXIMUM	0,017748 m
AVERAGE	0,25015 m

The distribution of the colors, and therefore of the deformations of the structure, are reasonable: there is a greater value at the points of apprication of the forces that vanish the closer you get to the ground attacks.

As in the total deformation diagram, also in the directional one the results were widely expected. Even the numerical data remains worrying: almost the entire structure has a lowering of more than 100 mm up to a peak of more than 500 mm. The sag length relationship is very low.

FIRST CALCULATION RESULTS

VON MISES ANALYSIS

The structural membrane in reinforced concrete, the subject of the thesis, requires a stress equivalent verification, analysis by Von Mises, for two main reasons:

- the design, as is known, was performed through a parametric approach where the imposed structural parameters sculpted the deformed membrane, acquiring its final shape, elastically following the properties imposed by the components that simulated the properties of Hooke's law

- the structural calculation, the approximation of the shape to make it feasible, and the choice of using bricks elements, linked in turn by the irregularity of the shape, for the simulation and the FEM calculation are situations that have in common the constant k, longitudinal elastic constant of the spring (N/m^{-1}).

The Von Mises resistance criterion concerns ductile, isotropic, compression resistant materials. This type of analysis assumes that the yield strength of the material is reached when the distortion energy reaches a limit value. Once the limit is reached, distortion, a component of deformation, causes a variation in the shape of a volume element, leaving the volume itself unchanged. Since the structural membrane is both elastic and composed of a continuous uniform material, both for construction and as a final result of shape, the Von Mises analysis can highlight resistance criticalities in localized areas, the risk is high as the membrane thickness is constant and the usefulness lies in evaluating whether the data generated by the algorithm, in relation to the thickness, is valid.

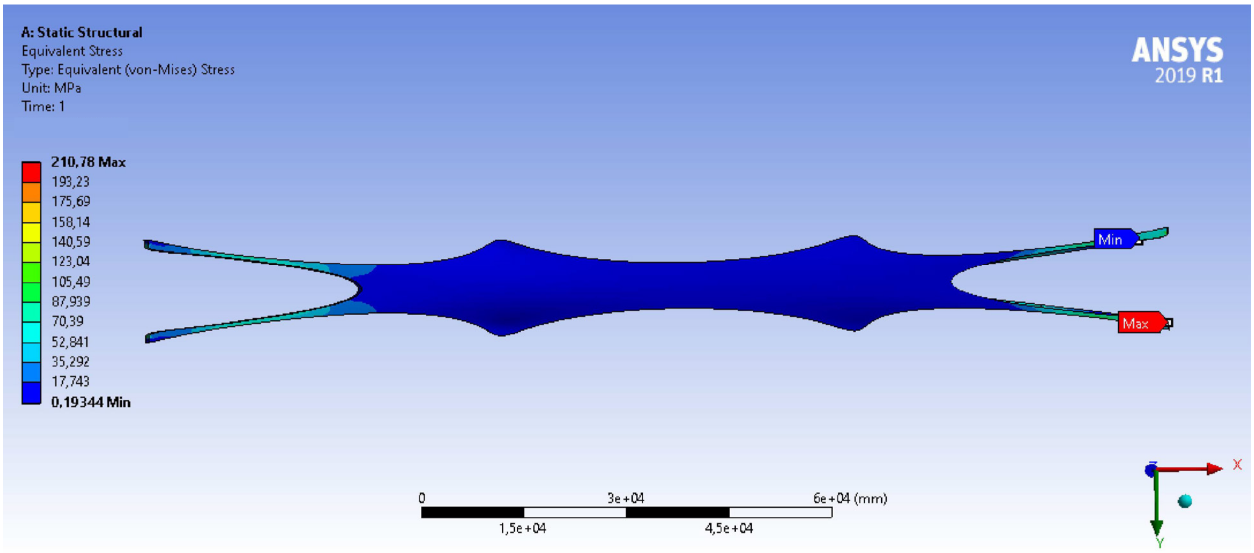
BUCKLING ANALYSIS

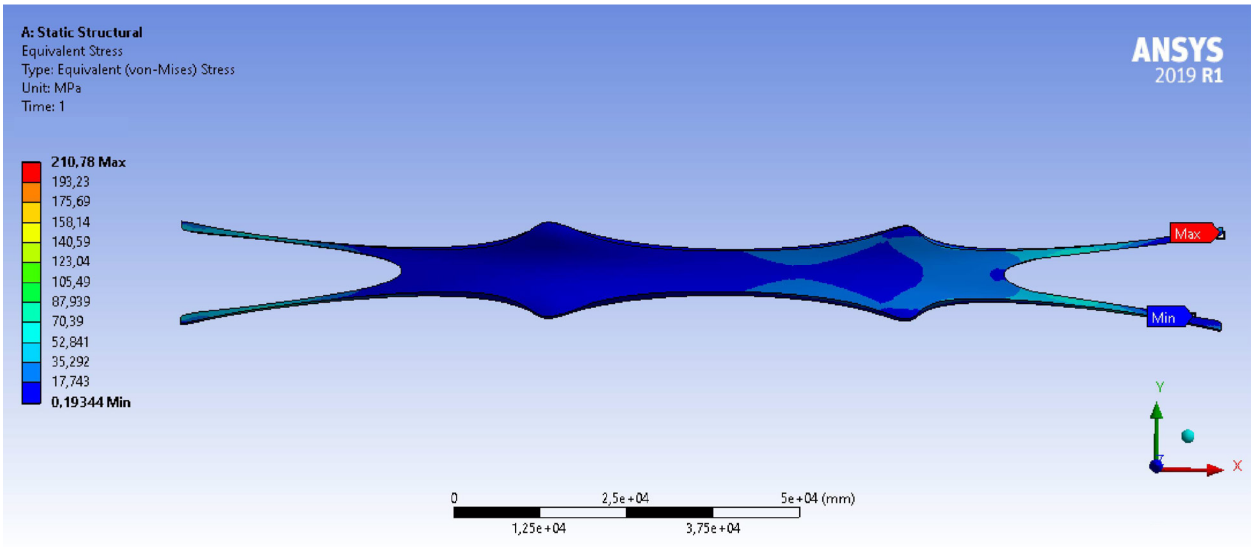
The instability of the structures, verifiable with the buckling analysis, is the study of the structural non-linear behavior linked to phenomena of instability caused by the acting loads, even if in equilibrium. Structural instability ultimately results in the collapse of the structure. This type of analysis is useful in this case for two reasons: the structural membrane, object of the thesis, is a structure subject to conservative loads, the instability is caused by geometric nonlinearity, the structure has a nonlinear character inclined to use its own kinematic energy to control the displacements that generate the deformation, and the risk is that we pass from a situation of equilibrium to instability; the limb structure of the bridge is, moreover, a slender elastic structure, hexa is a structure for which the effects of geometric nonlinearity intervene long before the effects of material nonlinearity are sensitive.

Therefore, since the structure is slender, elastic and subject to conservative loads, it is necessary to investigate its constitutive behavior according to the linear elasticity model and the study of instability phenomena through static equilibrium configurations. The analysis, from the operational point of view, produces dimensionless values, these are load multipliers. Permanent structural loads and not added to the membrane's own weight if, after being added, are multiplied by the multiplicators resulting from the analysis, they lead to system instability. Moreover, the analysis produces a critical deformation which is the situation just before the system's weakness. So, the higher the multiplied value and the safer the structure. Higher is the multiplier safer is the structure.

FIRST CALCULATION RESULTS

FIRST VON MISES ANALYSIS





VON MISES ANALYSIS
solutions

megaPascal		Pascal	
MINIMUM	0,19344 MPa	MINIMUM	1,9344e+005 P
MAXIMUM	210,78 MPa	MAXIMUM	2,1078e+008 P
AVERAGE	16,218 MPa	AVERAGE	1,6218e+007 P

FIRST CALCULATION **RESULTS**

FIRST BUCKLING ANALYSIS

BUCKLING ANALYSIS
solutions

load multipiers

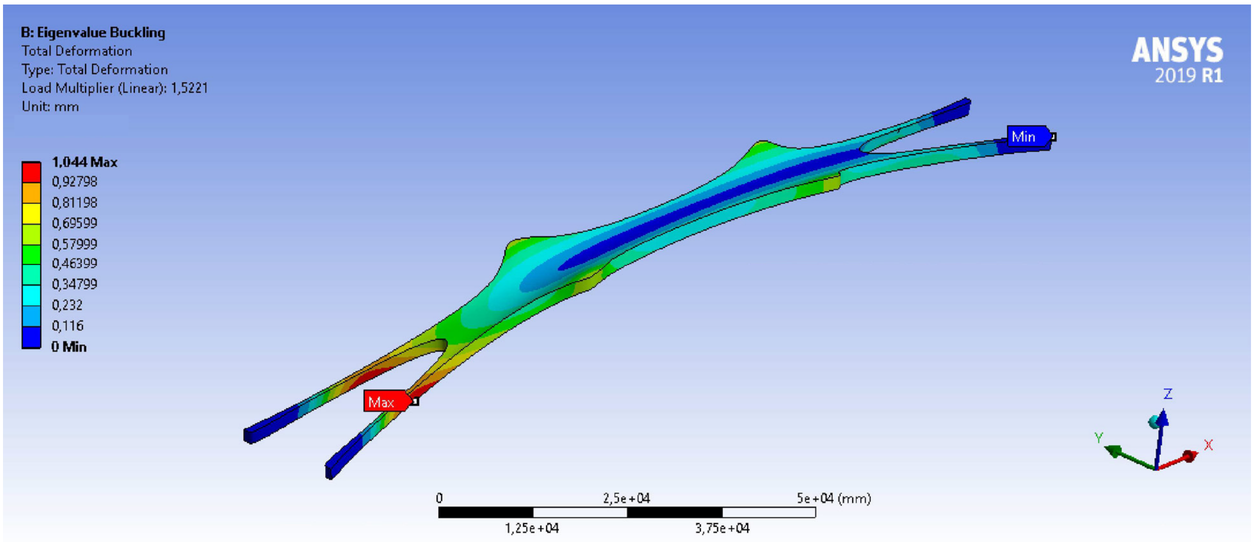
NUMBER 1	1,5221

total deformation NUMBER 1 (mm)

MINIMUM	no moviment
MAXIMUM	1,044 mm
AVERAGE	0,33925 mm

total deformation NUMBER 1 (m)

MINIMUM	no moviment
MAXIMUM	0,00144 m
AVERAGE	0,00033925 m



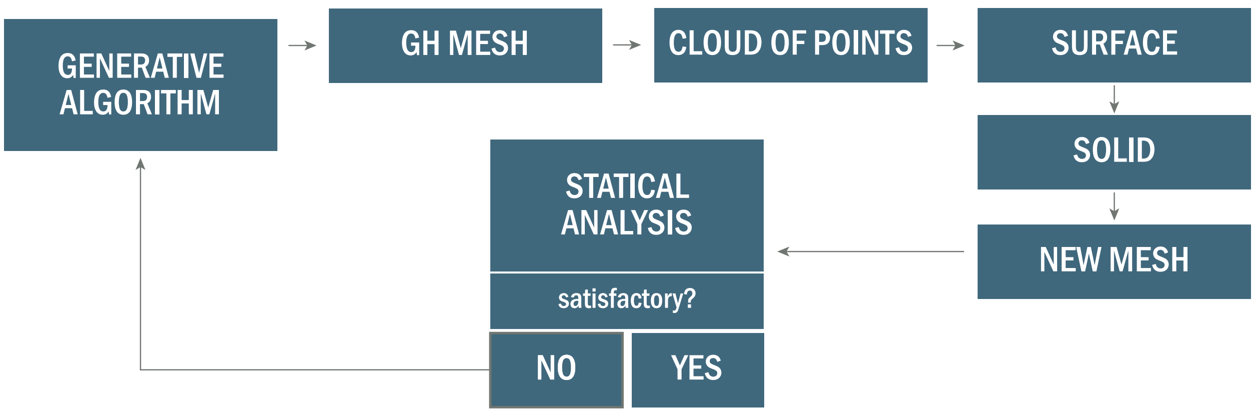
AFTER CALCULATION CONSIDERATIONS

Summarizing the diagrams obtained following a structural static analysis: the membrane undergoes simple distributed compression and deforms in known positions but has very high main stress values and consequent large deformations of lowering.

So, analyzing the geometry data, the only index that can be improved are the moments of inertia, for the rest the membrane is geometrically well constrained and resistant by shape.

Mi Ip1 = 5,3777e+010 t*mm^2
Mi Ip2 = 3,9209e+012 t*mm^2
Mi Ip3 = 3,9388e+012 t*mm^2

Thus, deciding to raise the value of the moments of inertia, the geometry must be changed. In turn, the geometry is constrained by the generative algorithm so parametric changes must be made to the geometry.



The most elementary example that explains the increase of the moment of inertia, and consequently of the resistance of an element, is given a plate positioned has a lower inertia than the same beam positioned in shear.

The moment of inertia is a geometric property of a body, defined as the second moment of the mass with respect to the position: returning to the elementary example of the beam, the moment of inertia is calculated with respect to the horizontal barycentral axis, x axis, and with respect to an axis parallel to the barycentral one by means of the Huygens-Steiner theorem. So:

$$Mi=(bh^3)/12$$

continuing with the example a beam plate positioned has b>h and a beam positioned in shear has h>b, so:

$$Mi_p<Mi_b$$

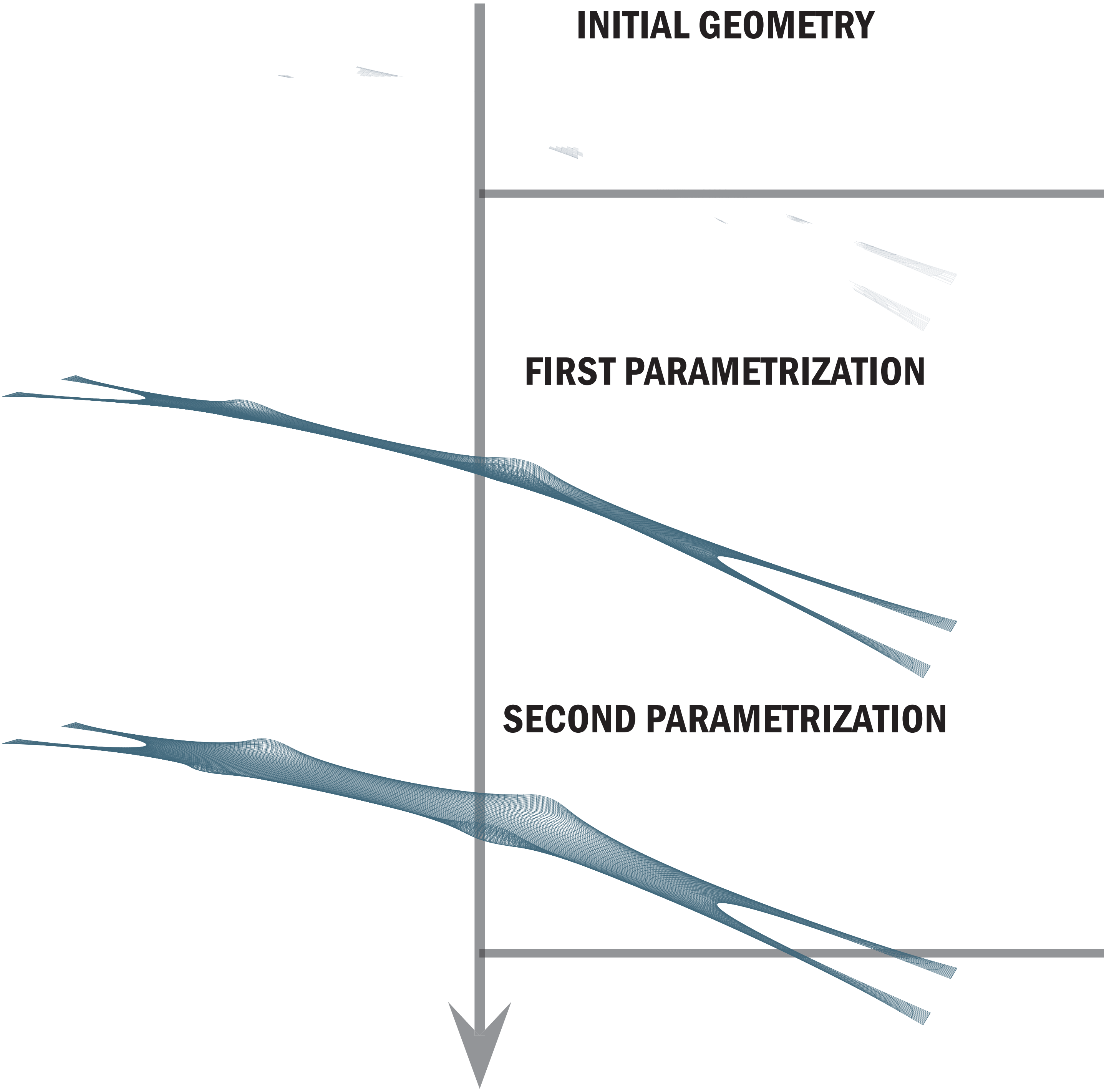
Continuing the reasoning and making a parallel with the design membrane, it has two main dimentions: its thickness and its surface, where the second one is largely bigger than the first. So, if the loads of the bridge's deck weigh on the thickness and not on the surface, the entire membrane would have a greater inertia. The solution is to change the membrane's section transverse to the main axis, by turning the edges of the membrane the loads rest on the outer edge, the entire structure will snap downwards becoming a sort of sectioned tube.

The principle applied is what Sergio Musmeci did in Potenza, the bridge, already explained,has a continuos concrete menbrane that thanks to its inertia can have a thickness of thirty centimeters.

SECOND CALCULATION STEPS

The modification of the initial mesh, caused by the formal and theoretical modification in order to pass from a minor mebranal moment of inertia to a major one, involves two executive steps.The first modifies the reference plane of the points of the protruding patios. This step involves, however, a global shrinkage of the entire membrane part by virtue of the elasticity of Hooke's method. The second step algorithm changes by adapting to the width of the road axes.

The membrane elasticity of the membrane defined by the generative algorithm widens the whole structure: the feet were already positioned in accordance with the resistance criteria as the change in the references that led from the initial mesh to the first modifi-

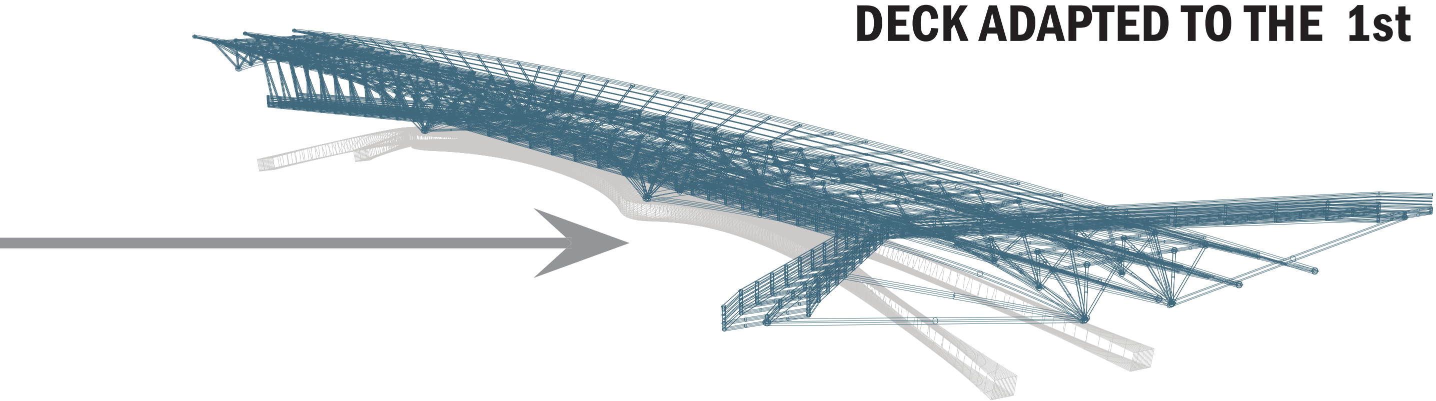


SECOND CALCULATION STEPS

cation did not affect the anchors. The upper part had to undergo a second modification because the change of references immediately took into account the road axes at a later time. Another obstacle to the completion of the bridge project is represented by the deck and its structure: it is composed of main arches, supporting beams of the road, a reticular structure connecting the beams and arches and lowered superstructure arches not acting on the underlying structures.

The generative algorithm of the implacato, created according to a positional form-finding criterion, recalculates the new points of application of the forces, that is the positioning bridges of the ends of the arches.

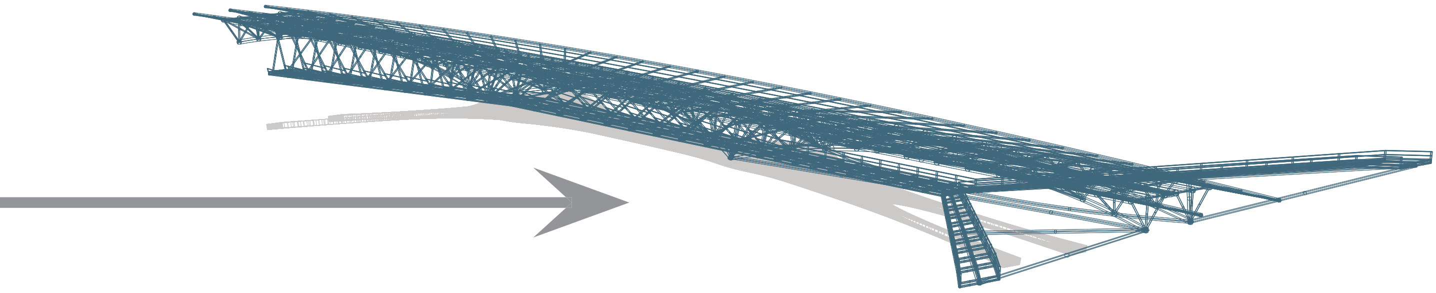
DECK ADAPTED TO THE 1st



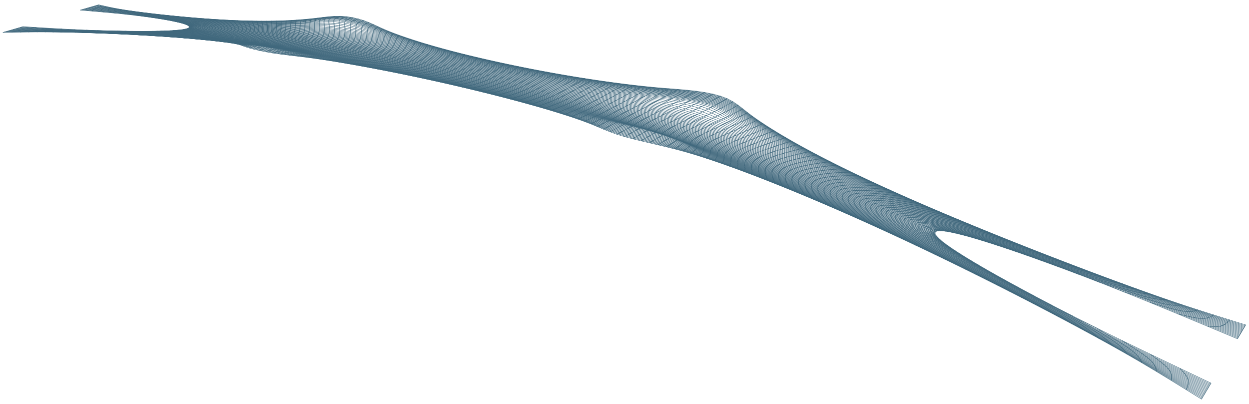
The formal modification of the arches modifies the entire steel structure by re-adapting each single beam to the new conditions.

Furthermore, the global modification of the concrete membrane allows for more space between the stepped surface and the curved surface of the membrane: the pedestrian walkway automatically lowers its walking surface, allowing greater height and greater distance from the road.

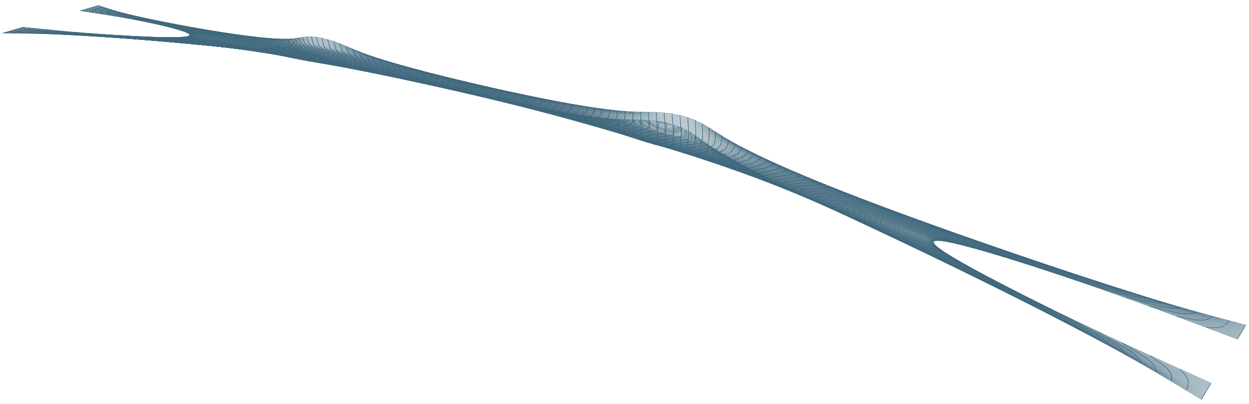
DECK ADAPTED TO THE 2st



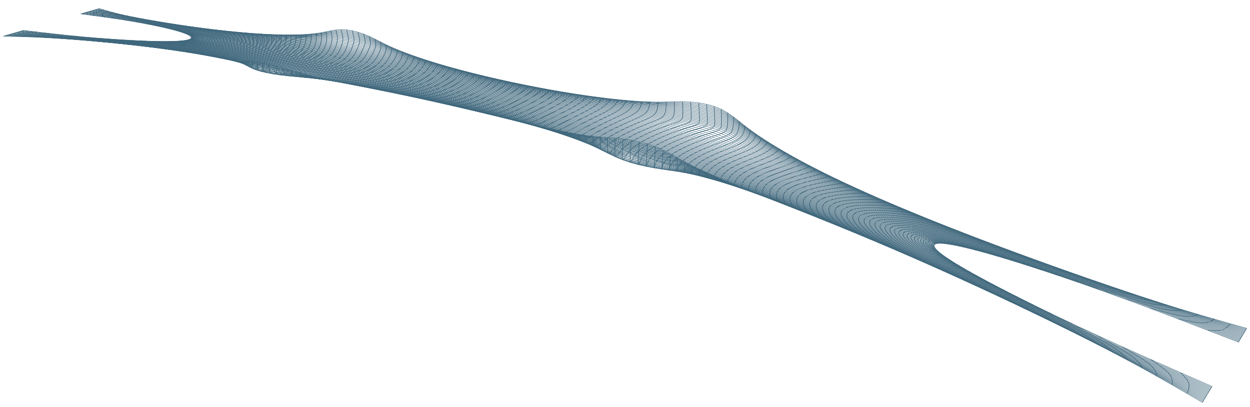
SECOND CALCULATION **STEPS**



initial mesh

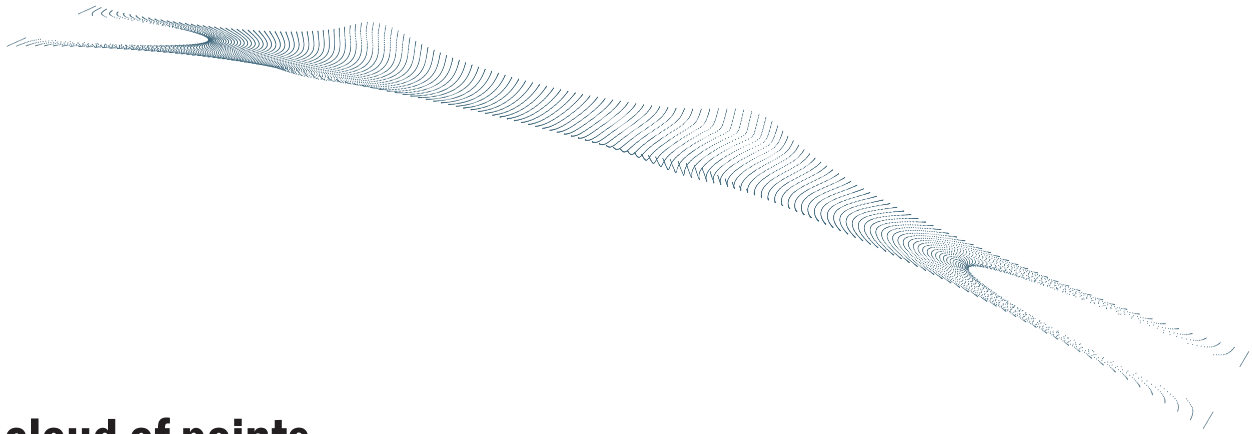


mesh modified parameter

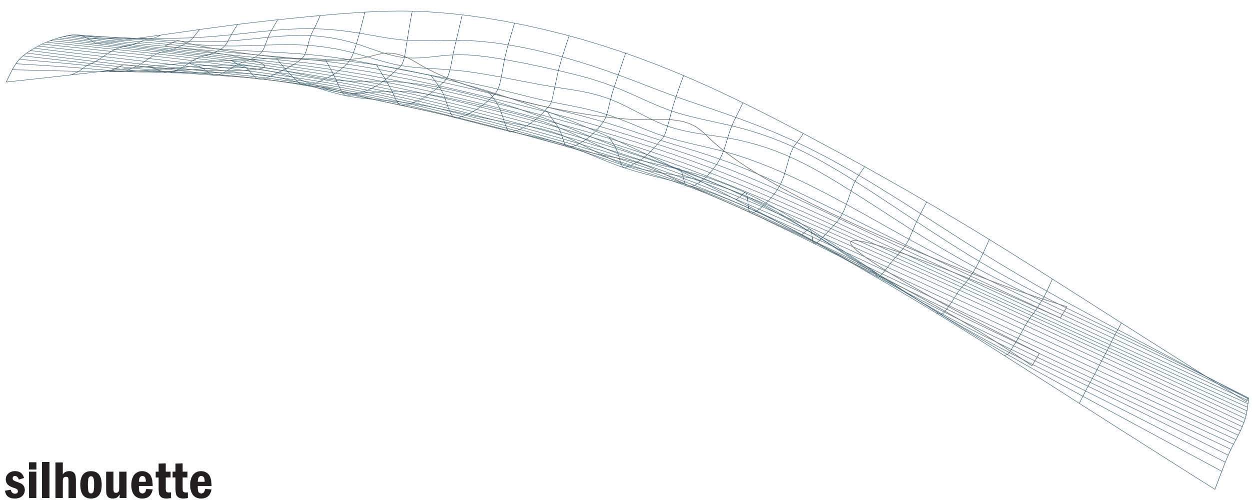


mesh adapted

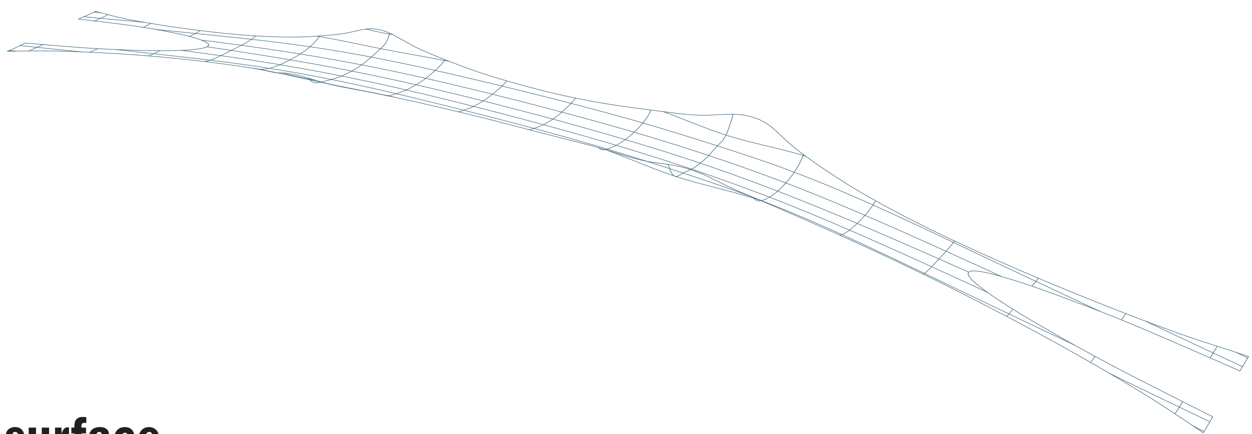
SECOND CALCULATION **STEPS**



cloud of points

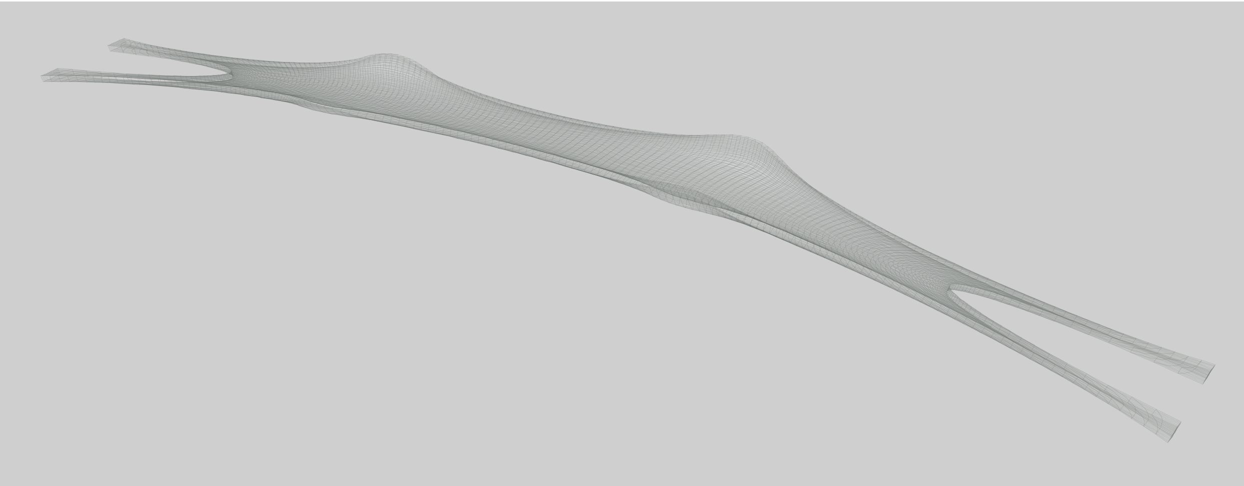


silhouette

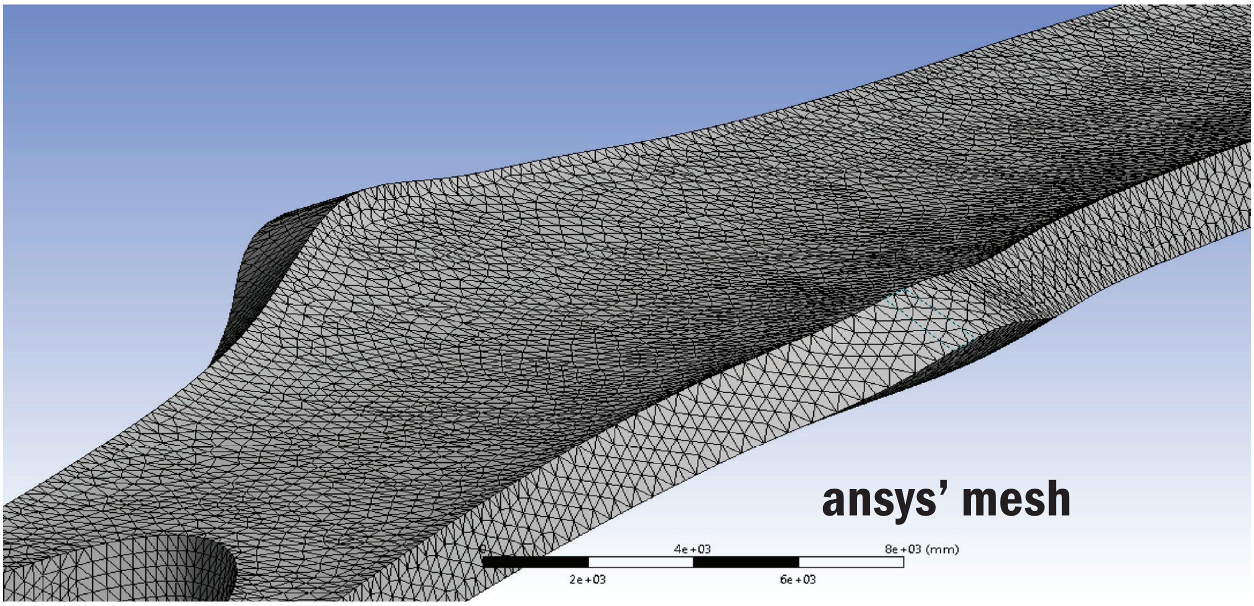


surface

SECOND CALCULATION **STEPS**



solidworks' solid



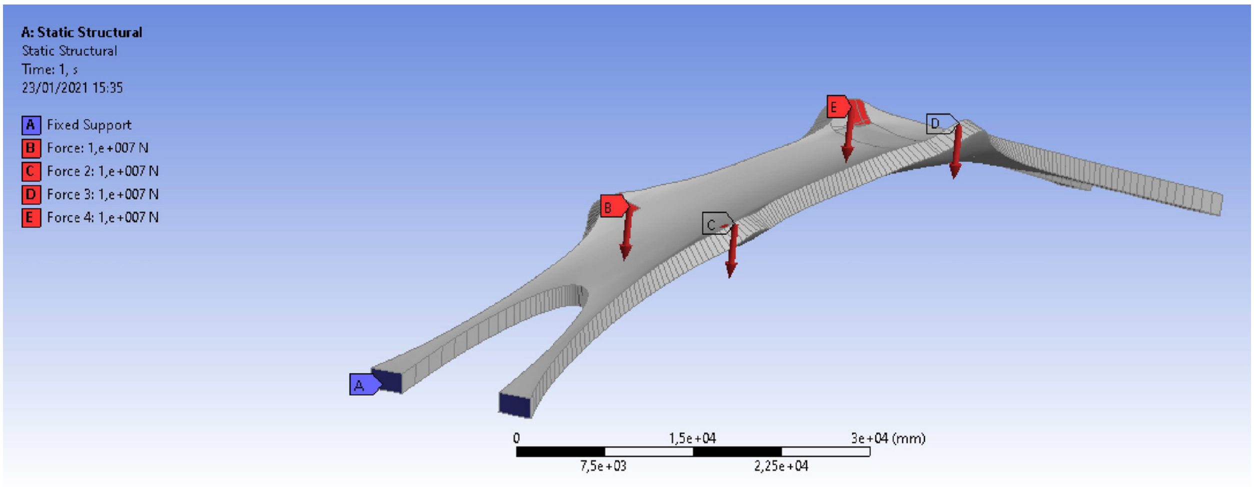
ansys' mesh

As we can see in flux diagram, in the previous pages, it was necessary to modify the initial geometry: the modification to the algorithm was fast as the change is concerned only with the spatial tying system of some points, which by changing have influenced the entire shape.

Afterwards it was necessary to do all the import and export phases from one program to another in order to arrive at the mesh that can be processed with Ansys, the FEM program. The processes were the same even if the formal results changed. Once the mesh for the FEM program has been generated, it is possible to start the calculation and the subsequent comparison with the one already done and not considered satisfactory.

Furthermore, the generative algorithm of the membrane being connected with that of positional form-finding of the deck to the modification of the membrane has automatically modified the deck itself. One of the main utilities of the algorithms in this field is also their quick use in the design phase, the algorithm modified generates a new mesh with all the previous mathematical conditions.

SECOND CALCULATION **SETTINGS**



GEOMETRY PROPERTIES

VOLUME 2,0965e+012 mm^3
MASS 4821,9 t
NODES 434140
ELEMENTS 291951
CENTROID Y 3999,6 mm
CENTROID Z 74,425 mm

MOMENT OF INERTIA Ip1
9,1314e+010 t*mm^2

MOMENT OF INERTIA Ip2
6,1402e+012 t*mm^2

MOMENT OF INERTIA Ip3
6,1543e+012 t*mm^2

MESH PROPERTIES

ELEMENT SIZE400 mm
AVAREAGE SURFACE AREA
6,8068e+006 mm^2
MINIMUM EDGE LENGTH
73,295 mm

TRANSITION RATIO 0.272
MAXIMUM LAYER 5
GROWTH RATE 1,2
NODES 434140
ELEMENTS 291951

LOADS

FORCE 1 -1,e+007 N
FORCE 2 -1,e+007 N
FORCE 3 -1,e+007 N
FORCE 4 -1,e+007 N

MATERIAL DATA

concrete C40/50

COEFICIENT THERMAL EXPANSION
1,4e-005 C^{-1}

HEAT CONSTANT PRESSURE
7,8e+008 mJ t^{-1} C^{-1}

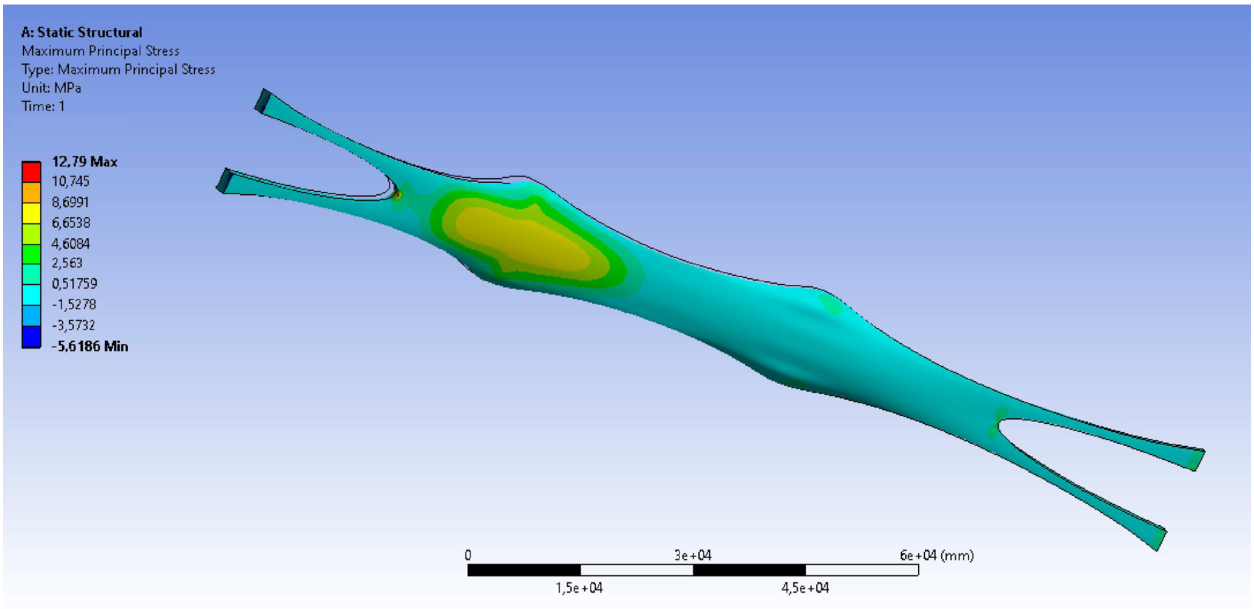
ISOTROPIC THERMAL CONDUCTIVITY
7,2e-004 W mm^{-1} C^{-1}

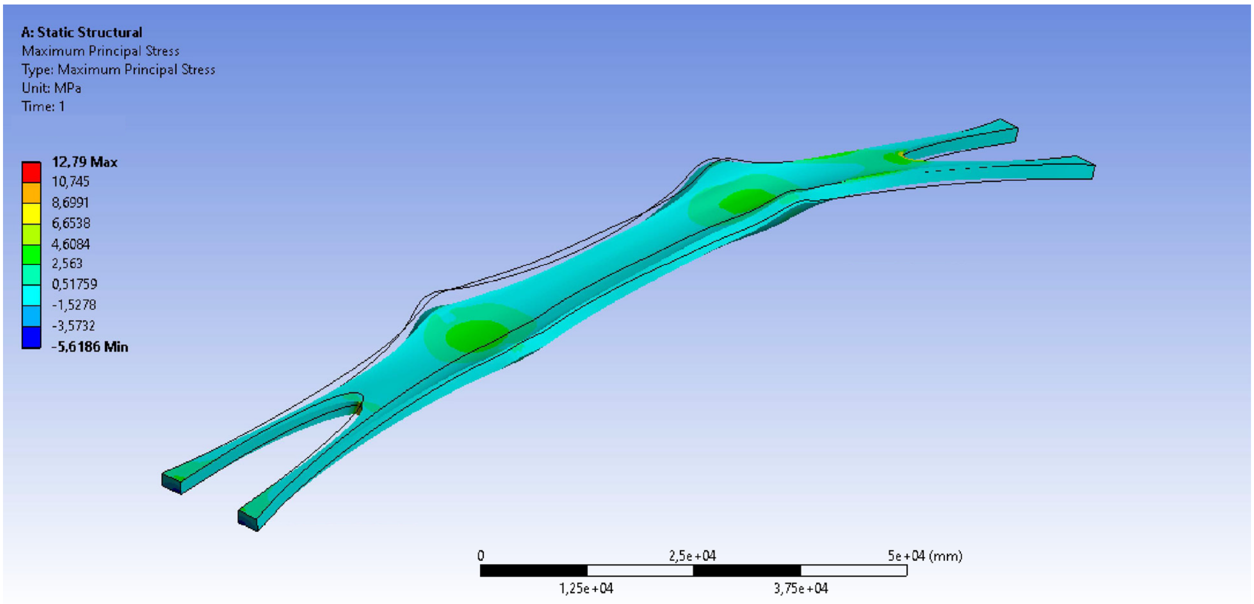
COMPRESSIVE ULTIMATE STRENGTH
49 MPa

TENSILE ULTIMATE STRENGTH
5 MPa

DENSITY 2,3e-009 t*mm^{-3}
YOUNG MODULUS 35347,1 MPa
POISSON RATIO 0,20
BULK MODULUS 22389 MPa
SHEAR MODULUS 16792 MPa
HOMOGENIZATION COEFFICIENT 5,21

SECOND CALCULATION RESULTS





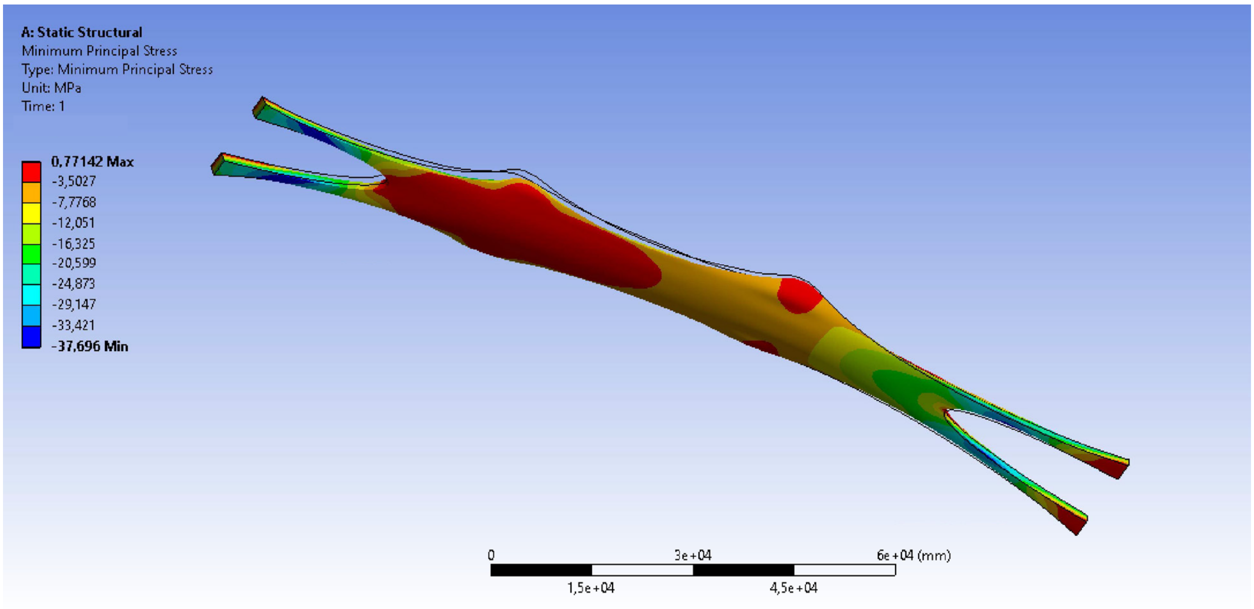
SECOND STATIC STRUCTURAL ANALYSIS

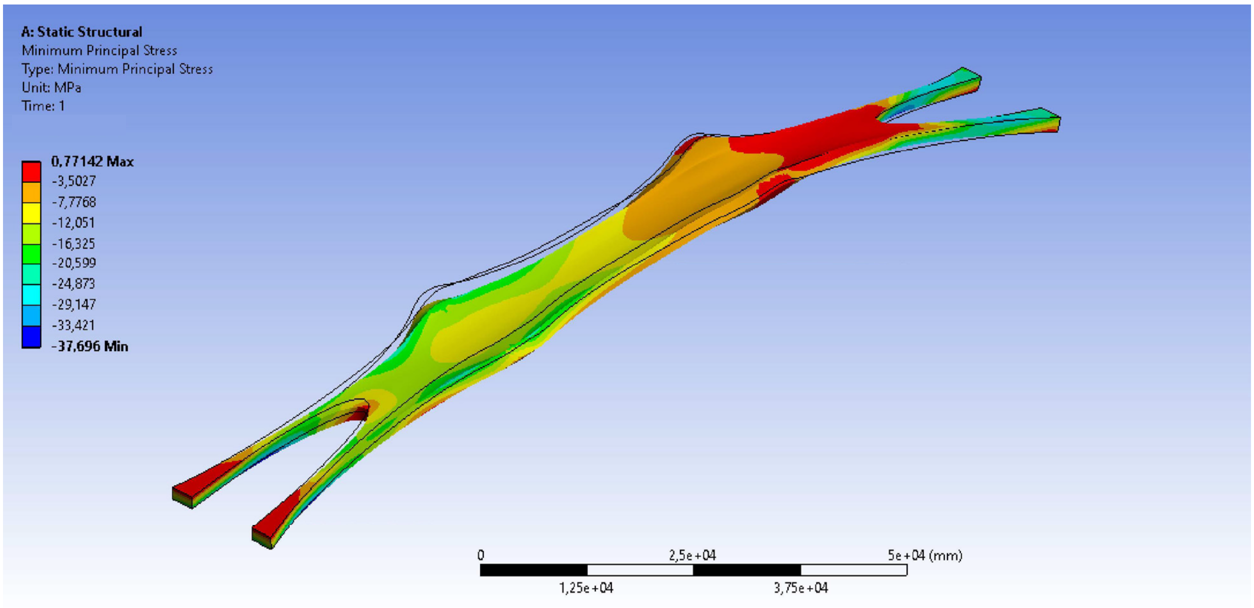
MAXIMUM PRINCIPAL STRESS
solutions

MINIMUM -5,6186 MPa
MAXIMUM 12,79 MPa
AVERAGE 0,50186 MPa

MOST DIFFUSED
0,51759 MPa < x < 8,6991 MPa

SECOND CALCULATION **RESULTS**



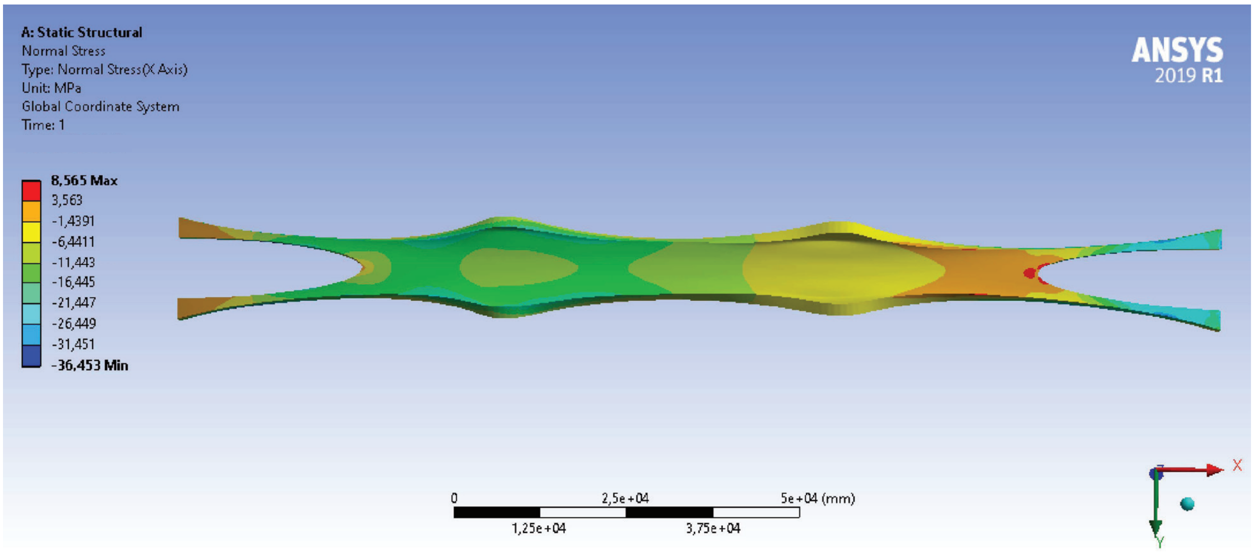


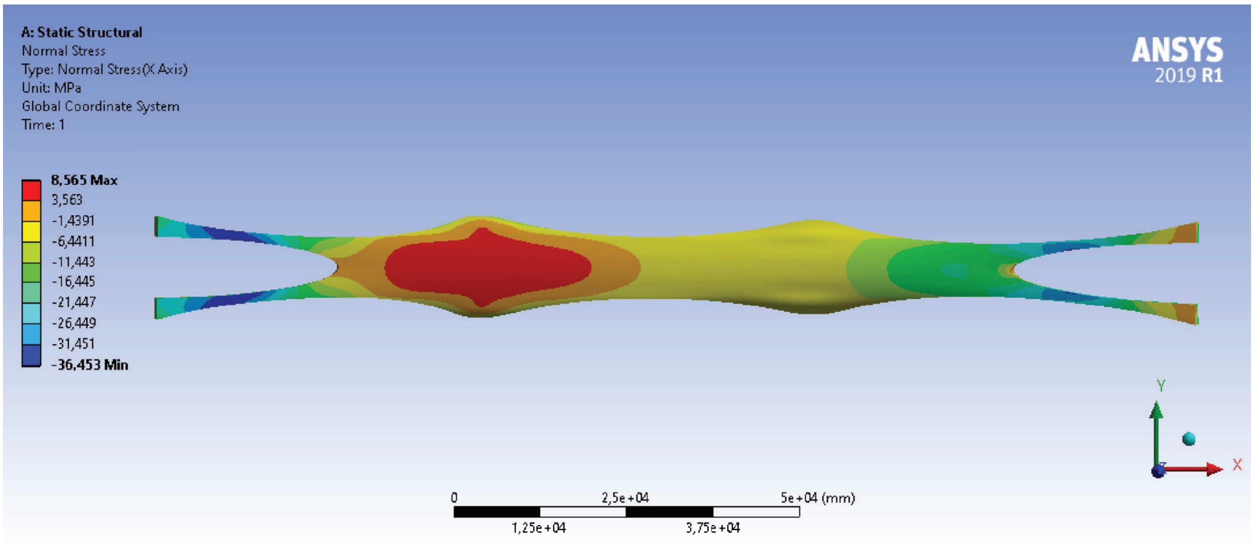
<u>MINIMUM PRINCIPAL STRESS</u>
solutions

MINIMUM -37,696 MPa
MAXIMUM 0,77142 MPa
AVERAGE -7,8398 MPa

MOST DIFFUSED
-20,599 MPa < x < 0,77142 MPa

SECOND CALCULATION **RESULTS**



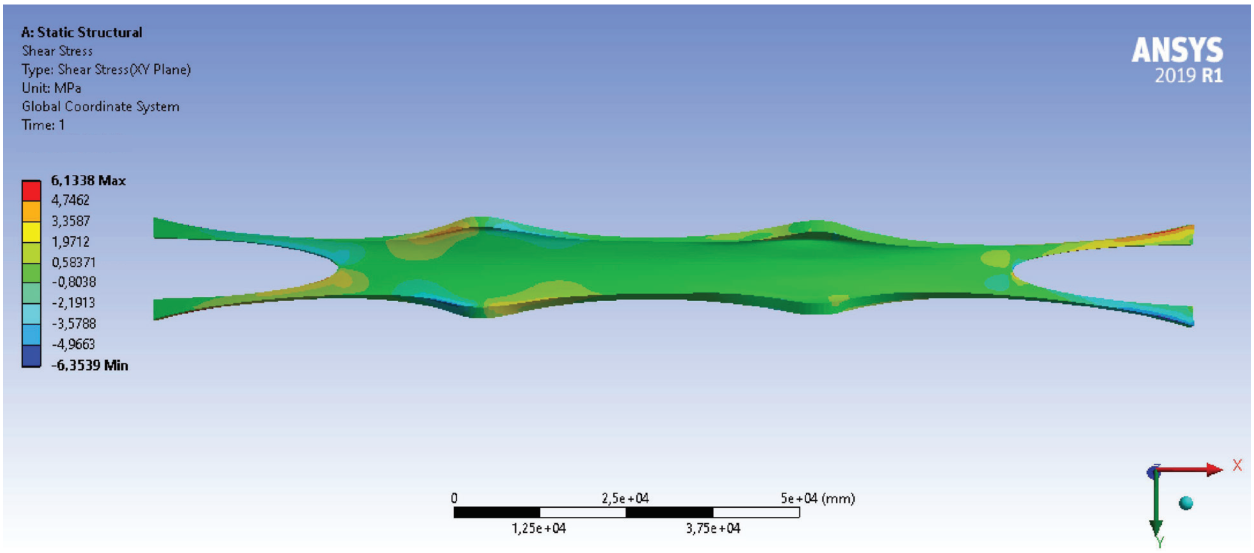


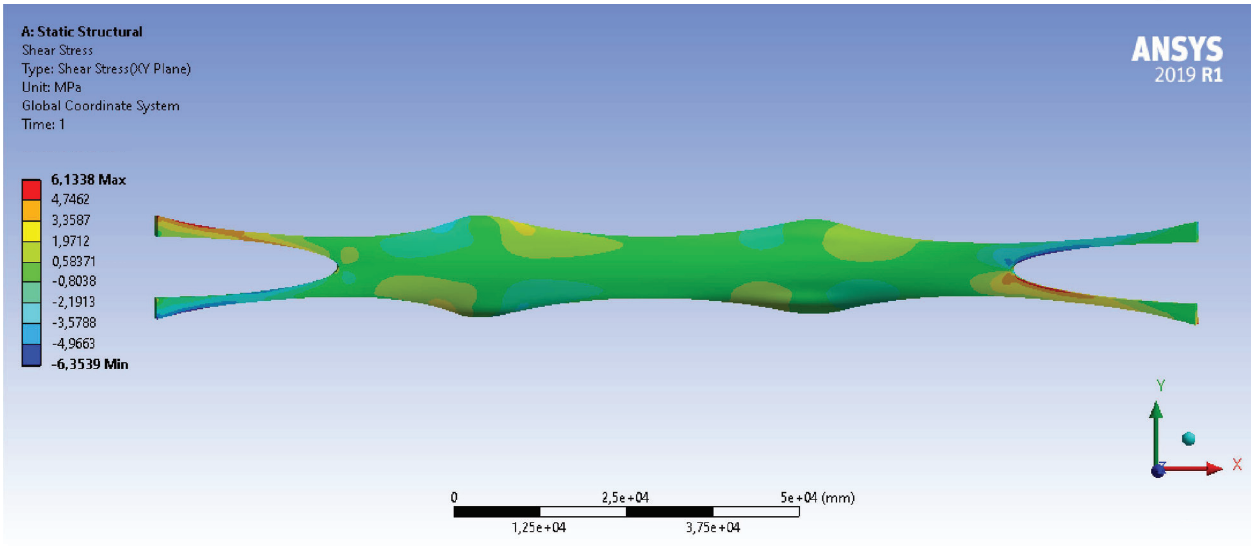
NORMAL STRESS
solutions

MINIMUM -36,453 MPa
MAXIMUM 8,565 MPa
AVERAGE -7,1682 MPa

MOST DIFFUSED
-21,447 MPa < x < 3,563 MPa

SECOND CALCULATION RESULTS





SHEAR STRESS
solutions

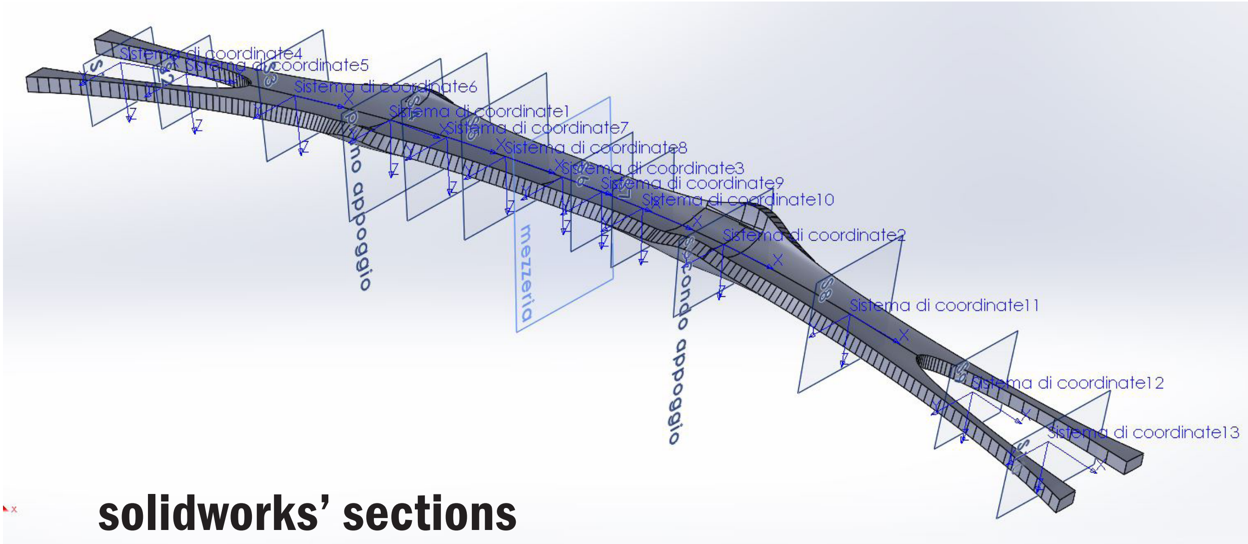
MINIMUM	-6,3539 MPa
MAXIMUM	6,1338 MPa
AVERAGE	2,165e-003 MPa

MOST DIFFUSED
-11,65 MPa < x < 15,603 MPa

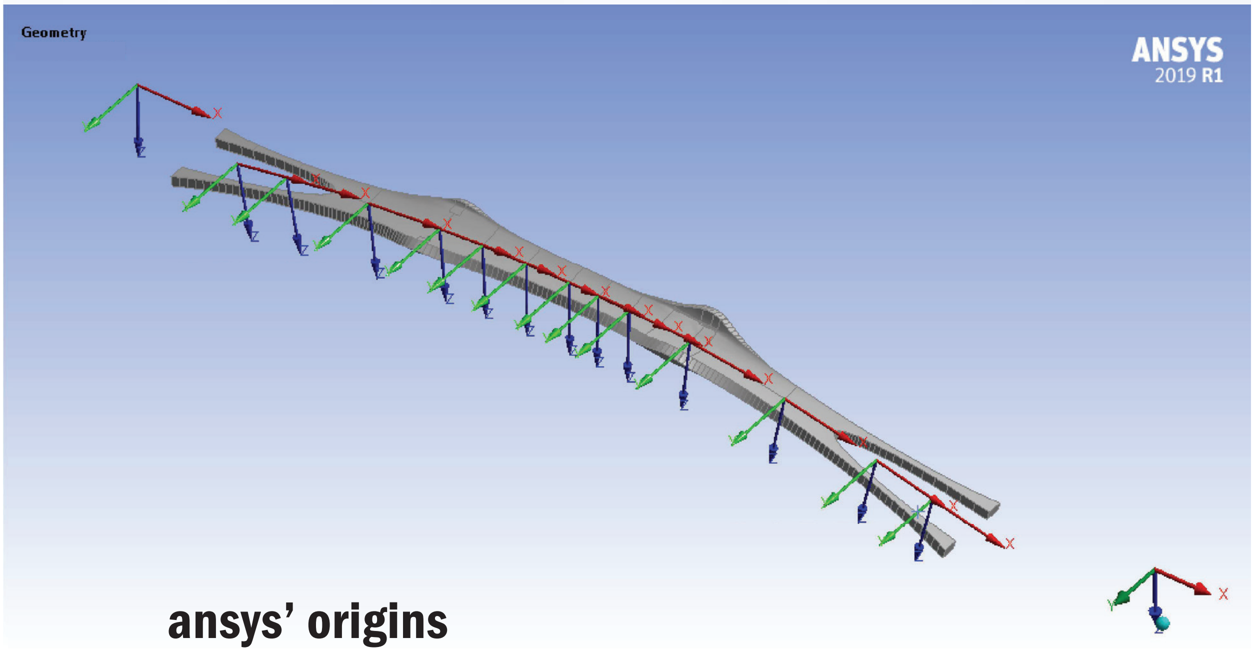
SECOND CALCULATION RESULTS
BENDING MOMENT

The calculation of the bending moment of the structural membrane has an operational difficulty in its explanation: as already said previously, the mesh produced with Ansys has swept the solid into tetrahedra, these only brick elements, the brick element, due to its mathematics cannot automatically generate bending moment graphs.

This is possible only using APDL or Macro programming languages, but these methods have a high efficiency in the calculation of more regular shaped structures with a great complication in the distribution of forces. That's not the case. Thus, thinking about the mathematics of the brick element: this element in the FEM context to a force applied to the model the program generates a deformed one, the brick has a k, relative to the imposed material, and through the program it returns the normal stresses σ. From the σ you can use the principles of construction science: the solid is divided, using the CAD system of Solid Works, in cutting sections with respect to the smaller size. So, the model is divided in 13 sections.

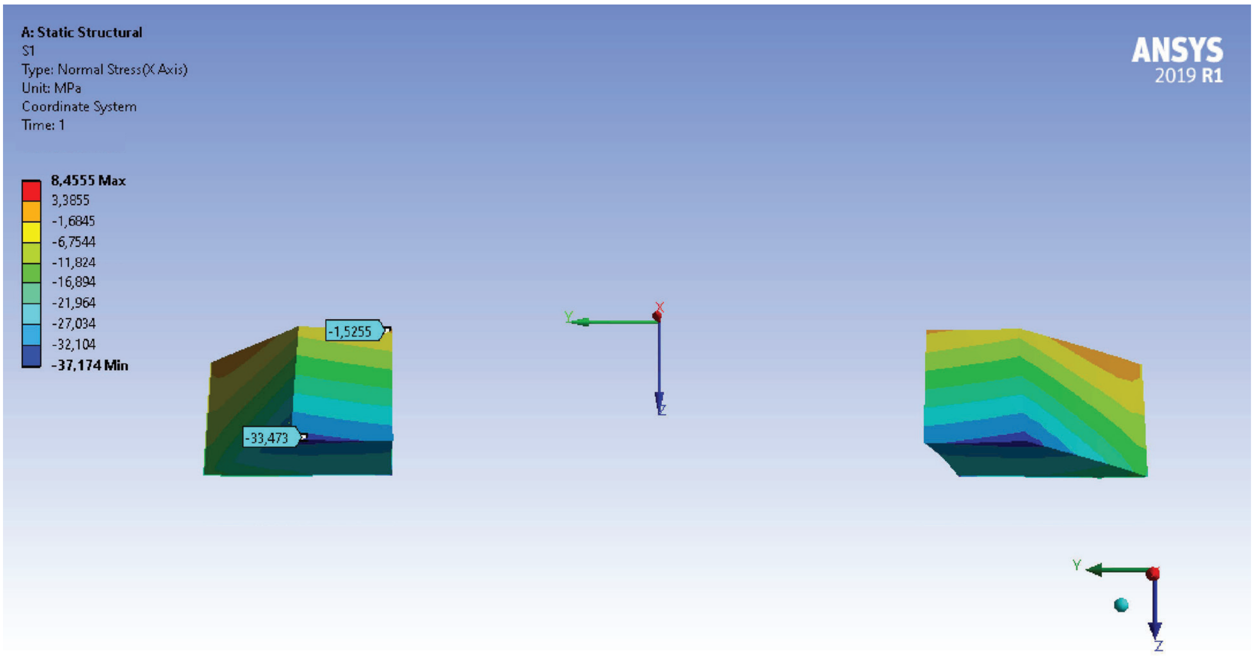


solidworks' sections



ansys' origins

SECOND CALCULATION **RESULTS**



SECTION 1

σ_{SUPERIOR} -1,5255 MPa

σ_{INFERIOR} -33,473 MPa

SECTION 1 CENTER OF GRAVITY (m)

X (0,00) | Y (0,00) | Z (0,90)

SECTION 1 MOMENT OF INERTIA

5,97 m^4

SECTION 1 AREA

5,57 m^2

SECTION 2

σ_{SUPERIOR} -12,532 MPa

σ_{INFERIOR} -28,292 MPa

SECTION 2 CENTER OF GRAVITY (m)

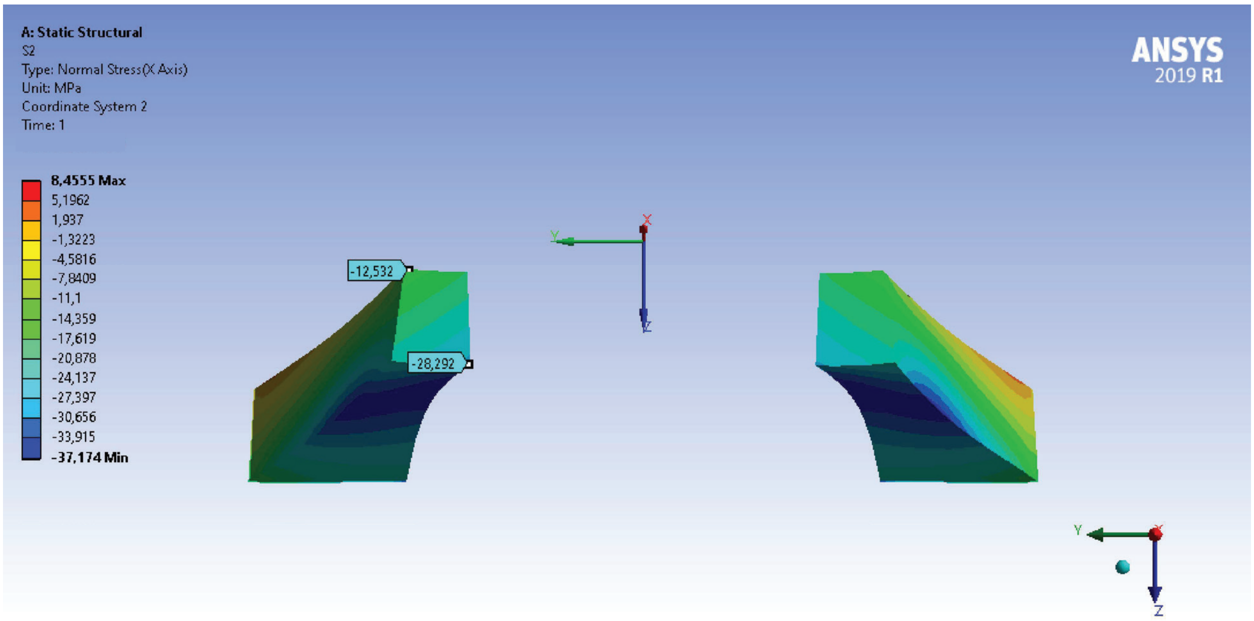
X (0,00) | Y (0,00) | Z (0,91)

SECTION 2 MOMENT OF INERTIA

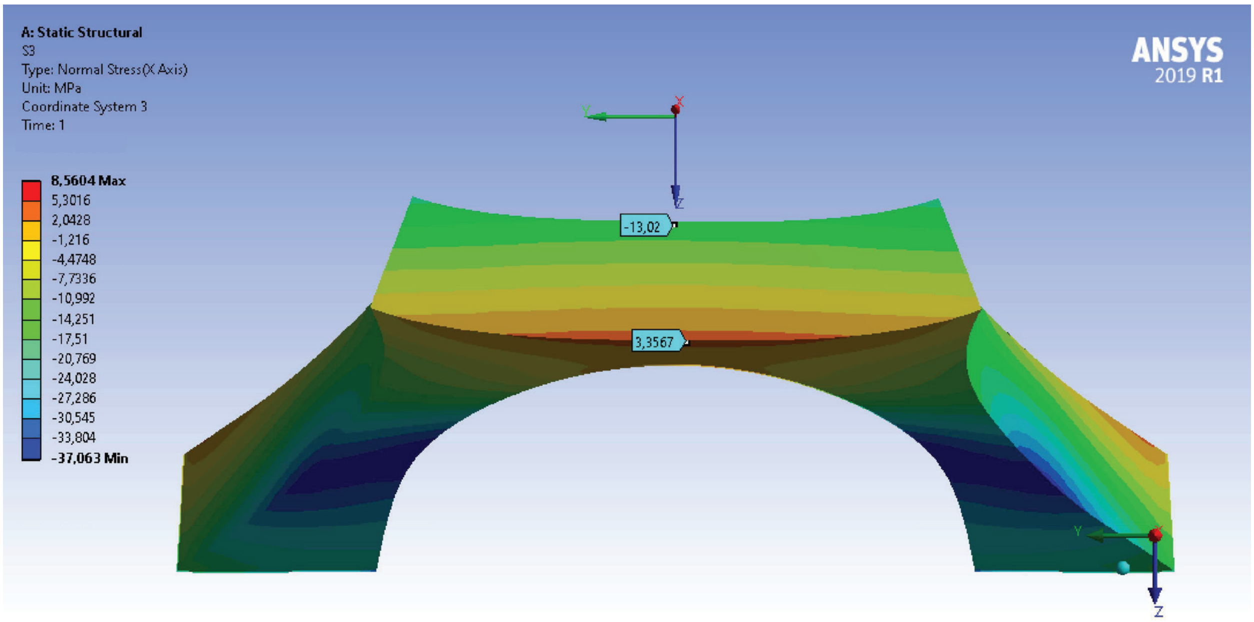
5,23 m^4

SECTION 2 AREA

4,82 m^2



SECOND CALCULATION **RESULTS**



<u>SECTION 3</u>

σ SUPERIOR	-13,02 MPa
σ INFERIOR	3,3567 MPa

SECTION 3 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,81)

SECTION 3 MOMENT OF INERTIA
14,45 m^4

SECTION 3 AREA
15,47 m^2

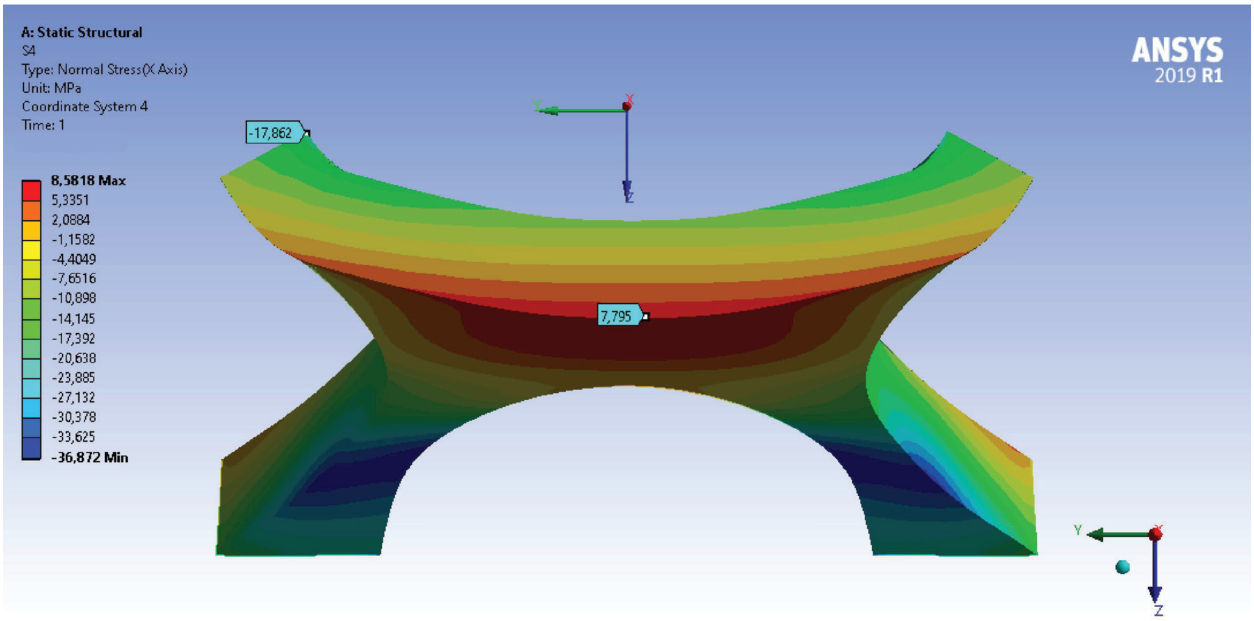
<u>SECTION 4 (SUPPORT)</u>

σ SUPERIOR	-17,862 MPa
σ INFERIOR	7,795 MPa

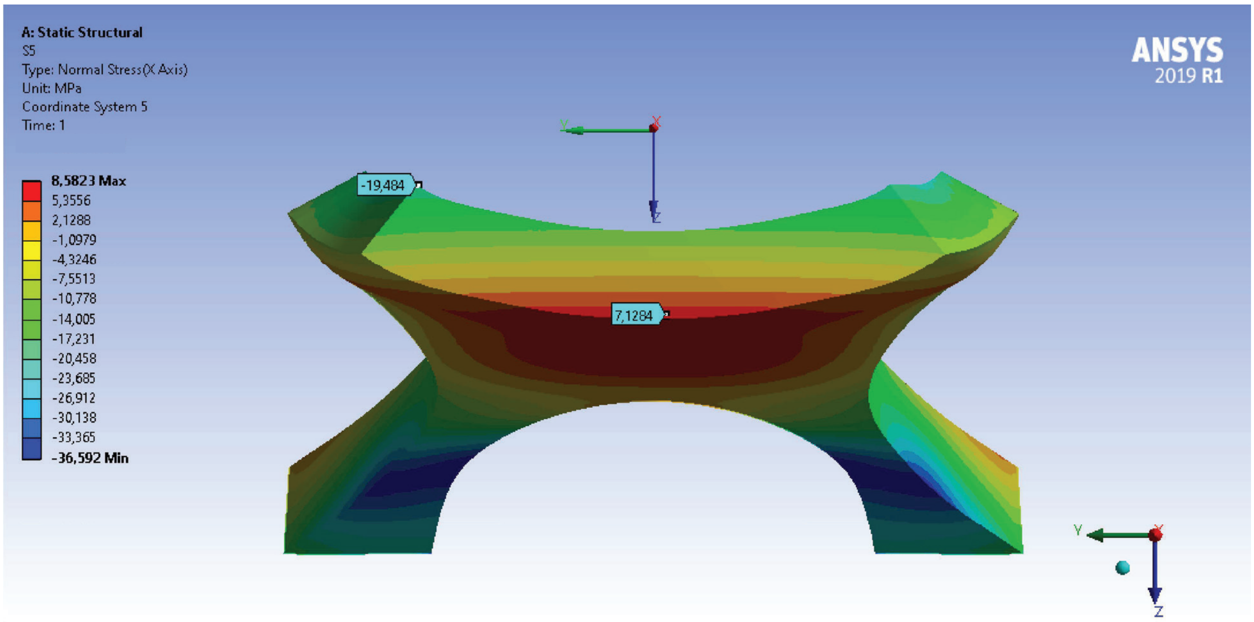
SECTION 4 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,32)

SECTION 4 MOMENT OF INERTIA
16,42 m^4

SECTION 4 AREA
25,96 m^2



SECOND CALCULATION RESULTS



SECTION 5		SECTION 6	
σ SUPERIOR	-19,484 MPa	σ SUPERIOR	-16,577 MPa
σ INFERIOR	7,8284 MPa	σ INFERIOR	2,7743 MPa

SECTION 5 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,57)

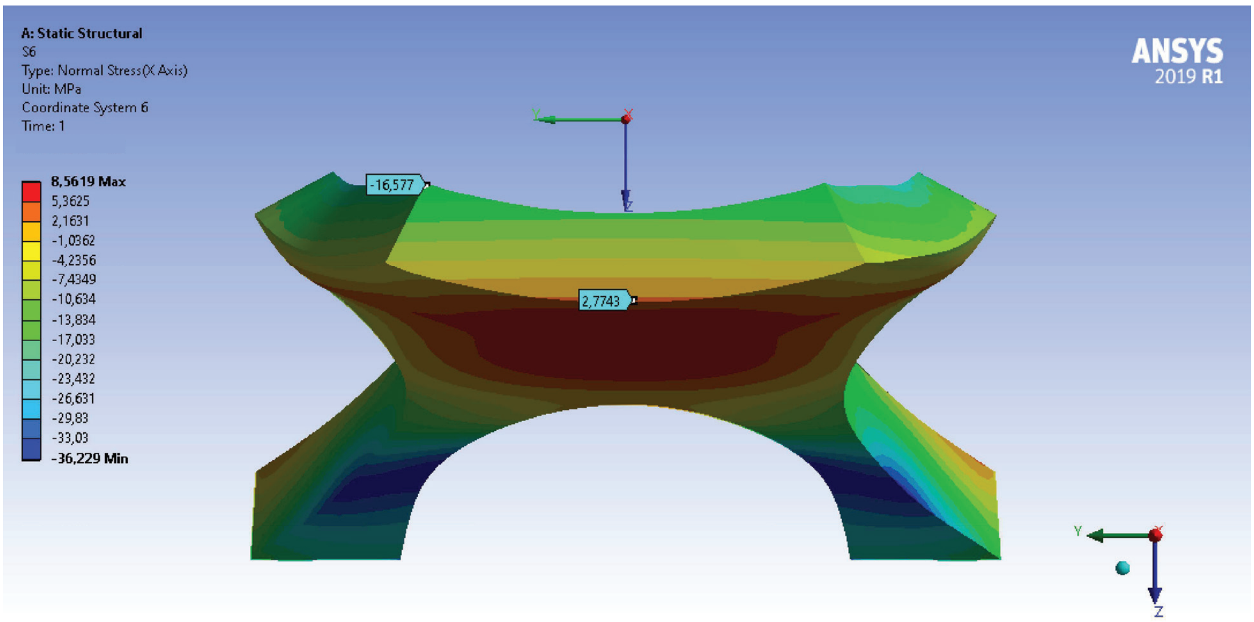
SECTION 6 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,70)

SECTION 5 MOMENT OF INERTIA
13,18 m^4

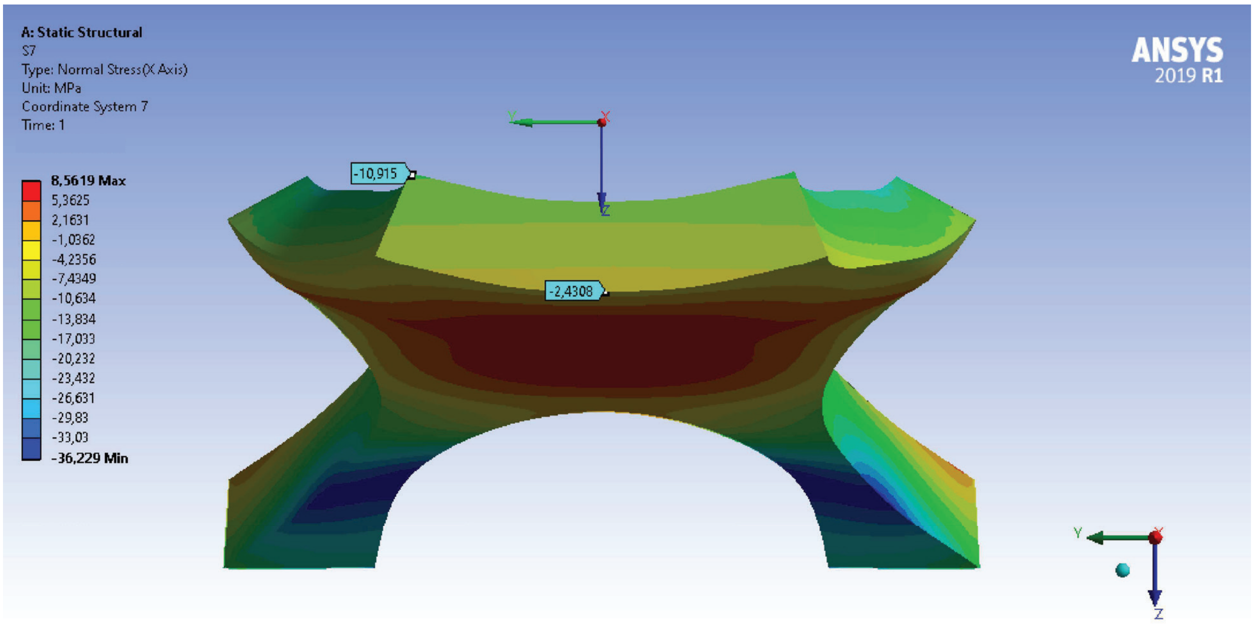
SECTION 6 MOMENT OF INERTIA
12,35 m^4

SECTION 5 AREA
19,80 m^2

SECTION 6 AREA
15,96 m^2



SECOND CALCULATION RESULTS



SECTION 7 (MEZZERIA)

σ SUPERIOR -10,915 MPa
σ INFERIOR 2,4308 MPa

SECTION 7 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,70)

SECTION 7 MOMENT OF INERTIA
11,92 m^4

SECTION 7 AREA
15,09 m^2

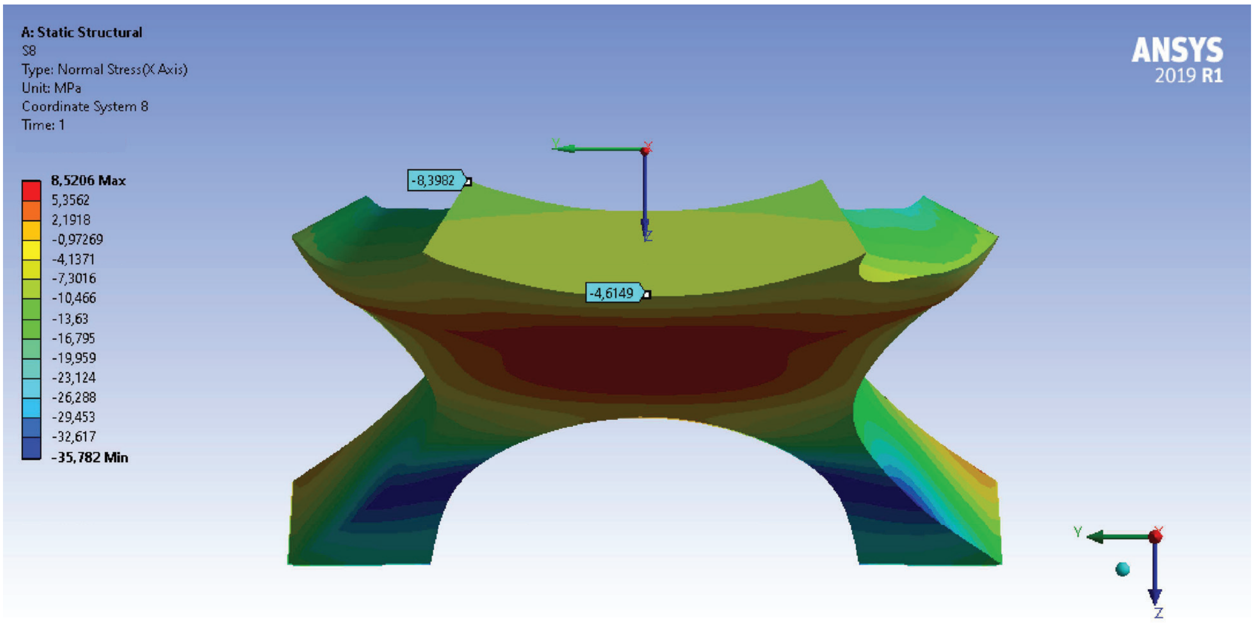
SECTION 8

σ SUPERIOR -8,3982 MPa
σ INFERIOR -4,6149 MPa

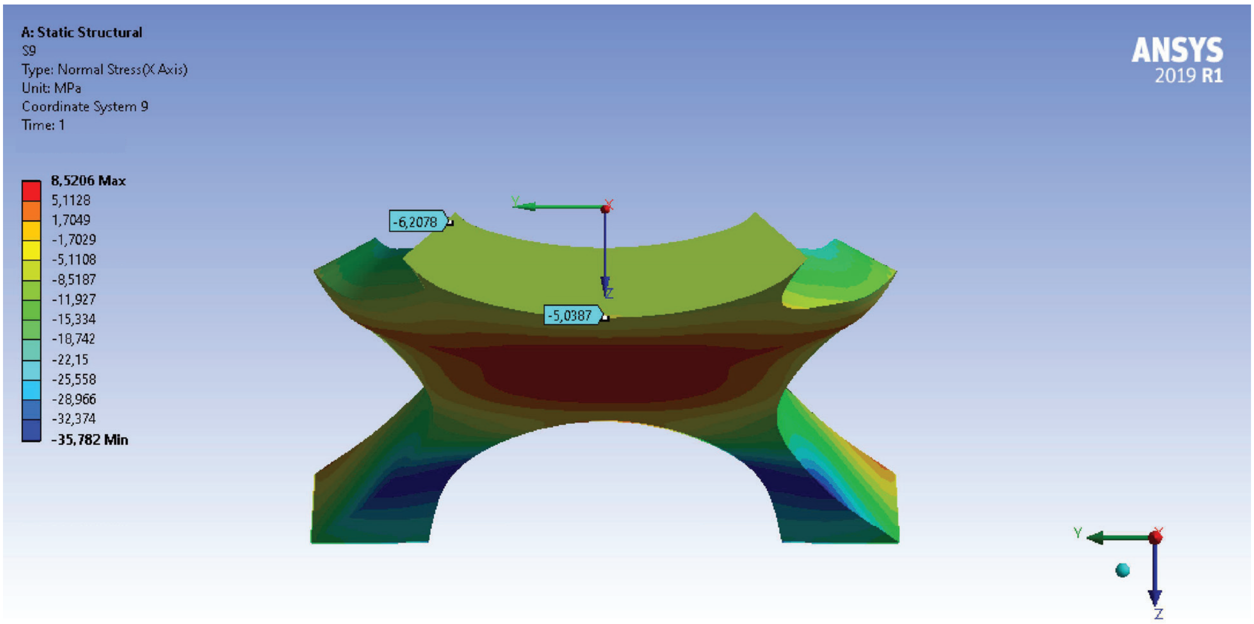
SECTION 8 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,68)

SECTION 8 MOMENT OF INERTIA
11,63 m^4

SECTION 8 AREA
15,38 m^2



SECOND CALCULATION **RESULTS**



SECTION 9

$\sigma_{SUPERIOR}$	-6,2078 MPa
$\sigma_{INFERIOR}$	-5,0387 MPa

SECTION 9 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,59)

SECTION 9 MOMENT OF INERTIA
11,60 m^4

SECTION 9 AREA
17,08 m^2

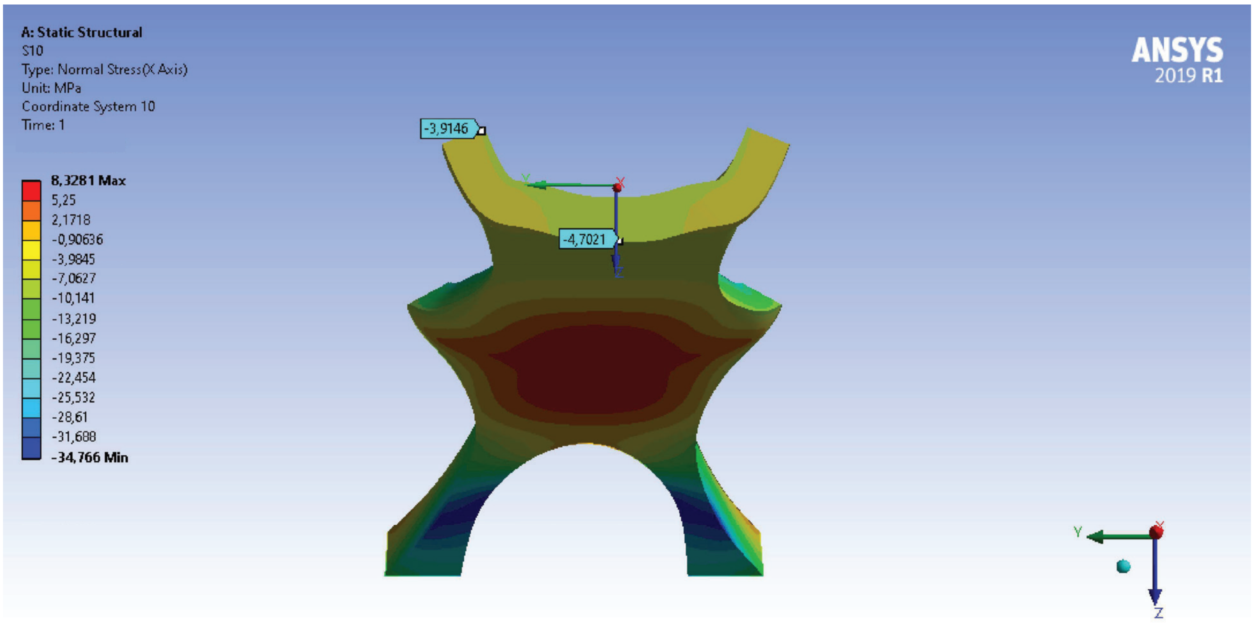
SECTION 10 (SUPPORT)

$\sigma_{SUPERIOR}$	-3,9146 MPa
$\sigma_{INFERIOR}$	-4,7021 MPa

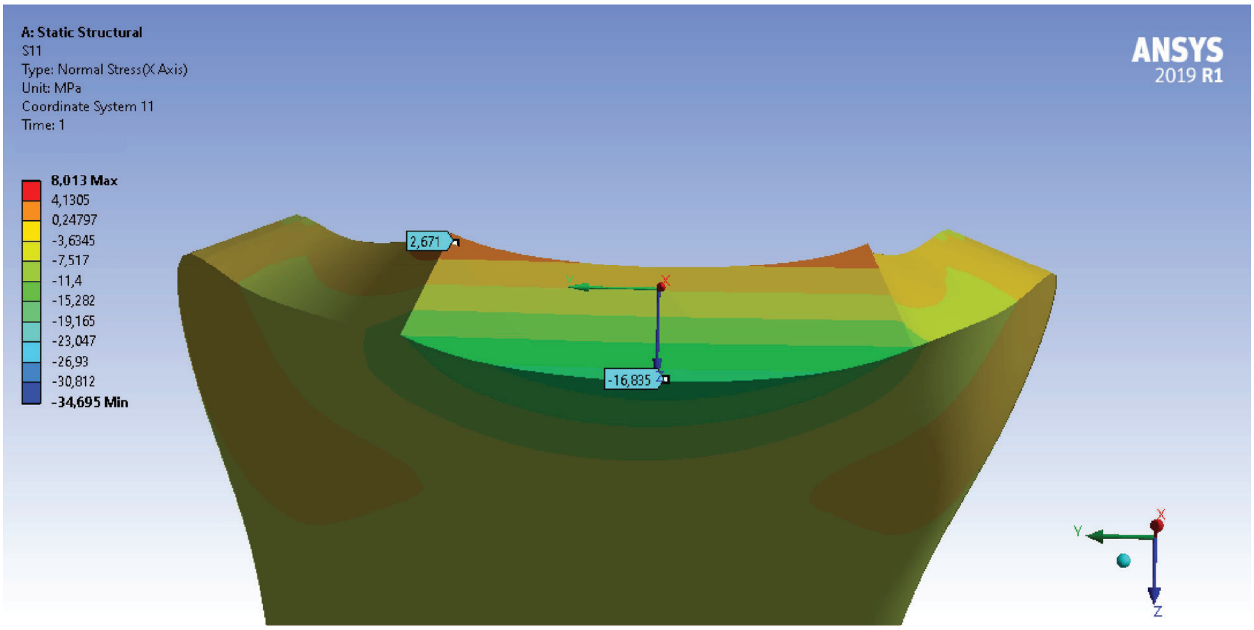
SECTION 10 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (-0,04)

SECTION 10 MOMENT OF INERTIA
30,65 m^4

SECTION 10 AREA
27,21 m^2



SECOND CALCULATION RESULTS



SECTION 11		SECTION 12	
σ SUPERIOR	2,671 MPa	σ SUPERIOR	-14,192 MPa
σ INFERIOR	-16,835 MPa	σ INFERIOR	-33,737 MPa

SECTION 11 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,77)

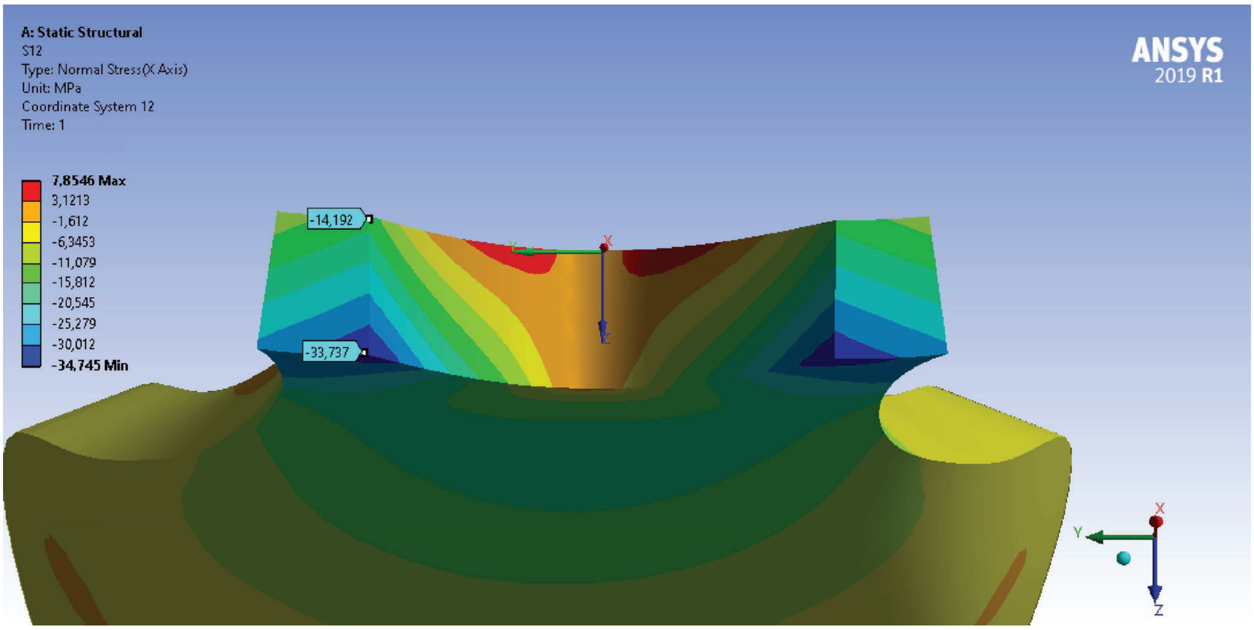
SECTION 12 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,89)

SECTION 11 MOMENT OF INERTIA
11,50 m^4

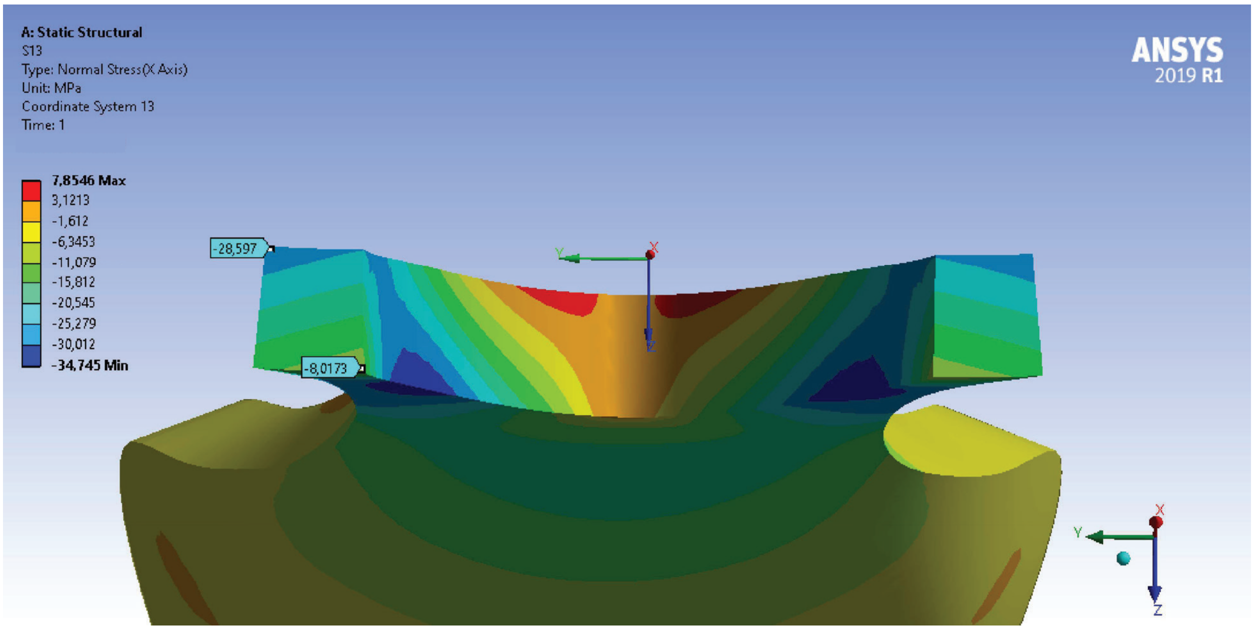
SECTION 12 MOMENT OF INERTIA
4,72 m^4

SECTION 11 AREA
13,26 m^2

SECTION 12 AREA
15,38 m^2



SECOND CALCULATION **RESULTS**



SECTION 13

$\sigma_{SUPERIOR}$ -28,597 MPa
$\sigma_{INFERIOR}$ -8,0173 MPa

SECTION 13 MOMENT OF INERTIA
5,41 m^4

SECTION 13 CENTER OF GRAVITY (m)
X (0,00) | Y (0,00) | Z (0,90)

SECTION 13 AREA
17,08 m^2

Each section has two independent coordinate systems, one related to the reference origin and one related to the center of gravity, each section different. The center of gravity obtained from the area and from the geometric properties through the use of SolidWorks: from here we also obtain the moments of inertia of the area in the centroid, the moments of inertia of the area in the reference system and the distances of

NORMAL STRESS SUPERIOR SURFACE σ sup [N/mm²]		NORMAL STRESS SUPERIOR SURFACE σ sup [N/m²]	
$\sigma_{1\ SUPERIOR}$	-1,5255	$\sigma_{1\ SUPERIOR}$	-1525500
$\sigma_{2\ SUPERIOR}$	-12,532	$\sigma_{2\ SUPERIOR}$	-12532000
$\sigma_{3\ SUPERIOR}$	-13,02	$\sigma_{3\ SUPERIOR}$	-13020000
$\sigma_{4\ SUPERIOR}$	-17,862	$\sigma_{4\ SUPERIOR}$	-17862000
$\sigma_{5\ SUPERIOR}$	-19,484	$\sigma_{5\ SUPERIOR}$	-19484000
$\sigma_{6\ SUPERIOR}$	-16,577	$\sigma_{6\ SUPERIOR}$	-16577000
$\sigma_{7\ SUPERIOR}$	-10,915	$\sigma_{7\ SUPERIOR}$	-10915000
$\sigma_{8\ SUPERIOR}$	-8,3982	$\sigma_{8\ SUPERIOR}$	-8398200
$\sigma_{9\ SUPERIOR}$	-6,2078	$\sigma_{9\ SUPERIOR}$	-6207800
$\sigma_{10\ SUPERIOR}$	-3,9146	$\sigma_{10\ SUPERIOR}$	-3914600
$\sigma_{11\ SUPERIOR}$	2,671	$\sigma_{11\ SUPERIOR}$	2671000
$\sigma_{12\ SUPERIOR}$	-14,192	$\sigma_{12\ SUPERIOR}$	-14192000
$\sigma_{13\ SUPERIOR}$	-28,597	$\sigma_{13\ SUPERIOR}$	-28597000

SECOND CALCULATION RESULTS

NORMAL STRESS INFERIOR SURFACE
σ inf [N/mm²]

$\sigma_{1 \text{ INFERIOR}}$	-33,473
$\sigma_{2 \text{ INFERIOR}}$	-28,292
$\sigma_{3 \text{ INFERIOR}}$	3,3567
$\sigma_{4 \text{ INFERIOR}}$	7,795
$\sigma_{5 \text{ INFERIOR}}$	7,8284
$\sigma_{6 \text{ INFERIOR}}$	2,7743
$\sigma_{7 \text{ INFERIOR}}$	2,4308
$\sigma_{8 \text{ INFERIOR}}$	-4,6149
$\sigma_{9 \text{ INFERIOR}}$	-5,0387
$\sigma_{10 \text{ INFERIOR}}$	-4,7021
$\sigma_{11 \text{ INFERIOR}}$	-16,835
$\sigma_{12 \text{ INFERIOR}}$	-33,737
$\sigma_{13 \text{ INFERIOR}}$	-8,0173

NORMAL STRESS INFERIOR SURFACE
σ inf [N/m²]

$\sigma_{1 \text{ INFERIOR}}$	-33473000
$\sigma_{2 \text{ INFERIOR}}$	-28292000
$\sigma_{3 \text{ INFERIOR}}$	3356700
$\sigma_{4 \text{ INFERIOR}}$	7795000
$\sigma_{5 \text{ INFERIOR}}$	7828400
$\sigma_{6 \text{ INFERIOR}}$	2774300
$\sigma_{7 \text{ INFERIOR}}$	2430800
$\sigma_{8 \text{ INFERIOR}}$	-4614900
$\sigma_{9 \text{ INFERIOR}}$	-5038700
$\sigma_{10 \text{ INFERIOR}}$	-4702100
$\sigma_{11 \text{ INFERIOR}}$	-16835000
$\sigma_{12 \text{ INFERIOR}}$	-33737000
$\sigma_{13 \text{ INFERIOR}}$	-8017300

SECTION MOMENT OF INERTIA
J yy [m⁴]

$J\,yy_{1}$	5,97
$J\,yy_{2}$	5,23
$J\,yy_{3}$	14,45
$J\,yy_{4}$	16,42
$J\,yy_{5}$	13,18
$J\,yy_{6}$	12,35
$J\,yy_{7}$	11,92
$J\,yy_{8}$	11,63
$J\,yy_{9}$	11,60
$J\,yy_{10}$	30,65
$J\,yy_{11}$	11,50
$J\,yy_{12}$	5,01
$J\,yy_{13}$	5,79

DISTANCE FROM THE CENTER OF GRAVITY OF THE SECTION
d [m]

$d_{1 \text{ SUPERIOR}}$	0,90
$d_{2 \text{ SUPERIOR}}$	0,91
$\sigma_{3 \text{ SUPERIOR}}$	0,81
$d_{4 \text{ SUPERIOR}}$	0,32
$\sigma_{5 \text{ SUPERIOR}}$	0,57
$d_{6 \text{ SUPERIOR}}$	0,70
$d_{7 \text{ SUPERIOR}}$	0,70
$d_{8 \text{ SUPERIOR}}$	0,68
$d_{9 \text{ SUPERIOR}}$	0,59
$d_{10 \text{ SUPERIOR}}$	0,04
$d_{11 \text{ SUPERIOR}}$	0,77
$d_{12 \text{ SUPERIOR}}$	0,89
$d_{13 \text{ SUPERIOR}}$	0,90

DISTANCE FROM THE NEUTRAL AXES OF THE SECTION
y [m]

y_{1}	1,80
y_{2}	1,80
y_{3}	-1,4311
y_{4}	-1,2531
y_{5}	-1,2841
y_{6}	-1,5419
y_{7}	-1,4721
y_{8}	1,80
y_{9}	1,80
y_{10}	1,80
y_{11}	1,5536
y_{12}	1,80
y_{13}	1,80

SECOND CALCULATION RESULTS

σ NORMAL STRESS SECTION [N/m²]		M_f BENDING MOMENT [N*m]	
σ_1	-31947500	$M_{f\ 1}$	-105959208,30
σ_2	-15760000	$M_{f\ 2}$	-45791555,56
σ_3	-13020000	$M_{f\ 3}$	131464607,60
σ_4	-17862000	$M_{f\ 4}$	234054776,20
σ_5	-19484000	$M_{f\ 5}$	199983739,60
σ_6	-16577000	$M_{f\ 6}$	132775115,10
σ_7	-10915000	$M_{f\ 7}$	88381767,54
σ_8	3783300	$M_{f\ 8}$	24444321,67
σ_9	1169100	$M_{f\ 9}$	7534200
σ_{10}	-787500	$M_{f\ 10}$	-13409375
σ_{11}	-16835000	$M_{f\ 11}$	-124615409,40
σ_{12}	-19545000	$M_{f\ 12}$	-54400250
σ_{13}	20579700	$M_{f\ 13}$	66198035

the two main surfaces of the solid from the center of gravity in each section.

From SolidWorks the sections are exported to the Ansys model to analyze the internal parts of the member for normal stress and shear stress. The “probe” command probes and returns the internal values, as seen in the responses plotted in the previous pages, the normal stress value σ greater than the upper surface and the greater than the lower surface. Having thus obtained the maximum and minimum σ, the data obtained from the CAD can be used to explain the pressure bending, formula of Navier. Being able to approximate the membrane structure as a curved beam, the Navier formula allows to determine the normal stresses acting on a cross section of an x-axis beam σ stressed in straight bending, so:

$$\sigma=(M_f/J_{yy})*y$$

where:

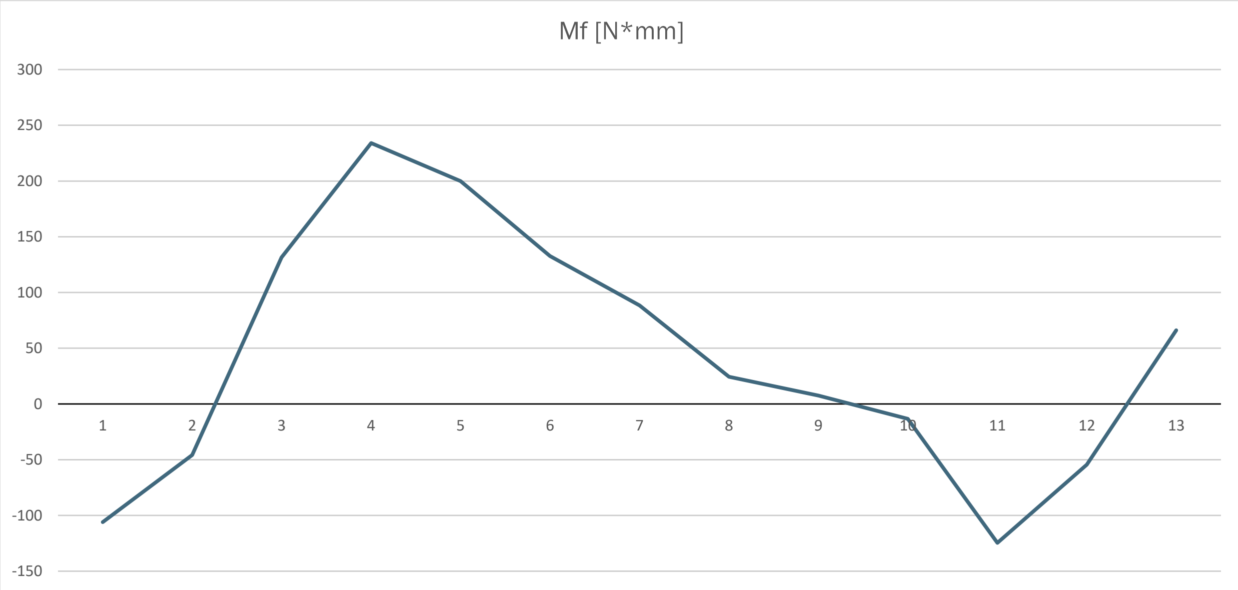
$$M_f=(\sigma*J_{yy})/y$$

Now, the discrepancies concerning the units of measurement derived from the two programs, geometric model in meters and FEM model in millimeters, must be adjusted and then with the aid of Excel calculated for each section, in the same way the normal stress and the distance from the neutral axes are calculated to find the bending moment.

Once all the bending moment values have been obtained, the bending moment trend graph can be created: being a real simulation of the bending moment, the two peaks corresponding to the section where the forces are applied are evident, in the vicinity of the center line the moment vanishes. Clear is the lower compression of the membrane in the lower surface, corresponding to section 4, the resistance of the section 10, thanks to the high value of the moment of inertia.

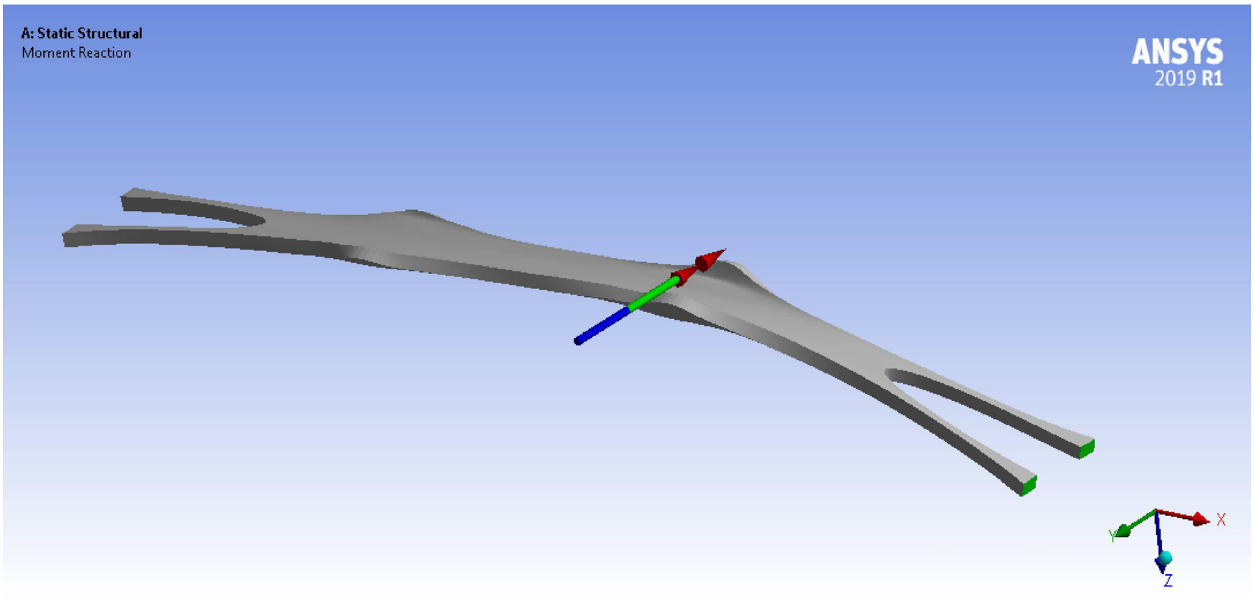
Naturally, even if not shown in the graphs, the maximum bending moment values correspond to the interlocking supports of the feet of the structure.

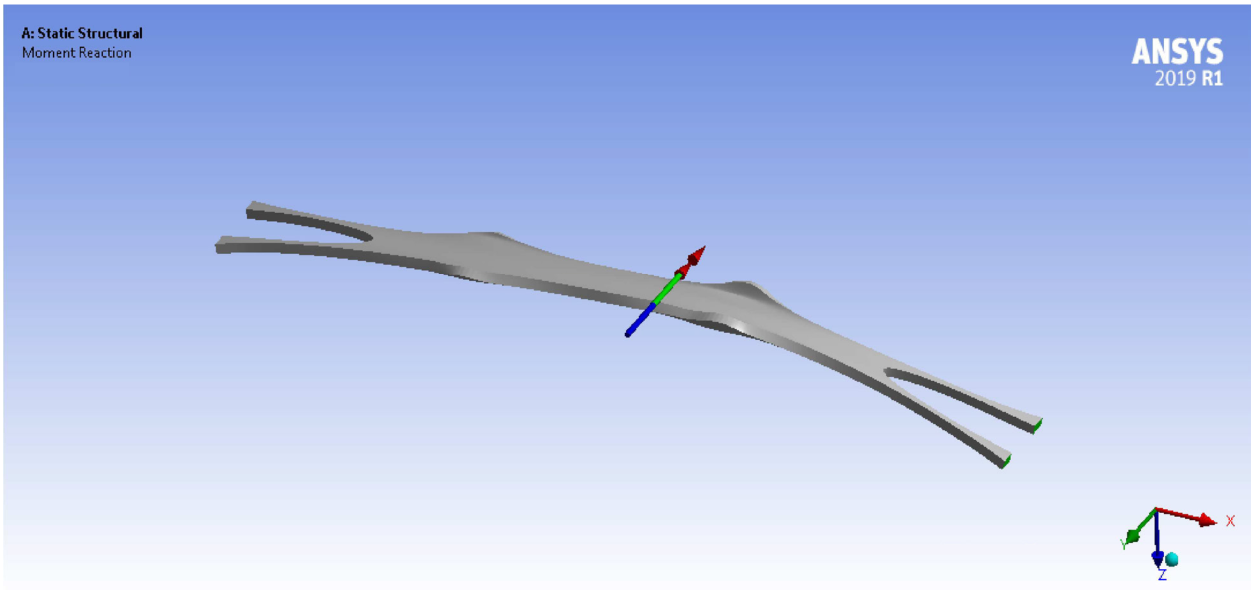
SECOND CALCULATION **RESULTS**



M_f BENDING MOMENT [N*m]		M_f BENDING MOMENT [N*mm]	
$M_{f\ 1}$	-105959208,30	$M_{f\ 1}$	-105,9592083
$M_{f\ 2}$	-45791555,56	$M_{f\ 2}$	-45,79155556
$M_{f\ 3}$	131464607,60	$M_{f\ 3}$	131,4646076
$M_{f\ 4}$	234054776,20	$M_{f\ 4}$	234,0547762
$M_{f\ 5}$	199983739,60	$M_{f\ 5}$	199,9837396
$M_{f\ 6}$	132775115,10	$M_{f\ 6}$	132,7751151
$M_{f\ 7}$	88381767,54	$M_{f\ 7}$	88,38176754
$M_{f\ 8}$	24444321,67	$M_{f\ 8}$	24,44432167
$M_{f\ 9}$	7534200	$M_{f\ 9}$	7,5342
$M_{f\ 10}$	-13409375	$M_{f\ 10}$	-13,409375
$M_{f\ 11}$	-124615409,40	$M_{f\ 11}$	-124,6154094
$M_{f\ 12}$	-54400250	$M_{f\ 12}$	-54,400250
$M_{f\ 13}$	66198035	$M_{f\ 13}$	66,198035

SECOND CALCULATION RESULTS





MOMENT REACTION
solutions

MOMENT REACTION (X)
5,0788e+008 MPa

MOMENT REACTION (Y)
-1,2919e+011 MPa

MOMENT REACTION (Z)
-4199,1 MPa

TOTAL MOMENT REACTION
1,2919e+011 MPa

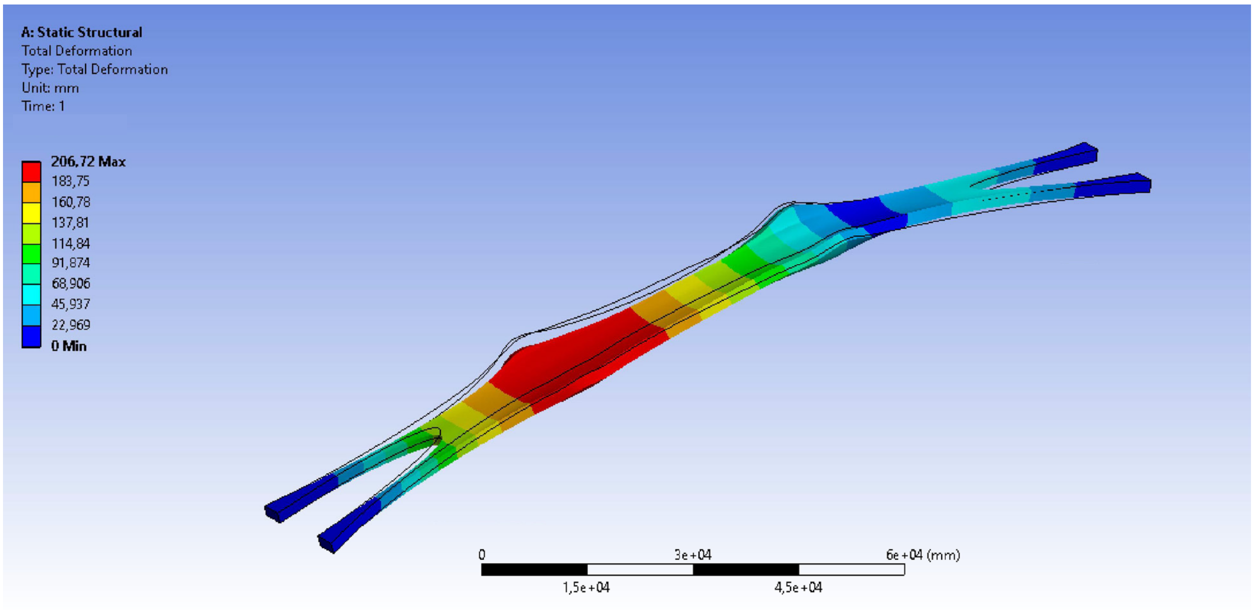
MOMENT REACTION (X)
5,0788e+014 Pa

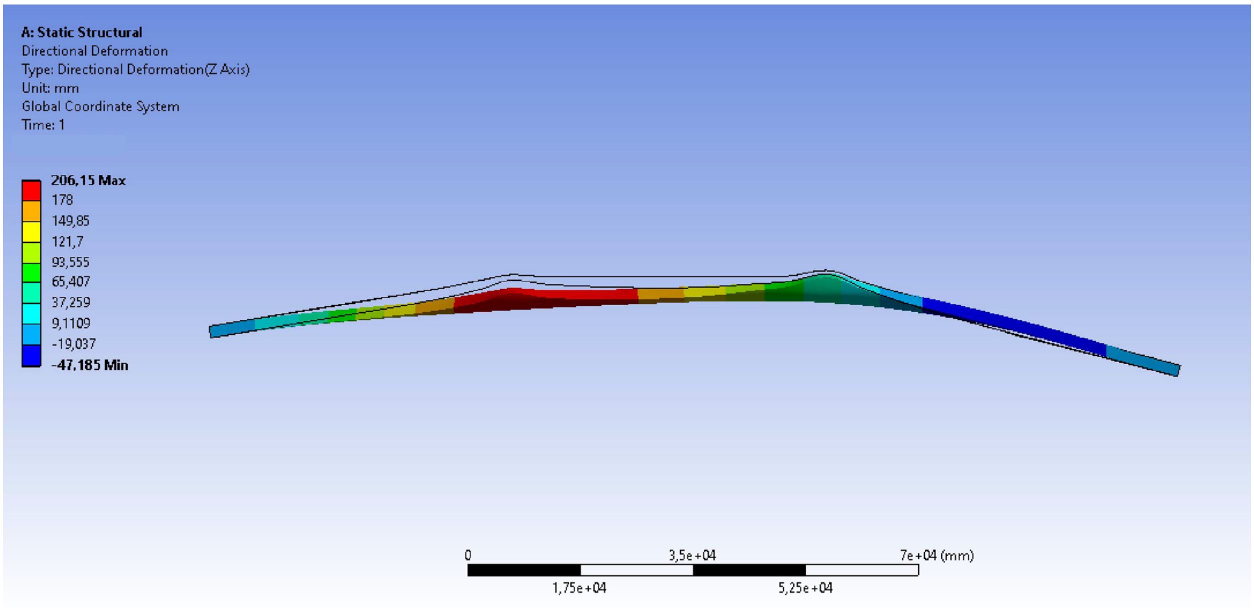
MOMENT REACTION (Y)
-1,2919e+017 Pa

MOMENT REACTION (Z)
-4,1991e+009 Pa

TOTAL MOMENT REACTION
1,2919e+017 Pa

SECOND CALCULATION RESULTS





TOTAL DEFORMATION
solutions

millimeters

MINIMUM	no moviment
MAXIMUM	206,72 mm
AVERAGE	106,85 mm

meters

MINIMUM	no moviment
MAXIMUM	0,20672 m
AVERAGE	0,10685 m

DIRECTIONAL Z DEFORMATION
solutions

millimeters

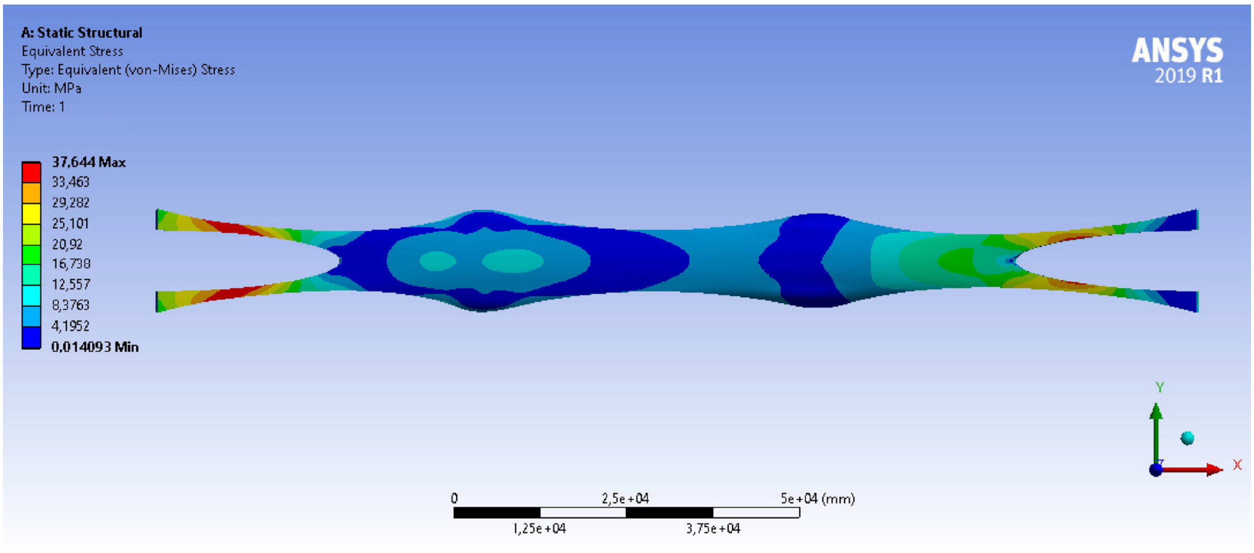
MINIMUM	-47,185 mm
MAXIMUM	206,15 mm
AVERAGE	97,717 mm

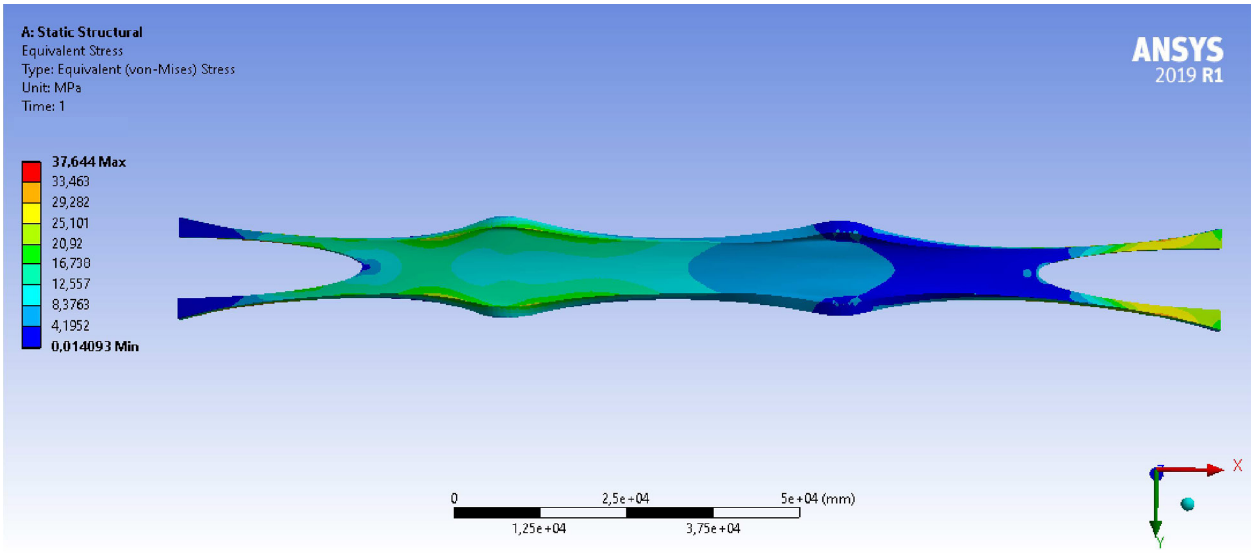
meters

MINIMUM	0,047185 m
MAXIMUM	0,20615 m
AVERAGE	0,097717 m

SECOND CALCULATION RESULTS

SECOND VON MISES ANALYSIS





VON MISES ANALYSIS
solutions

megaPascal		Pascal	
MINIMUM	1,4093e-002 MPa	MINIMUM	1,4093e+005 P
MAXIMUM	37,644 MPa	MAXIMUM	3,7644e+007 P
AVERAGE	8,1608 MPa	AVERAGE	8,1608e+006 P

SECOND CALCULATION RESULTS

SECOND BUCKLING ANALYSIS

total deformation (mm)

MINIMUM	no moviment
MAXIMUM	211,24 mm
AVERAGE	100,17 mm

total deformation (m)

MINIMUM	no moviment
MAXIMUM	0,21124 m
AVERAGE	0,10017 m

load multipiers

NUMBER 1	5,6192
NUMBER 2	6,1644
NUMBER 3	7,9931
NUMBER 4	9,633
NUMBER 5	10,59
NUMBER 6	14,241

directional deformation (mm)

MINIMUM	-52,882 mm
MAXIMUM	210,65 mm
AVERAGE	76,929 mm

directional deformation (m)

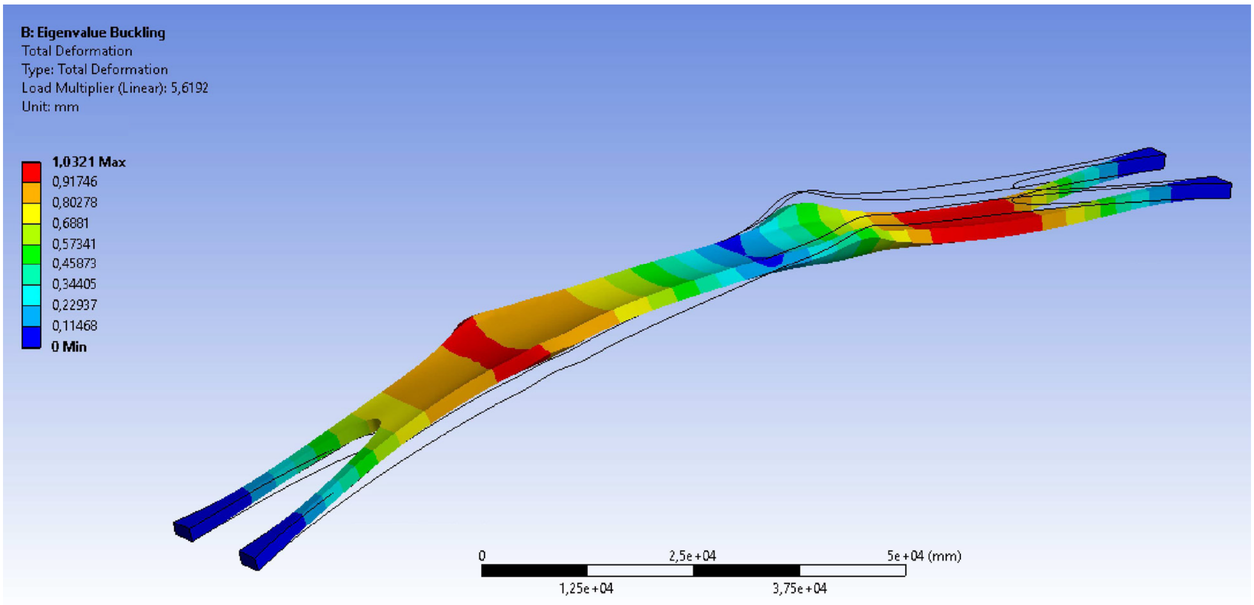
MINIMUM	-0,052882 m
MAXIMUM	0,21065 m
AVERAGE	0,076929 m

total deformation NUMBER 1 (mm)

MINIMUM	no moviment
MAXIMUM	1,0321 mm
AVERAGE	0,67893 mm

total deformation NUMBER 1 (m)

MINIMUM	no moviment
MAXIMUM	0,0010321 m
AVERAGE	0,00067911 m



AFTER CALCULATION CONSIDERATIONS

The incresing of the inertia of the concrete membrane modifing the shape and maintaing the same thickness produced better results. The moments of inertia increasements are:

Mi_1 Ip1 = 5,3777e+010 t*mm²
Mi_2 Ip1 = 9,1314e+010 t*mm²
D(Mi_2 Ip1 - Mi_1 Ip1) = 3,7537e+010 t*mm²

I(%) = +69,80%

Mi_1 Ip2 = 3,9209e+012 t*mm²
Mi_2 Ip2 = 6,1402e+012 t*mm²
D(Mi_2 Ip2 - Mi_1 Ip2) = 2,2193e+010 t*mm²

I(%) = +56,60%

Mi_1 Ip3 = 3,9388e+012 t*mm²
Mi_2 Ip3 = 6,1543e+012 t*mm²
D(Mi_2 Ip3 - Mi_1 Ip3) = 2,2155e+010 t*mm²

I(%) = +56,24%

The increasements of the moments of inertia are all more than 50%, just changing the geometry and maintaing equal the thickness (=1800 mm) with a consequent not relevant incresement in terms of mass (from 3765,8 t to 4821,9 t) and volume (from 1,6373e+012 mm³ to 2,0965e+012 mm³). The most relevant dat is related to the statical total deformation: the maximum lowering passes from 523,91 mm to 206,72 mm.

$L1_{MAX}$ = 523,91 mm
$L2_{MAX}$ = 206,72 mm
D($L1_{MAX}$ - $L2_{MAX}$) = 317,19 mm

R(%) = -60,54%

The reduction in terms of total deformation is almost fifty percent. Therefore the increase of the total inertia of the structure is inversely proportional to the total deformation of the same. Also the problems linked with the high values of compression in the analysis of first membrane have decreased significantly.

The highest value in the maximum principal stress, equal to 69,538 MPa, is now arrived to 12,79 MPa.

$P1_{MAX}$ = 69,538 MPa
$P2_{MAX}$ = 12,79 MPa
D($P1_{MAX}$ - $P2_{MAX}$) = 56,748 MPa

R(%) = -81,60%

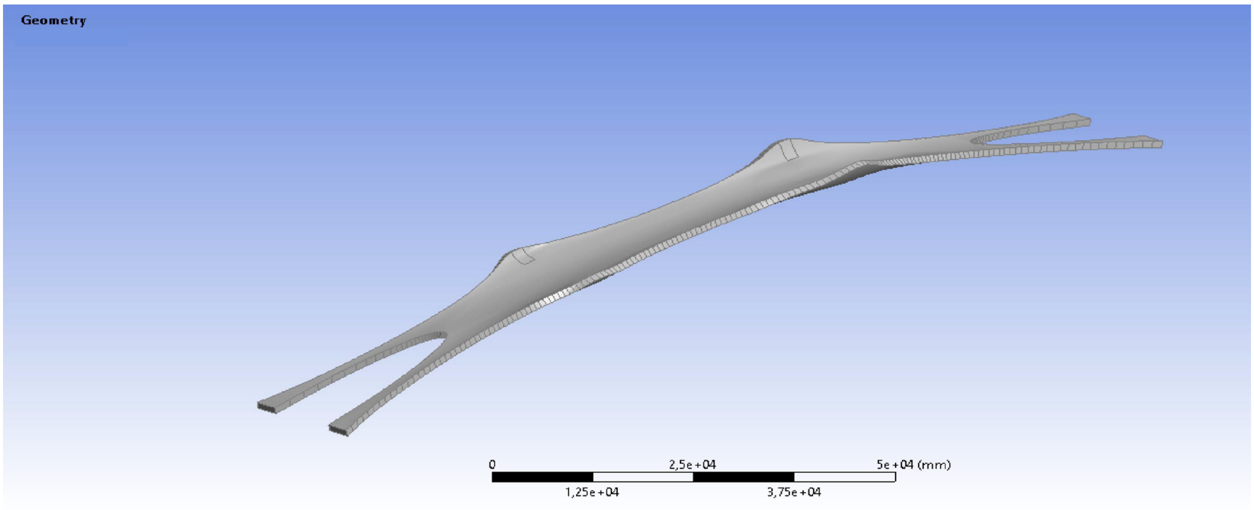
Analyzing the data related to the Buckling Analysis, the structure has the maximum lowering equal to -71,044 mm (that is 0,071044 m) and a deformation of the same direction but opposite sign, that means upward, with a value of 282,91 mm (that is 0,28291 m).

So, the total and directional deformation values are very similar to the same in the statical structural analysis. Moreover, from the same analysis the FEM program has worked out six values, called load multipiers (n), they are number that multiplied by the applied loads, equal to (G/6)*4 = 4,e+007 N, and the proper weight of the structure lead to system instability. So, take a look to the numbers and generated the critical deformation caused by the smallest multiplier, and therefore the most probable statistically, we can see the structure of the structure the moment before the system's weakness.So:

[(G/6)*4] * n = system instability
n_1 = 5,6192
L_{MAX} = 1032,1 mm = 1,0321 m

A lowering of more than one meters is very high and it is the maximum limit before the break caused by the frequence of the bridge:the structure has stiffness mass inertia and proper frequency. The values of n are based to the vibrations that the bridge has in relation to its natural frequency, this is exactly what lead to the instability of the system.

THIRD CALCULATION **STEPS**



thickness 1000 mm

Having proved with the calculation of the second membrane that it is more performing than the previus thank to its shape, we approach other calculations, processing different membranes maintaining the shape above drawed with different thickness'. That is to understand if it is possible to project the membrane lighter with all the consequences. The decrease in the mass of material of the structure leads for example to economic savings and a minor environmental impact.

In the following calculations the settings of the previuos ones will remain unalterd in order to recreate the same conditions and verify how much different are the performances of a thinner membrane.

In the following calculation the value of thickness imposed will be 1000 mm, that is exactly 1 meter, if the performances of the membrane will be better we can try with a value of thickness less than one, if the performances will worst we have to try with a value greater than one by less than 1800 mm, that is 1,80 meters. This value was one of the resulting data worked out from the generative algorithm of Grasshopper that doesn't change even if the shape of the mesh changed.

GEOMETRY PROPERTIES

VOLUME 1,2256e+012 mm^3
MASS 2819 t
NODES 80814
ELEMENTS 43269
CENTROID Y 3994,8 mm
CENTROID Z 408,13 mm

MOMENT OF INERTIA Ip1
5,5166e+010 $t*mm^2$

MOMENT OF INERTIA Ip2
3,5648e+012 $t*mm^2$

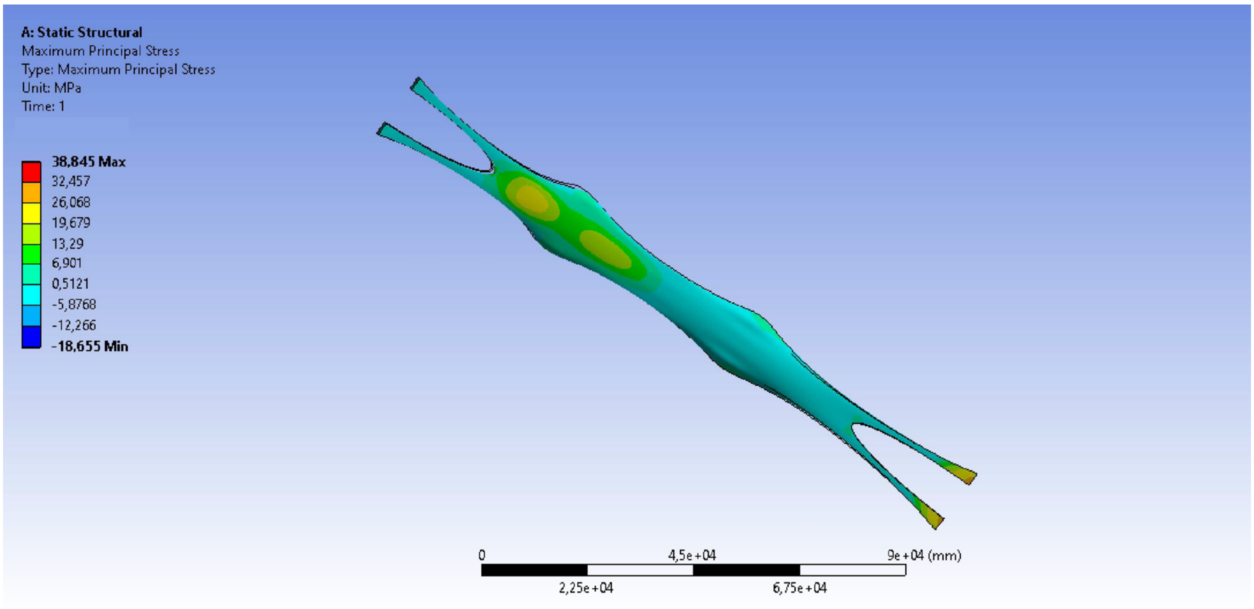
MOMENT OF INERTIA Ip3
3,5756e+012 $t*mm^2$

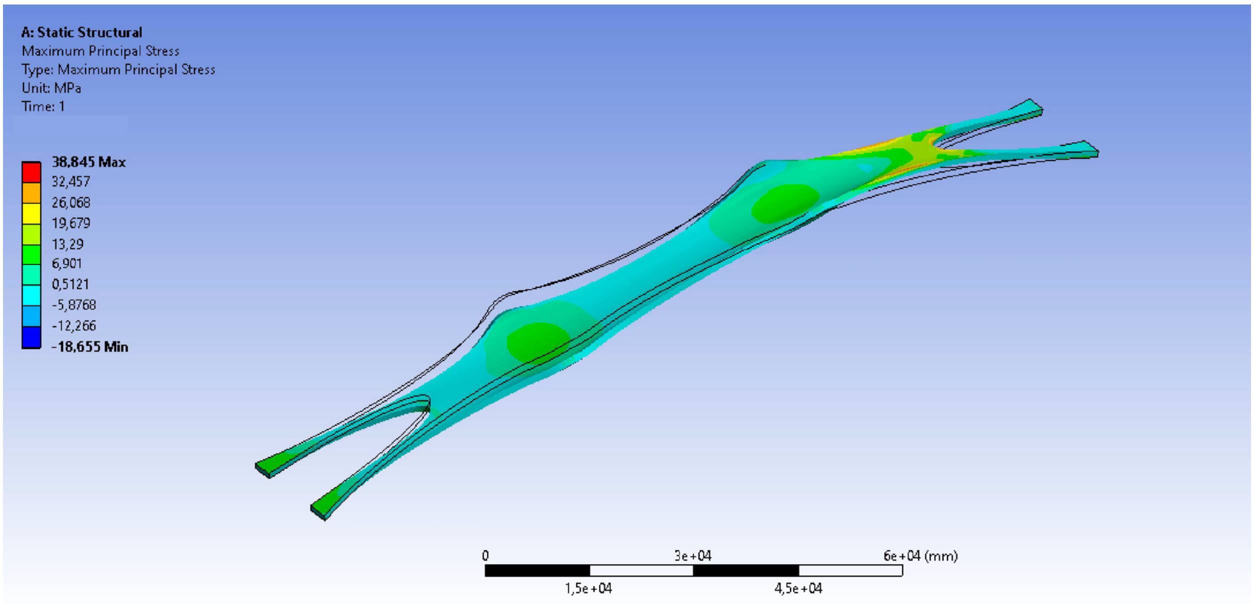
MESH PROPERTIES

ELEMENT SIZE 400 mm
AVAREAGE SURFACE AREA
6,5641e+006 mm^2
MINIMUM EDGE LENGTH
96,564 mm

TRANSITION RATIO 0,272
MAXIMUM LAYER 5
GROWTH RATE 1,2
NODES 80814
ELEMENTS 43269

THIRD CALCULATION RESULTS





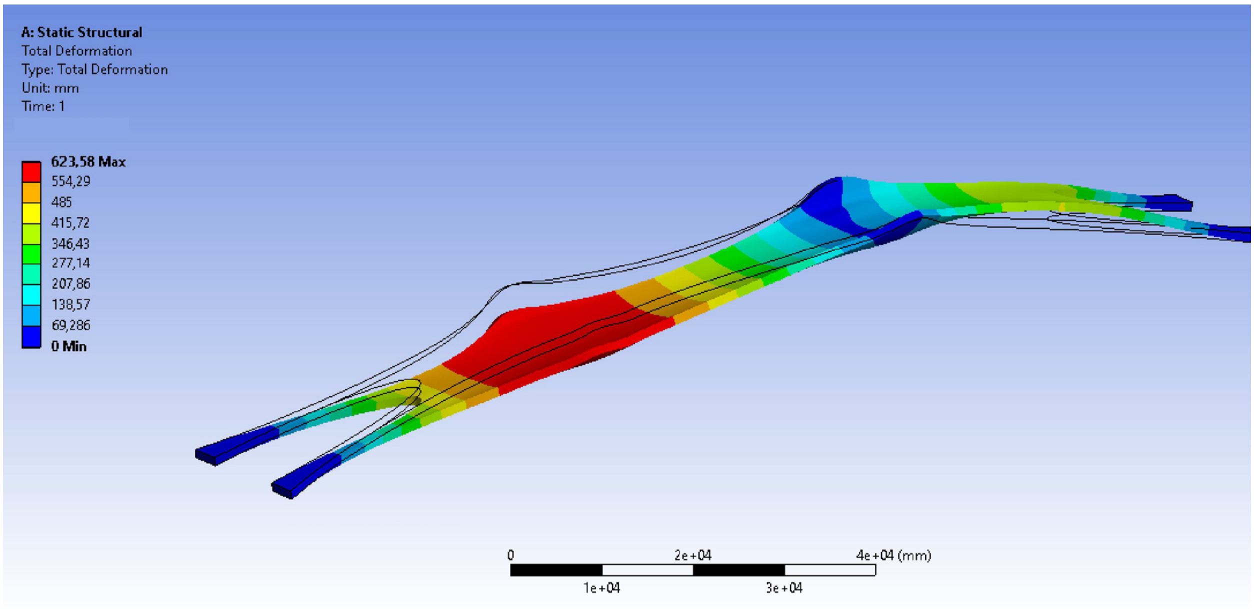
THIRD STATIC STRUCTURAL ANALYSIS

MAXIMUM PRINCIPAL STRESS
solutions

MINIMUM	-18,655 MPa
MAXIMUM	38,845 MPa
AVERAGE	2,2998 MPa

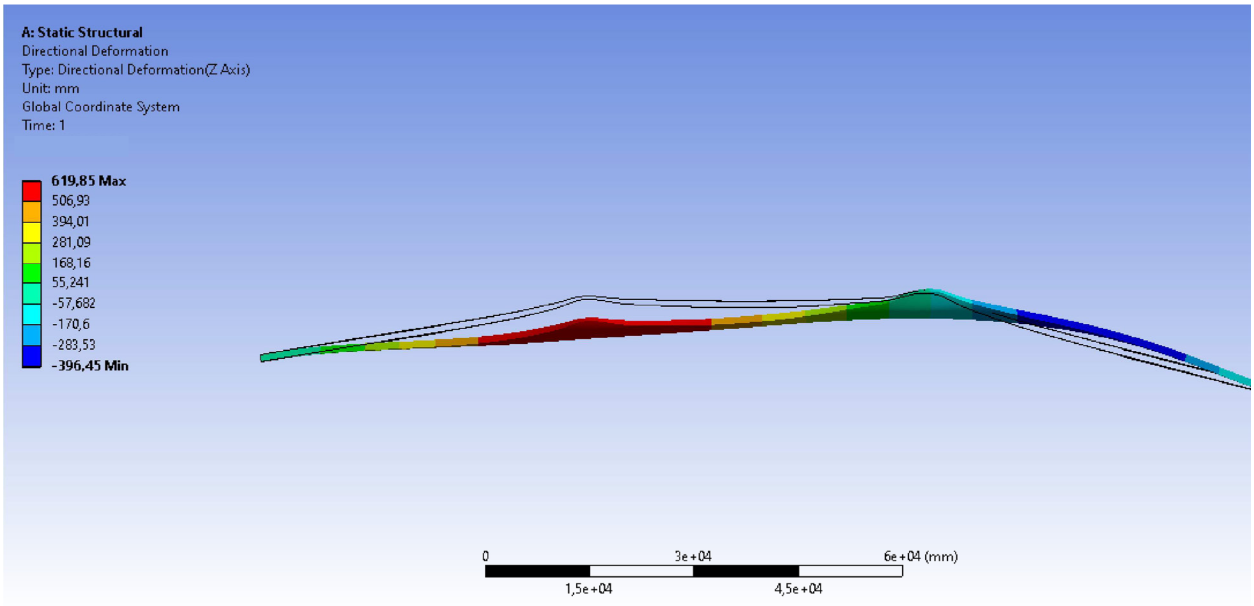
MOST DIFFUSED
0,5121 MPa < x < 26,068 MPa

THIRD CALCULATION RESULTS



TOTAL DEFORMATION
solutions

millimeters		meters	
MINIMUM	no moviment	MINIMUM	no moviment
MAXIMUM	623,58 mm	MAXIMUM	0,62358 m
AVERAGE	339,71 mm	AVERAGE	0,33971 m

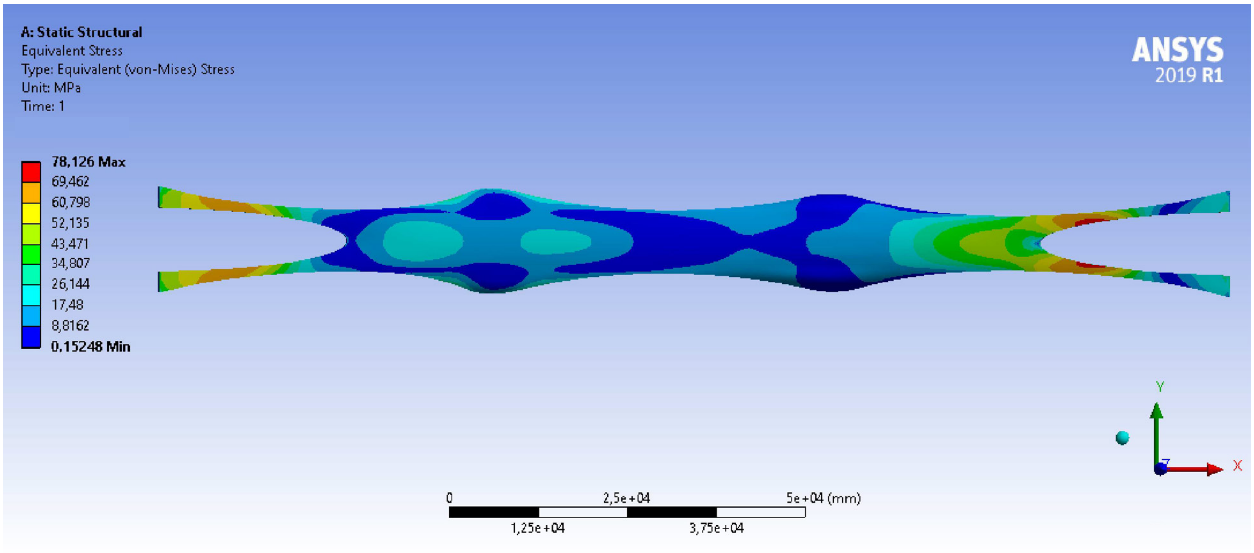


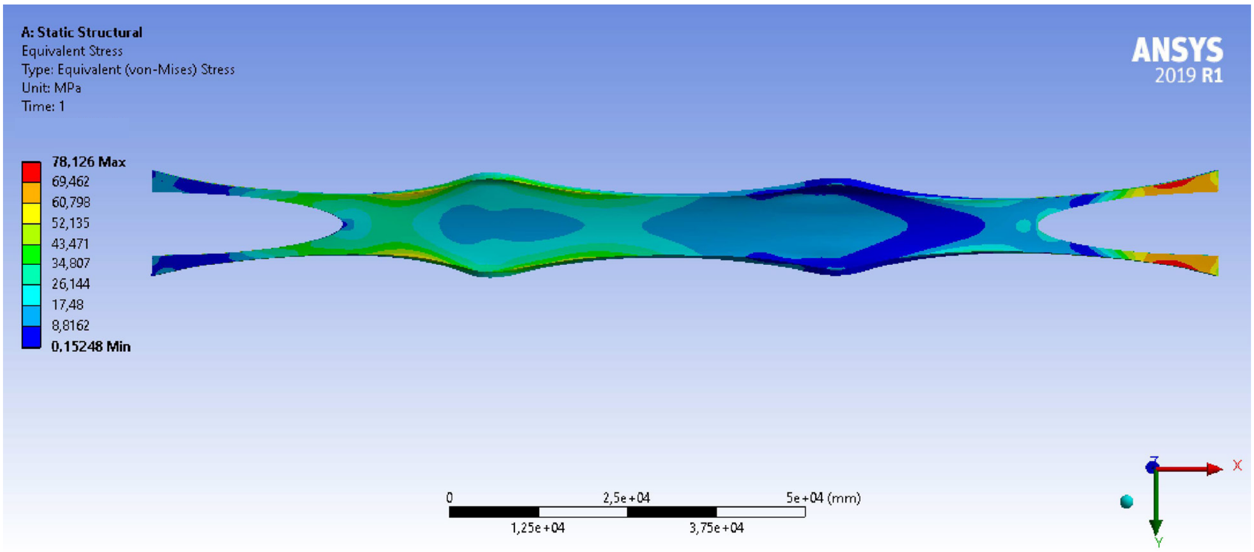
DIRECTIONAL Z DEFORMATION
solutions

millimeters		meters	
MINIMUM	-396,45 mm	MINIMUM	-0,39645
MAXIMUM	619,85 mm	MAXIMUM	0,61985 m
AVERAGE	165,28 mm	AVERAGE	0,16528 m

THIRD CALCULATION RESULTS

THIRD VON MISES ANALYSIS





VON MISES ANALYSIS
solutions

megaPascal	
MINIMUM	0,15248 MPa
MAXIMUM	78,126 MPa
AVERAGE	18,023 MPa

Pascal	
MINIMUM	1,9344e+005 P
MAXIMUM	7,126e+007 P
AVERAGE	1,8023e+007 P

THIRD CALCULATION **RESULTS**

THIRD BUCKLING ANALYSIS

BUCKLING ANALYSIS
solutions

load multipiers

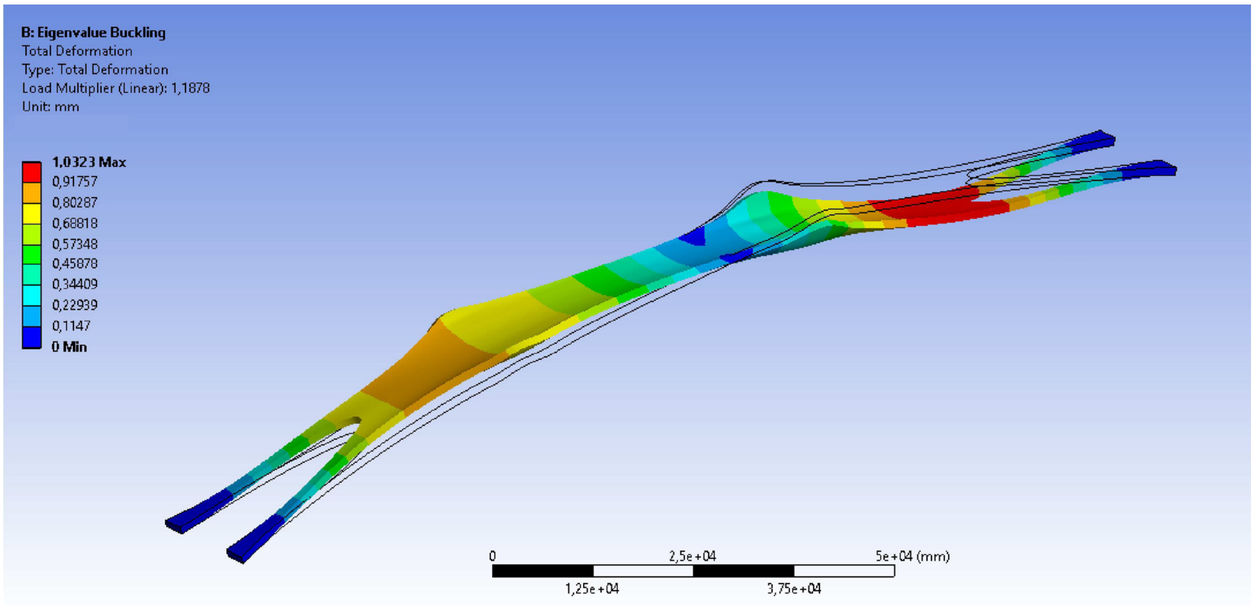
NUMBER 1	1,1878

total deformation NUMBER 1 (mm)

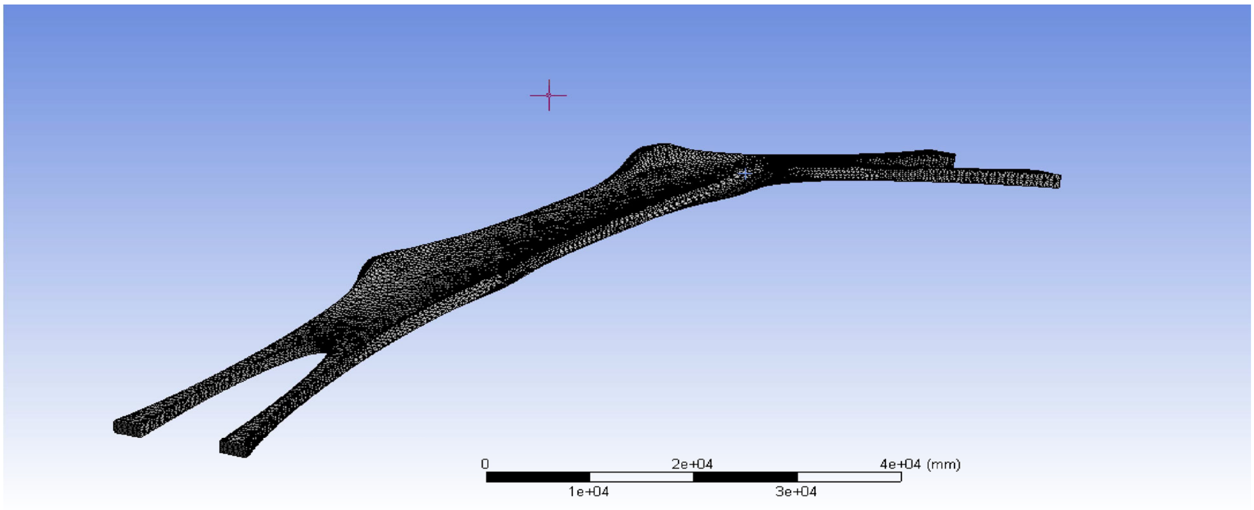
MINIMUM	no moviment
MAXIMUM	1,0323 mm
AVERAGE	0,58287 mm

total deformation NUMBER 1 (m)

MINIMUM	no moviment
MAXIMUM	0,0010323 m
AVERAGE	0,00058287 m



FOURTH CALCULATION **STEPS**



thickness 1500 mm

Always starting from both the static results and the buckling analysis of the membrane with higher inertia, always maintaining the shape and further modifying the thickness with a value of 1000 mm <T <1800 mm given as a domain, according to the buckling data of the 1000 membrane mm not encouraging. By bringing the thickness to 1500 mm, the aim is to understand if the consequent decreases in mass and volume of the material of the structure can lead the project to have greater economic savings and a lower environmental impact.

Also in the following calculations they will have unchanged material settings to recreate the same conditions and verify how different the performance of a membrane with a thickness of 1500 mm is.

In the subsequent calculation, the thickness value will therefore be 1500 mm, i.e. exactly one and a half meters, since the performance of the 1000 mm membrane is worse than the value set as a maximum of 1800 mm, resulting from the Grasshopper generative algorithm.

GEOMETRY PROPERTIES

VOLUME 1,7907e+012 mm³
MASS 4118,6 t
NODES 88140
ELEMENTS 48260
CENTROID Y 3995,9 mm
CENTROID Z 193,89 mm

MOMENT OF INERTIA Ip1
7,8729e+010 t*mm²

MOMENT OF INERTIA Ip2
5,2301e+012 t*mm²

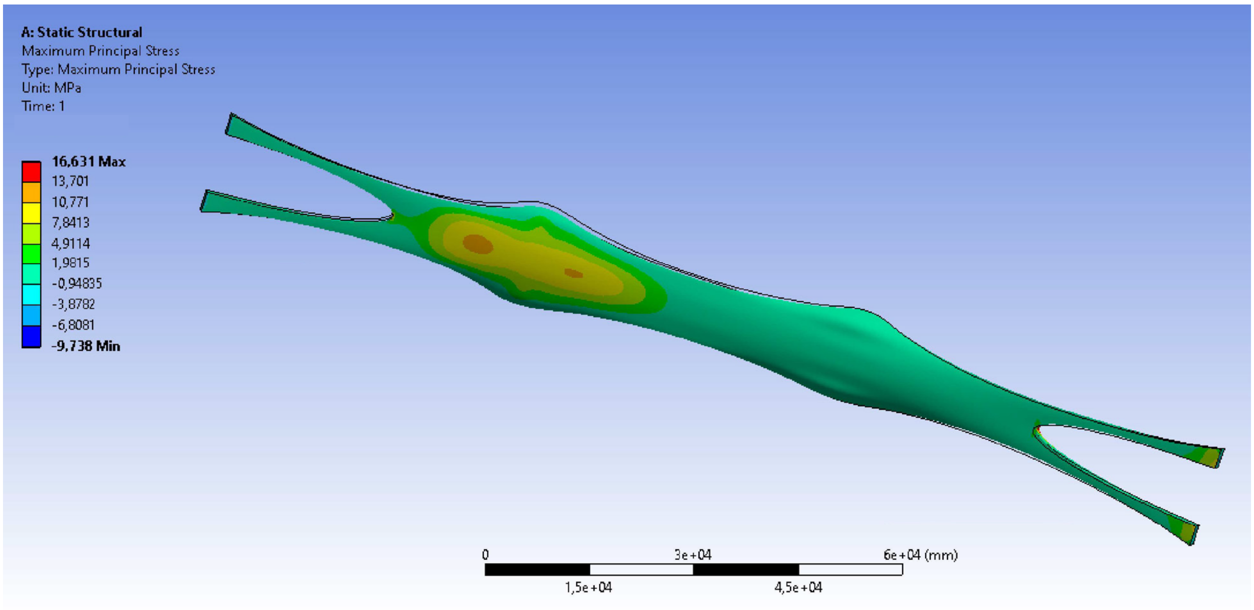
MOMENT OF INERTIA Ip3
5,2435e+012 t*mm²

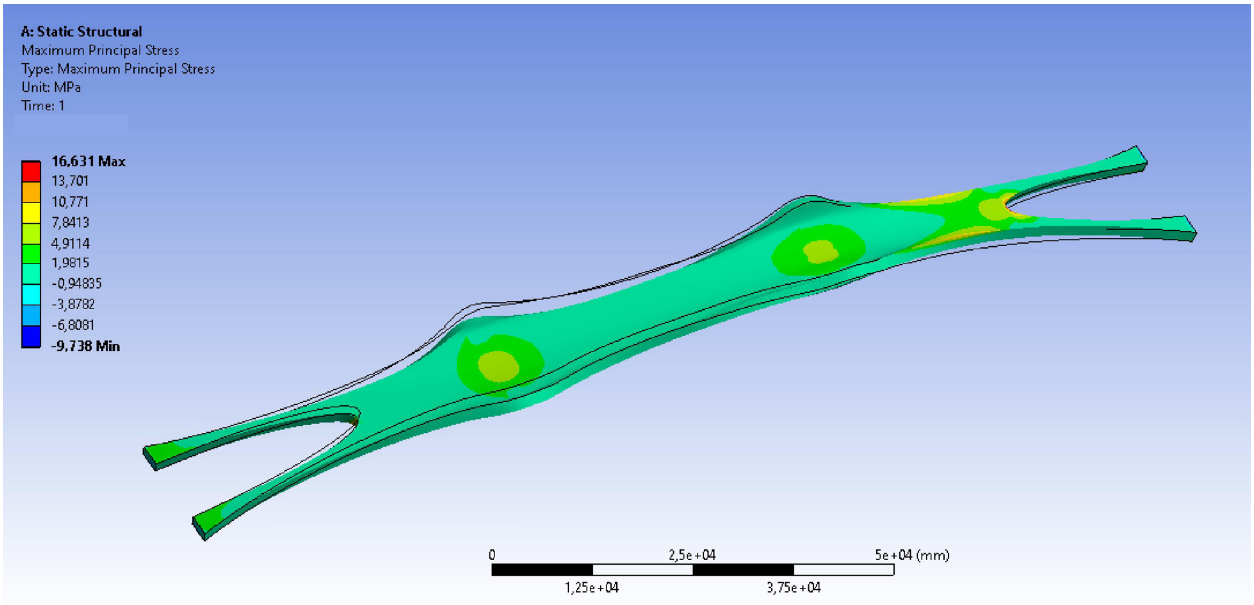
MESH PROPERTIES

ELEMENT SIZE 400 mm
AVAREAGE SURFACE AREA
6,8932e+006 mm²
MINIMUM EDGE LENGTH
98,854 mm

TRANSITION RATIO 0,272
MAXIMUM LAYER 5
GROWTH RATE 1,2
NODES 88140
ELEMENTS 48260

FOURTH CALCULATION RESULTS





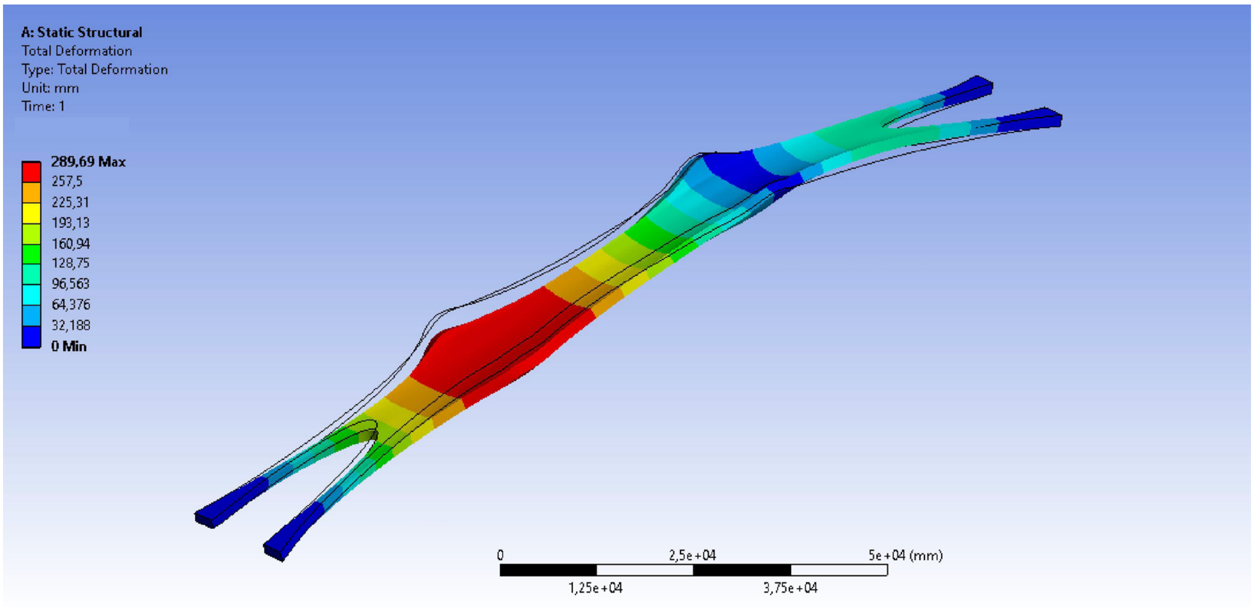
FOURTH STATIC STRUCTURAL ANALYSIS

MAXIMUM PRINCIPAL STRESS
solutions

MINIMUM -9,738 MPa
MAXIMUM 16,631 MPa
AVERAGE 0,87933 MPa

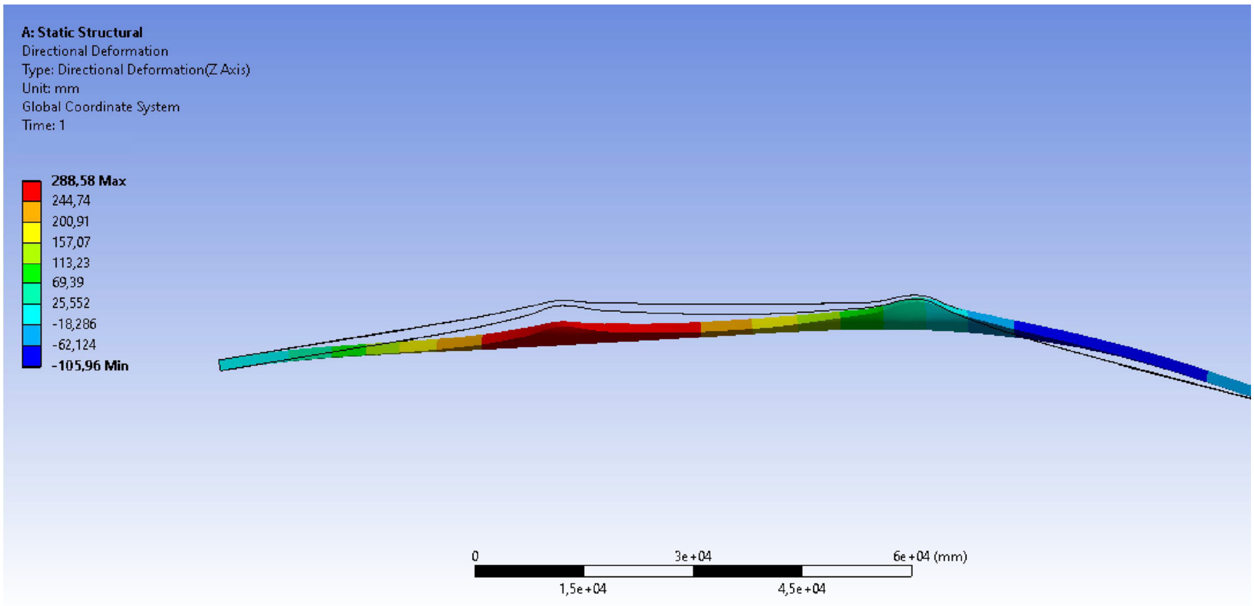
MOST DIFFUSED
0,94835 MPa < x < 10,772 MPa

FOURTH CALCULATION **RESULTS**



TOTAL DEFORMATION
solutions

millimeters		meters	
MINIMUM	no moviment	MINIMUM	no moviment
MAXIMUM	289,69 mm	MAXIMUM	0,28969 m
AVERAGE	145,41 mm	AVERAGE	0,14541 m

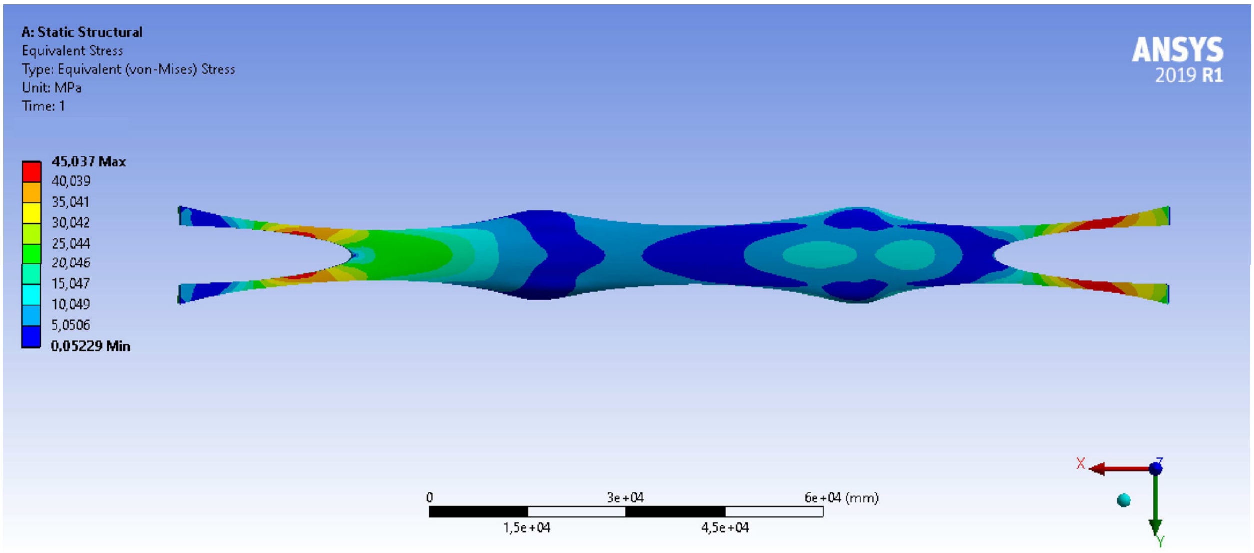


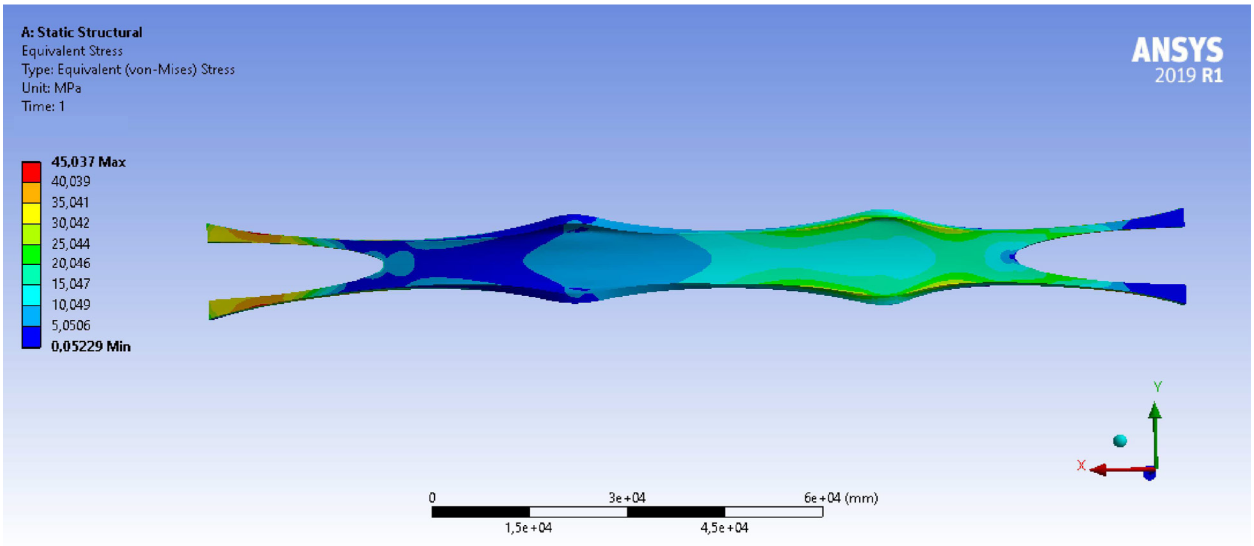
DIRECTIONAL Z DEFORMATION
solutions

millimeters		meters	
MINIMUM	-105,96 mm	MINIMUM	0,10596 m
MAXIMUM	288,58 mm	MAXIMUM	0,28858 m
AVERAGE	103,96 mm	AVERAGE	0,10396 m

FOURTH CALCULATION **RESULTS**

FOURTH VON MISES ANALYSIS





VON MISES ANALYSIS
solutions

megaPascal		Pascal	
MINIMUM	5,229e-002 MPa	MINIMUM	5,229e+004 P
MAXIMUM	45,037 MPa	MAXIMUM	4,5037e+007 P
AVERAGE	11,176 MPa	AVERAGE	1,1176e+007 P

FOURTH CALCULATION **RESULTS**

FOURTH BUCKLING ANALYSIS

BUCKLING ANALYSIS
solutions

load multipiers

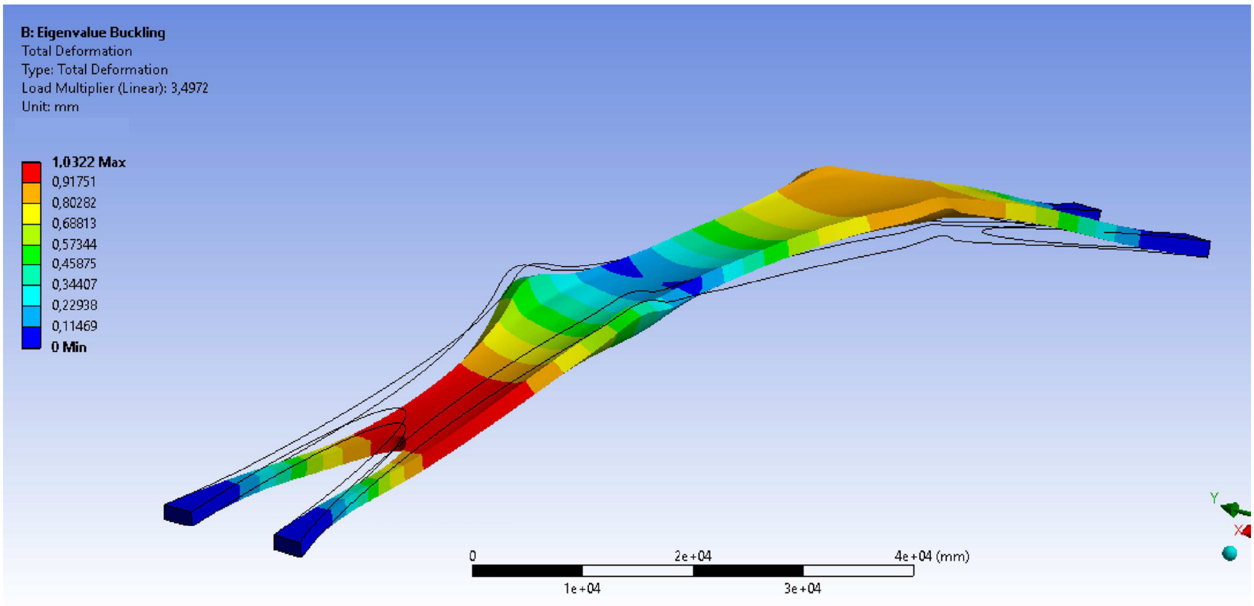
NUMBER 1	3,4972

total deformation NUMBER 1 (mm)

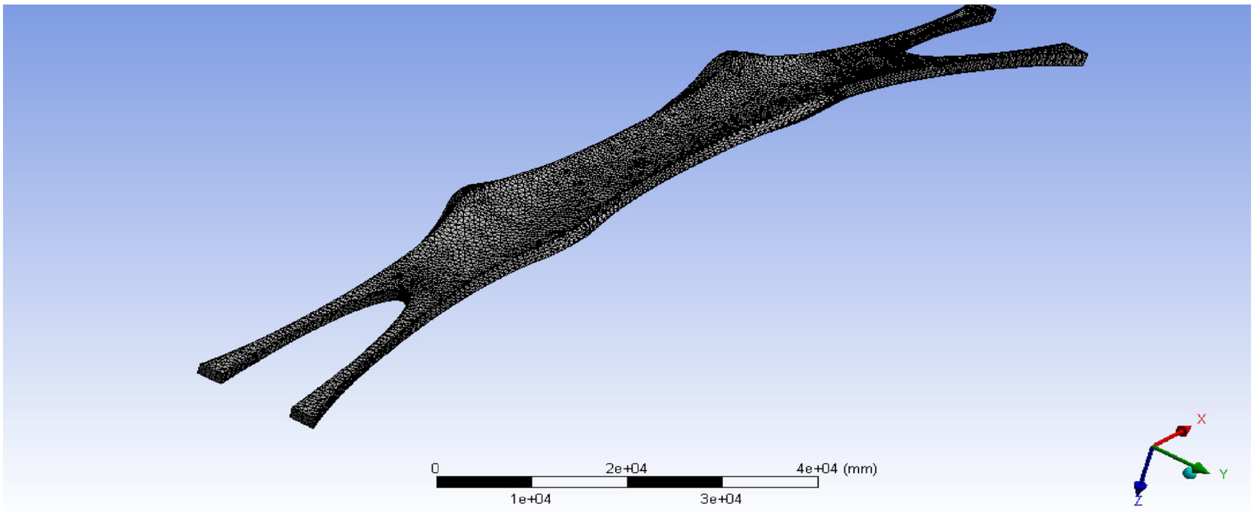
MINIMUM	no moviment
MAXIMUM	1,0322 mm
AVERAGE	0,60699 mm

total deformation NUMBER 1 (m)

MINIMUM	no moviment
MAXIMUM	0,0010322 m
AVERAGE	0,00060699 m



FIFTH CALCULATION STEPS



thickness 1600 mm

Maintaining the membrane setting with a higher moment of inertia and given the static results that from the instability analysis of the membranes at different thicknesses, also maintaining the shape and material properties, but further modifying the thickness with a value of 1500 mm <T <1800 mm given as a domain, according to the 1500 mm instability data, which were evaluated as effective but subject to other analyzes. By bringing the thickness to 1600 mm, we want to understand if the consequent decreases in mass and volume of the material of the structure can lead the project to have greater economic savings and a lower environmental impact. The calculations following this page will keep material settings unchanged to recreate the same conditions and verify how different the resulting range of values is by setting a membrane with a thickness of 1600 mm. In the subsequent calculation, the thickness value will therefore be 1600 mm, therefore a value slightly higher than that set in the previous calculation, given the performance of the 1500 mm membrane, the data can be interpreted as an improvement compared to the previous more unstable 100 mm, thus moving the domain of values between 1500 mm and a maximum of 1800 mm.

GEOMETRY PROPERTIES

VOLUME 1,8983e+012 mm^3
MASS 4366,1 t
NODES 87186
ELEMENTS 47741
CENTROID Y 3996,3 mm
CENTROID Z 153,36 mm

MOMENT OF INERTIA Ip1
8,3146e+010 $t*mm^2$

MOMENT OF INERTIA Ip2
5,5523e+012 $t*mm^2$

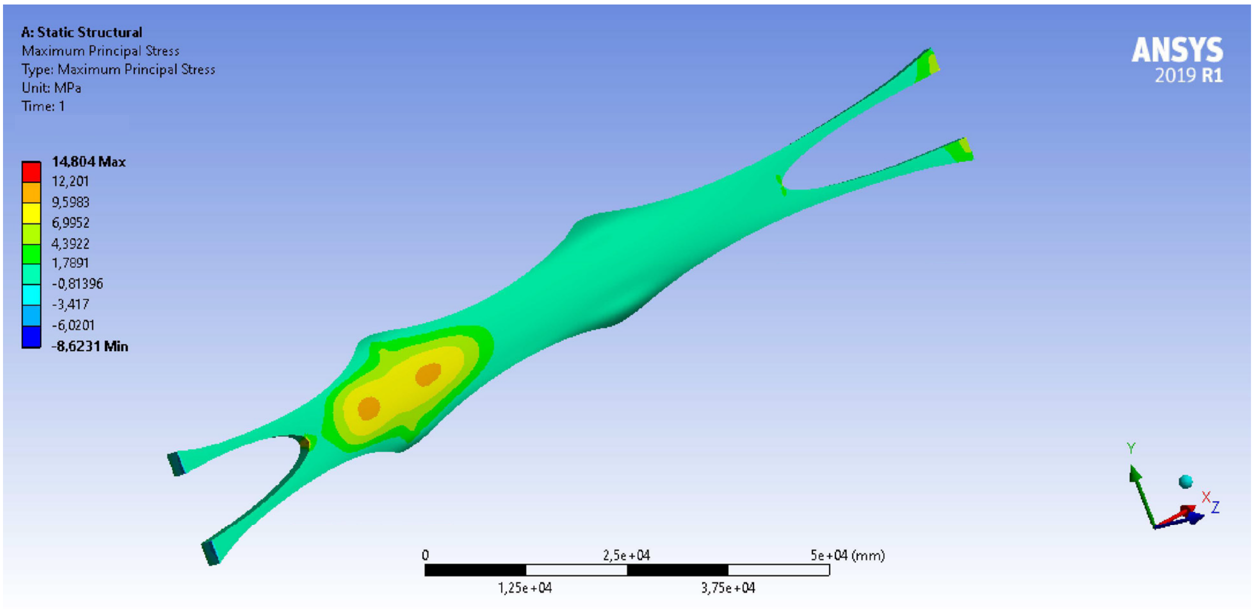
MOMENT OF INERTIA Ip3
5,566e+012 $t*mm^2$

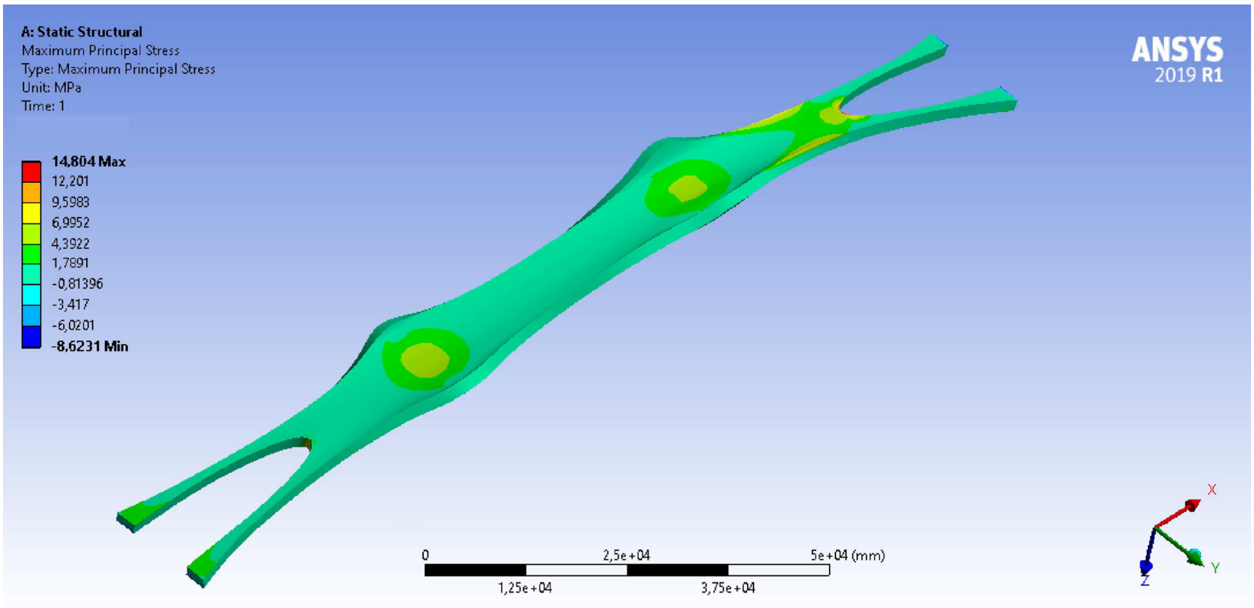
MESH PROPERTIES

ELEMENT SIZE400 mm
AVAREAGE SURFACE AREA
6,9592e+006 mm^2
MINIMUM EDGE LENGTH
97,516 mm

TRANSITION RATIO 0,272
MAXIMUM LAYER 5
GROWTH RATE 1,2
NODES 87186
ELEMENTS 47741

FIFTH CALCULATION RESULTS





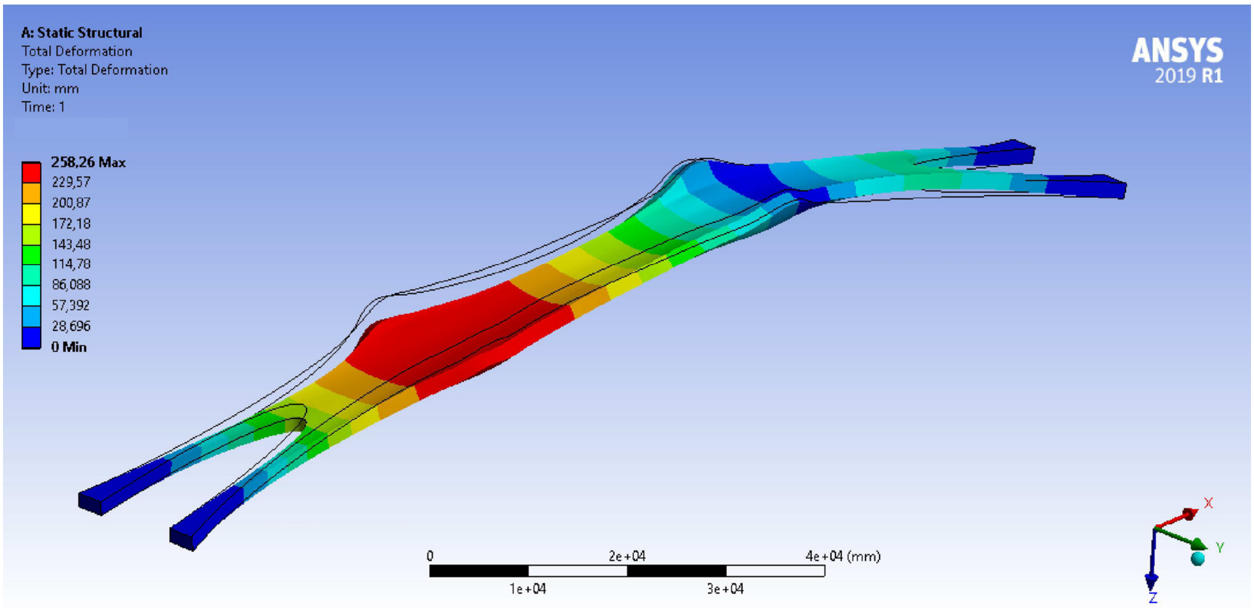
FIFTH STATIC STRUCTURAL ANALYSIS

MAXIMUM PRINCIPAL STRESS
solutions

MINIMUM -8,6231 MPa
MAXIMUM 14,804 MPa
AVERAGE 0,79838 MPa

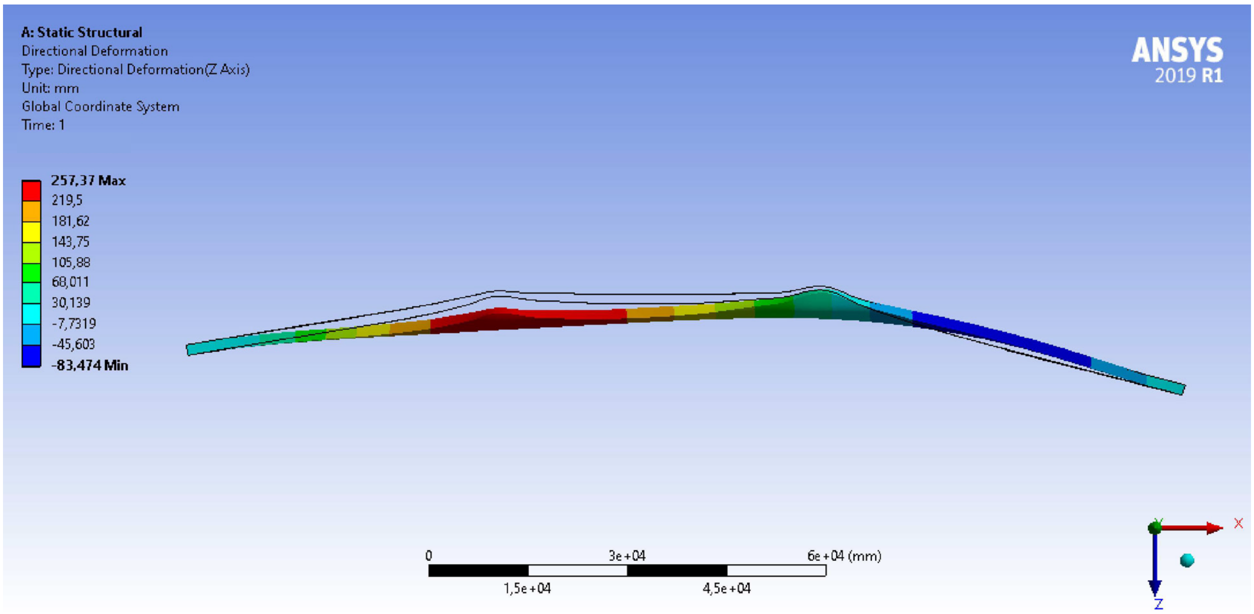
MOST DIFFUSED
0,81396 MPa < x < 9,5983 MPa

FIFTH CALCULATION RESULTS



TOTAL DEFORMATION
solutions

millimeters		meters	
MINIMUM	no moviment	MINIMUM	no moviment
MAXIMUM	258,26 mm	MAXIMUM	0,25826 m
AVERAGE	127,82 mm	AVERAGE	0,12782 m

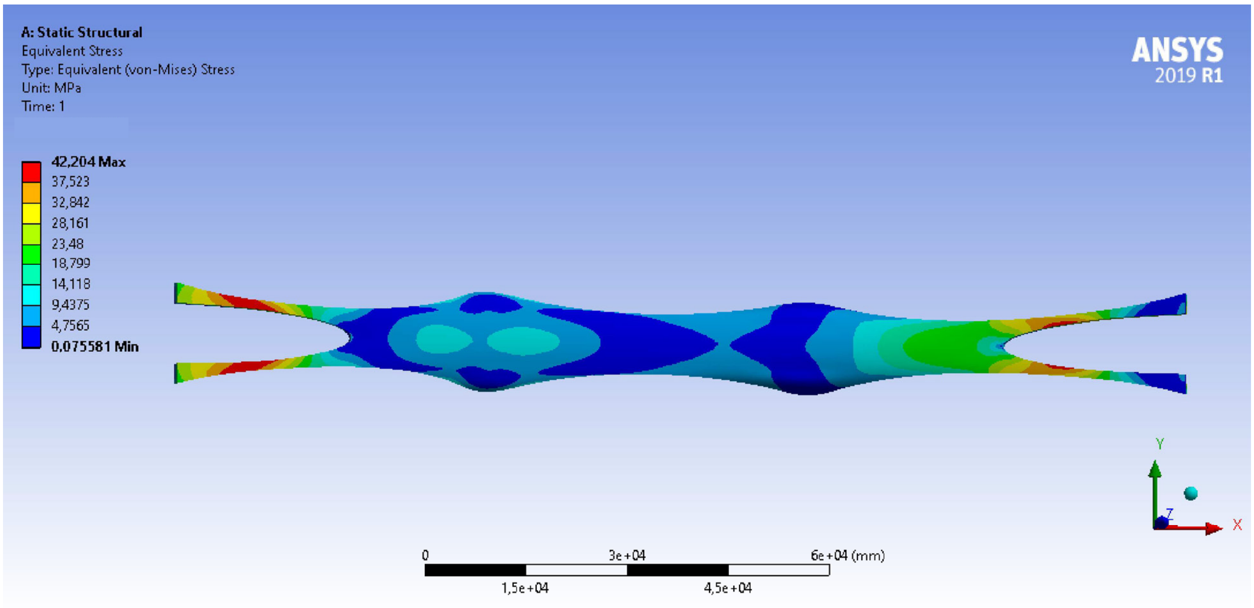


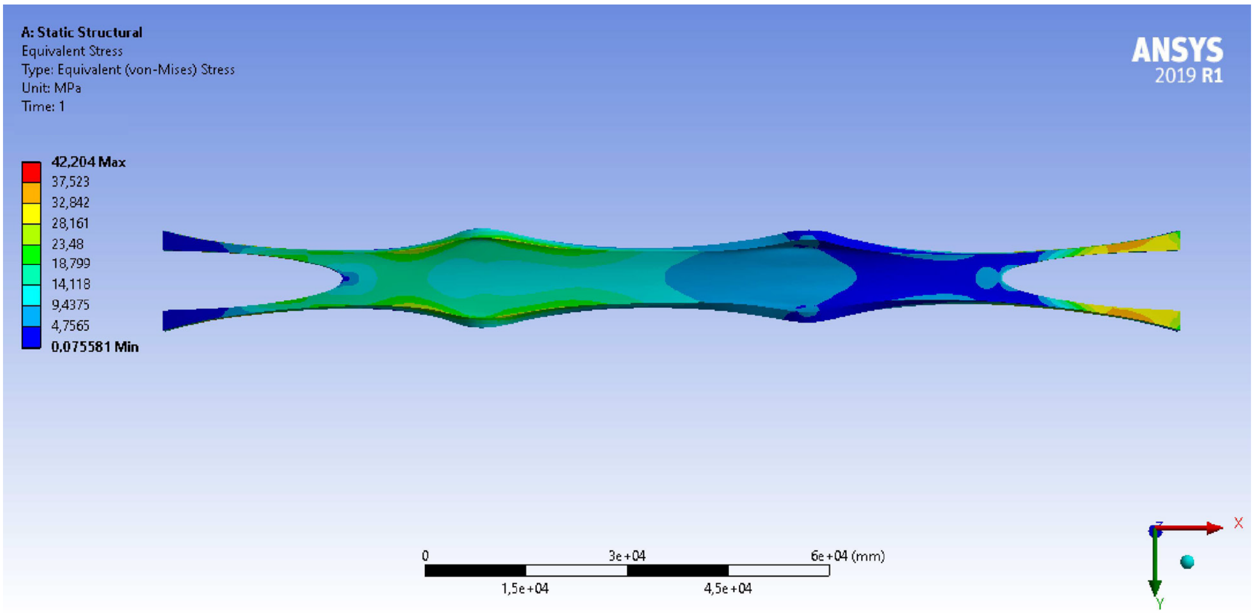
DIRECTIONAL Z DEFORMATION
solutions

millimeters		meters	
MINIMUM	-83,474 mm	MINIMUM	-0,083474 m
MAXIMUM	257,37 mm	MAXIMUM	0,25737 m
AVERAGE	95,833 mm	AVERAGE	0,095833 m

FIFTH CALCULATION RESULTS

FIFTH VON MISES ANALYSIS





VON MISES ANALYSIS
solutions

megaPascal		Pascal	
MINIMUM	7,5581e-002 MPa	MINIMUM	7,5581e+004 P
MAXIMUM	42,204 MPa	MAXIMUM	2,2204e+007 P
AVERAGE	10,363 MPa	AVERAGE	1,0363e+007 P

FIFTH CALCULATION RESULTS

FIFTH BUCKLING ANALYSIS

BUCKLING ANALYSIS
solutions

load multipiers

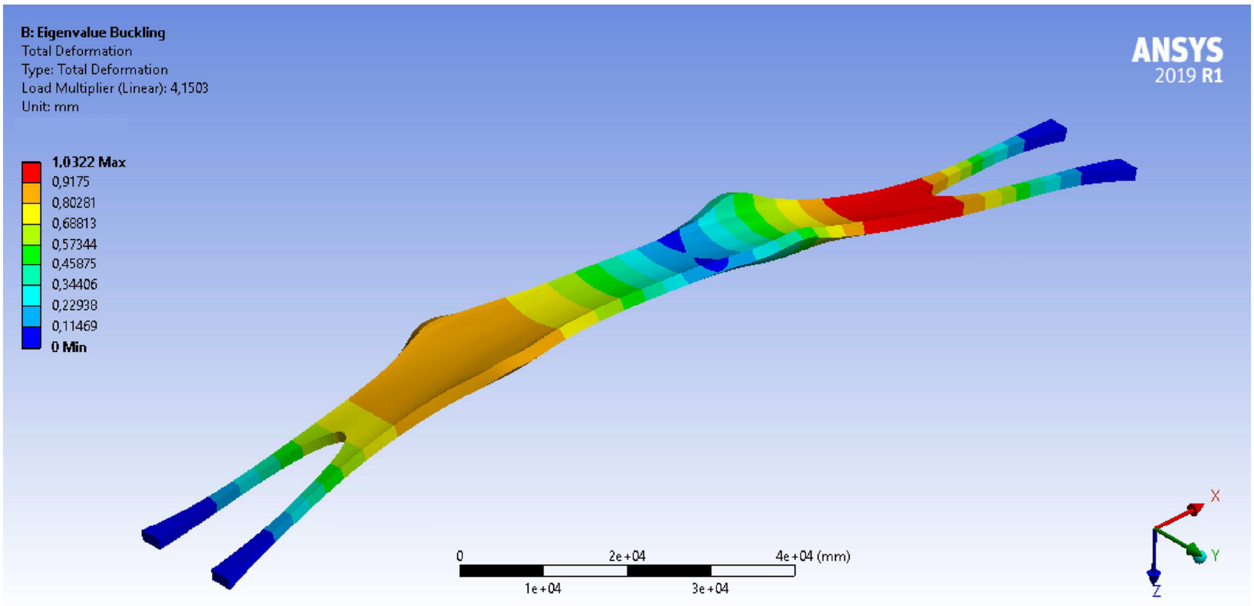
NUMBER 1	4,1503

total deformation NUMBER 1 (mm)

MINIMUM	no moviment
MAXIMUM	1,0322 mm
AVERAGE	0,61385 mm

total deformation NUMBER 1 (m)

MINIMUM	no moviment
MAXIMUM	0,0010322 m
AVERAGE	0,00061385 m



AFTER CALCULATION CONSIDERATIONS

Decreasing of the thickness of the concrete membrane maintaning the same performing mesh shape, the FEM program process produces different result using the same material (set concrete C40/50).

VOLUME (mm^3)

$T_{1800} = 2,10e+012$
$T_{1600} = 1,89e+012$
$T_{1500} = 1,79e+012$
$T_{1000} = 1,23e+012$

$$R(\%)_{1800} = 100\%$$
$$R(\%)_{1600} = -9,45\%$$
$$R(\%)_{1500} = -14,58\%$$
$$R(\%)_{1000} = -41,53\%$$

MASS (t)

$T_{1800} = 4821,90$
$T_{1600} = 4366,10$
$T_{1500} = 4118,60$
$T_{1000} = 2819,00$

$$R(\%)_{1800} = 100\%$$
$$R(\%)_{1600} = -9,45\%$$
$$R(\%)_{1500} = -14,58\%$$
$$R(\%)_{1000} = -41,53\%$$

MAXIMUM PRINCIPAL STRESS (MPa)

$T_{1800} = 12,790$
$T_{1600} = 14,804$
$T_{1500} = 16,631$
$T_{1000} = 38,845$

$$R(\%)_{1800} = 100\%$$
$$R(\%)_{1600} = +15,74\%$$
$$R(\%)_{1500} = +30,03\%$$
$$R(\%)_{1000} = +203,71\%$$

The reduction of the thickness with the same maximum surface has as consequences the decrease of volume and mass but the internal stress of the structure increases exponentially.

TOTAL DEFORMATION (mm)

$T_{1800} = 206,72$
$T_{1600} = 258,26$
$T_{1500} = 289,69$
$T_{1000} = 623,58$

$$R(\%)_{1800} = 100\%$$
$$R(\%)_{1600} = +24,93\%$$
$$R(\%)_{1500} = +40,13\%$$
$$R(\%)_{1000} = +201,65\%$$

DIRECTIONAL Z DEFORMATION (mm)

$T_{1800} = 206,15$
$T_{1600} = 257,37$
$T_{1500} = 288,58$
$T_{1000} = 619,85$

$$R(\%)_{1800} = 100\%$$
$$R(\%)_{1600} = +24,84\%$$
$$R(\%)_{1500} = +38,98\%$$
$$R(\%)_{1000} = +200,67\%$$

Considering that the concrete membrane has a predominant length of 150 meters, and the maximum total drops are, in meters, equal to 0,206 (in turn equal to 0,13% of the total length), to 0,257 (in turn equal to 0,17% of the total length), to 0,288 (in turn equal to 0,19% of the total length), to 0,619 (in turn equal to 0,41% of the total length). All values are less than 2% of the total length. Schematizing:

DIRECTIONAL Z DEFORMATION (m)

$T_{1800} = 0,20615$
$T_{1600} = 0,25737$
$T_{1500} = 0,28858$
$T_{1000} = 0,61985$
$L_{tot} = 150,00$

$$R[L/T](\%)_{1800} = 0,13\%$$
$$R[L/T](\%)_{1600} = 0,17\%$$

AFTER CALCULATION CONSIDERATIONS

$R[L/T](\%)_{1500} = 0{,}19\%$
$R[L/T](\%)_{1000} = 0{,}41\%$

all data is less than 2%

BUCKLING MULTIPIERS

$T_{1800} = 5{,}6192$
$T_{1600} = 4{,}1503$
$T_{1500} = 3{,}4972$
$T_{1000} = 1{,}1878$

$R(\%)_{1800} = 100\%$
$R(\%)_{1600} = +24{,}14\%$
$R(\%)_{1500} = +37{,}76\%$
$R(\%)_{1000} = +78{,}86\%$

and related deformations (mm)

$T_{1800} = 1{,}0321$
$T_{1600} = 1{,}0322$
$T_{1500} = 1{,}0322$
$T_{1000} = 1{,}0323$

$R(\%)_{1800} = 100\%$
$R(\%)_{1600} = +0{,}009\%$
$R(\%)_{1500} = +0{,}009\%$
$R(\%)_{1000} = +0{,}019\%$

The values shown are the limit multipliers and the decreases in their relation are of the order of one millimeter out of 1,5e+05 mm. So, considering the maximum deformation related to the most burdensome Buckling multiper and the predominant length of the membrane, equal to 150 meters, the perentages results of the relation between the predominant length a the deformations are, considering all the thickness imposed, neatly 0,000688067%, 0,000688133% 0,000688133%, 0,0006882%.

BUCKLING DEFORMATION (m)

$T_{1800} = 0{,}0010321$
$T_{1600} = 0{,}0010322$
$T_{1500} = 0{,}0010322$
$T_{1000} = 0{,}0010323$

$L_{tot} = 150{,}00$

$R[L/T](\%)_{1800} = 0{,}000688067\%$
$R[L/T](\%)_{1600} = 0{,}000688133\%$
$R[L/T](\%)_{1500} = 0{,}000688133\%$
$R[L/T](\%)_{1000} = 0{,}0006882\%$

all data is less than 2%

Another way to ensure that the interpretation of the data is correct is to consider the NTC 2018 limits, as far as bridges and large span structures are concerned, there are no relationship parameters between light and deformation to be respected, everything concerning these data is at the discretion of the designer. But there are some relative to the floors in public and private buildings: the axial deformation must have a maximum value of 1 in 250th of the span of the ceiling. Although the core object of the thesis is well within these limits, the data are absolutely safe as any designer has a greater deformation prediction as the light increases and the spans of the ceilings are less than those of bridge structures. Schematizing:

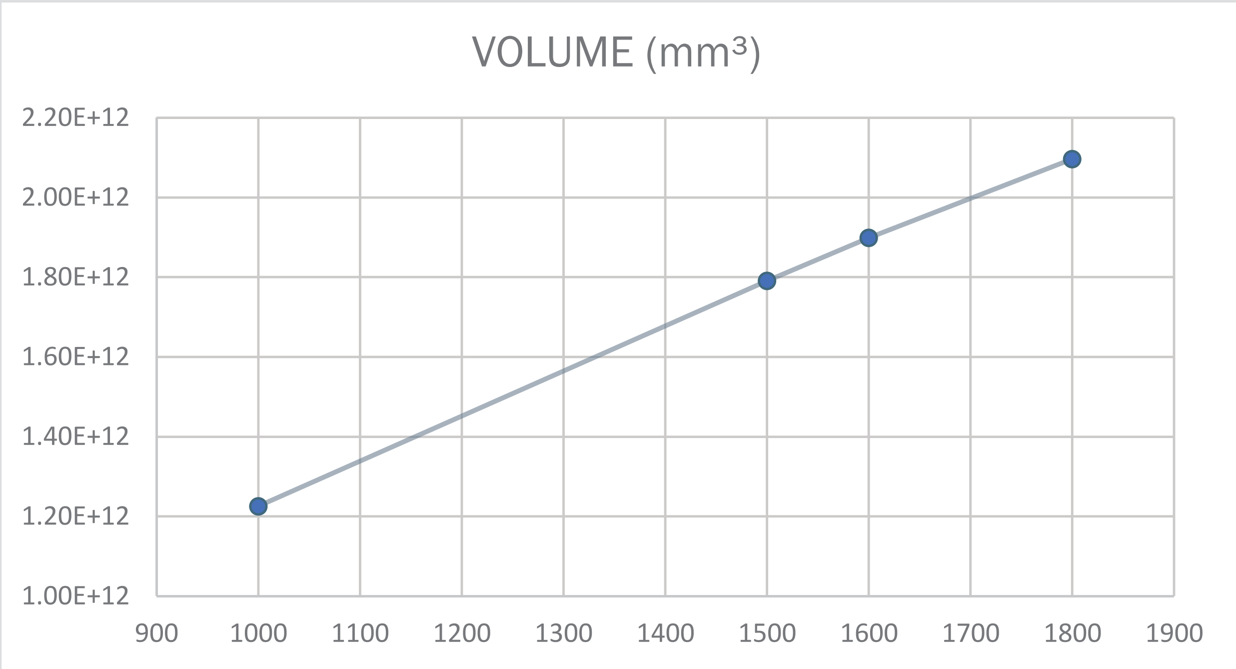
DIRECTIONAL Z DEFORMATION (m)

$T_{1800} = 0{,}20615$
$T_{1600} = 0{,}25737$
$T_{1500} = 0{,}28858$
$T_{1000} = 0{,}61985$
$L_{tot}/250 = 150{,}00/250 = 0{,}60$

three out of four data
are less than 0,60 meters

The thickness of 1000 mm does not respect the data relating to the NTC 2018 limit binding for the ceilings of buildings with accessibility. Even if the difference is less than 2 centimeters, precisely 0,01985 meters.

AFTER CALCULATION TRENDS



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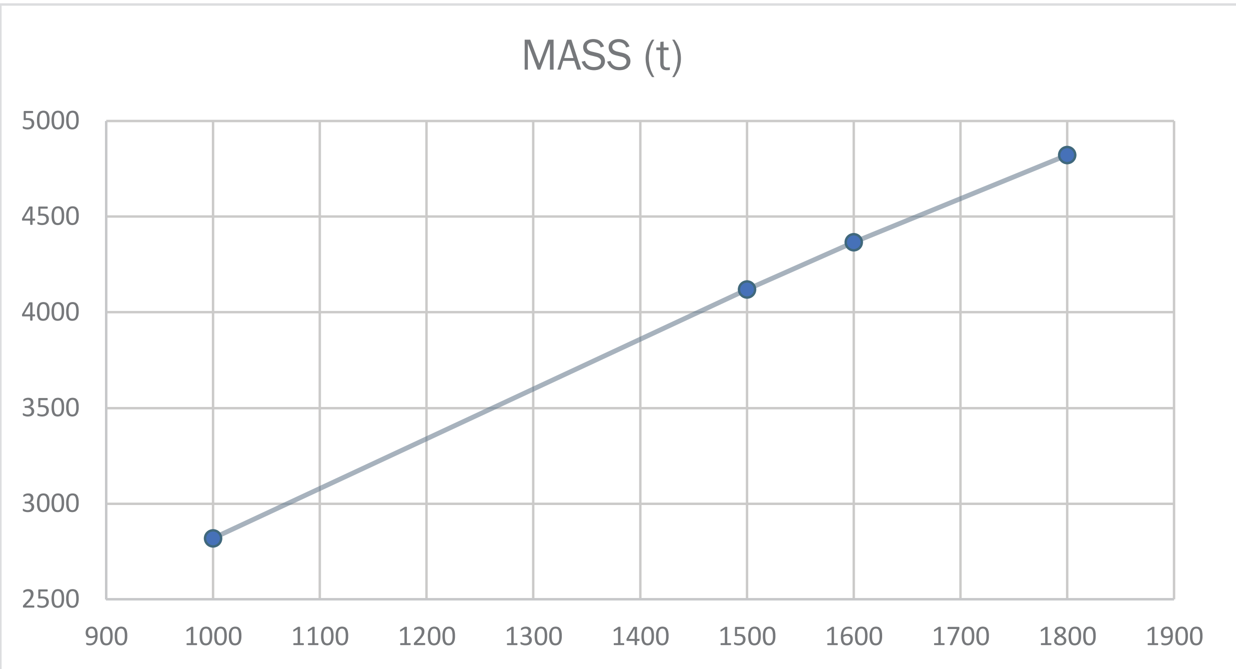
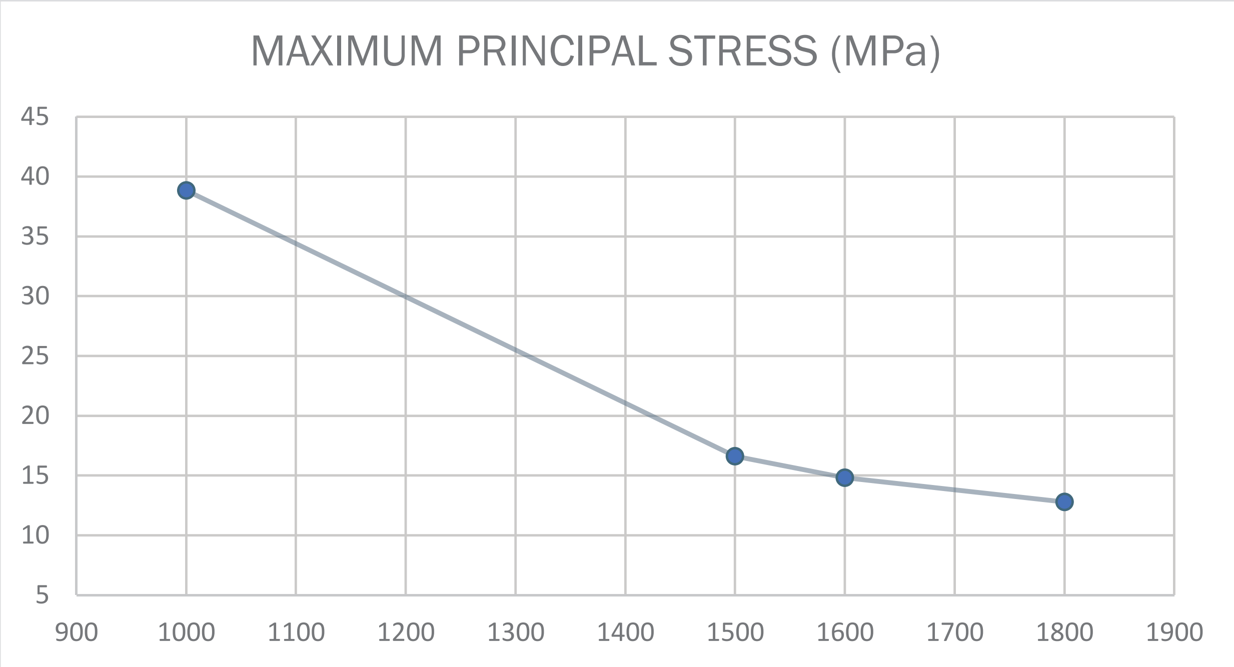


AFTER CALCULATION **TRENDS**



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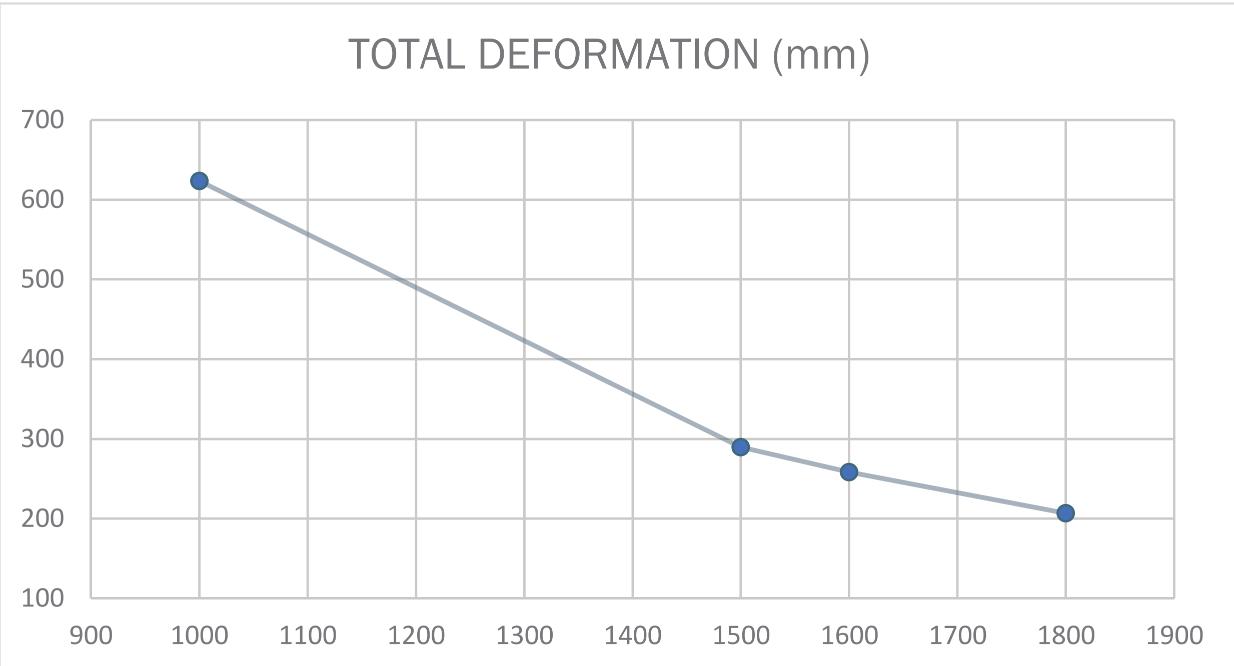
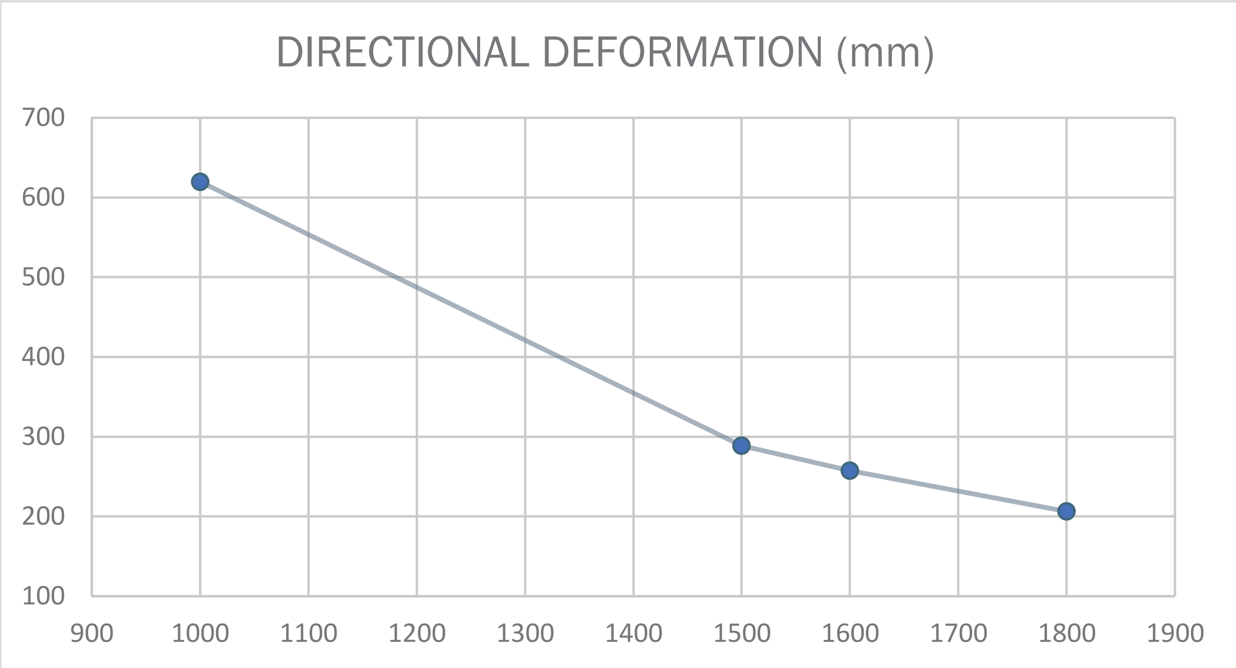


AFTER CALCULATION TRENDS



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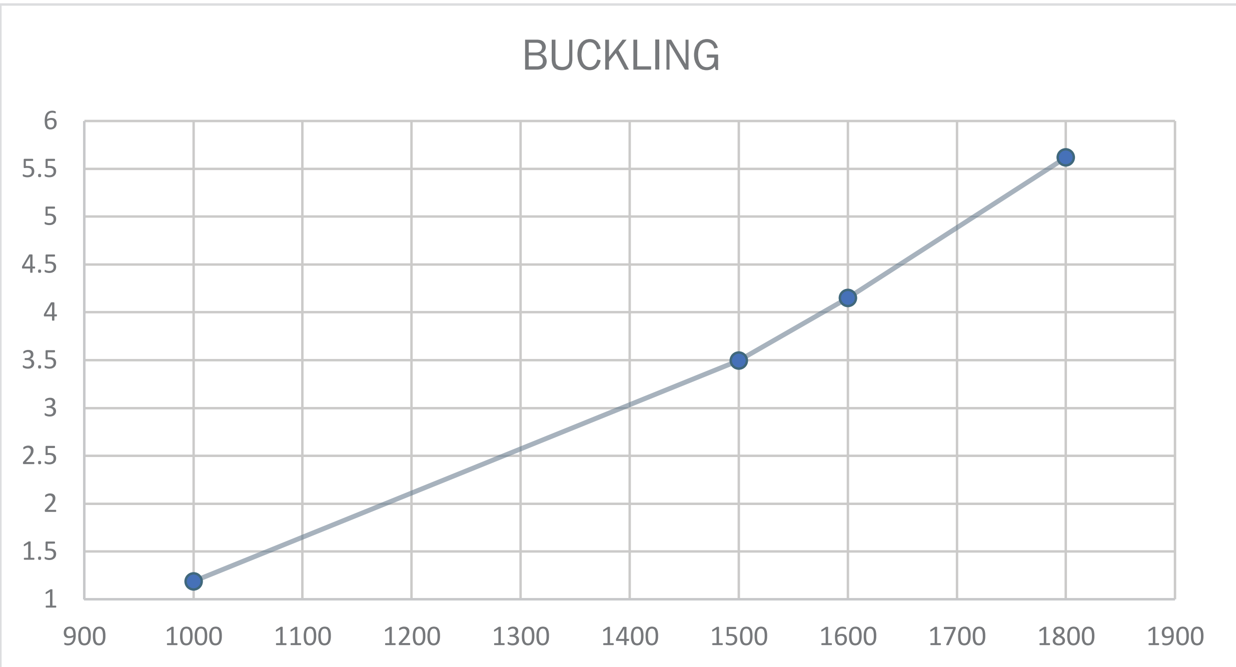
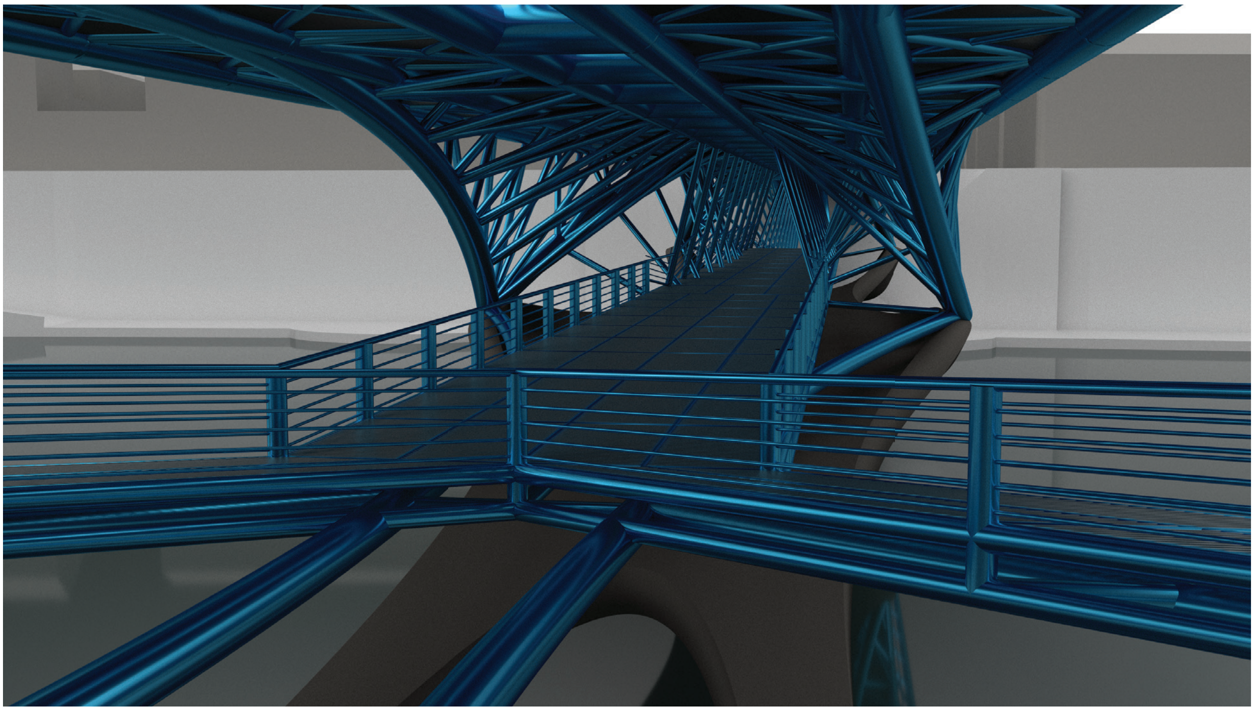




THE NEW BRIDGE

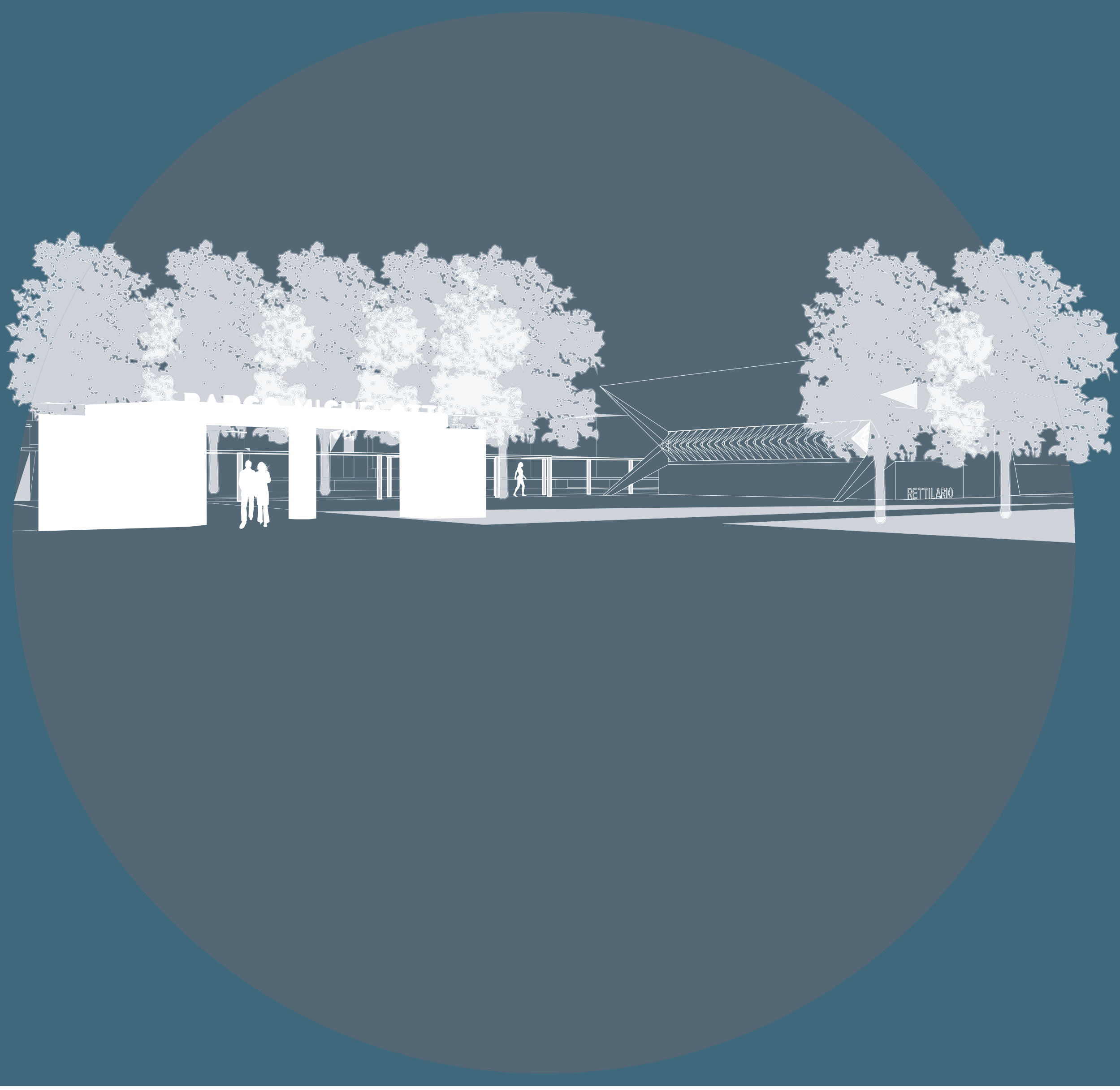
CHAPTER TEN

THE PROJECTS

Verrà la morte e avrà i tuoi occhi.
Sarà come smettere un vizio.

Cesare Pavese *(Poesie, 1951)*

Death will come and it has your eyes.
It will be like removing a vice.



Death will come and it has your eyes. It will be like removing a vice. It is my persoal translation of a poem, written by Cesare Pavese. “Verrà la morte e avrà i tuoi occhi” is, at the same time, the title of the poem and the most meaningful sentence. I am personally attached to this poem and I think it is suitable for the introduction to the last chapter of my thesis. At the end of a journey, the results are collected, the experiences are reported and we think about ourselves. So this chapter lives in the results of a long design that started from the bridge and influenced the project area to redefine a new structure of the city of Turin. At the beginning of the thesis it was explained how the project lot is an unsolved area of the city, its being such is, however, also part of the magic that this part of the city emanates.

Returning to the part of poetry reported in the city, death is the subject: it in its deepest meanings is a symbol of the end, when an existence comes to an end there is liberation from that same life that has brought with it different aspects. The bridge, the subject of the thesis, is one of the possibilities that the city can adopt to resolve that part of itself, especially the Michelotti Park, is living a life that is not adequate to its potential, death would be a change. Then, the verbs “verrà”, “avrà” and “sarà+” are all future. It represents the hope linked to change and at the same time does not define limits or conditions of time: this is my idea, as a designer, for the very future of the area. There must not be a major redevelopment that closes the park for years and imposes new functions and spaces, but the change must be gradual: starting from the bridge, people must return to experience the park and over time, guided by its use, the park will shape itself. Turin has always demonstrated in its history that it is never the same, that it does not have a definition but that it can prove that it is always in the making. The conclusion of the sentence is surprising: death with the eyes of the beloved is full of further meanings, the hope that the conclusion of a cycle, which has now lasted since the zoological park was closed, can bring all that a positive change. Another significant element is represented by “tuoi”, when you say “your eyes” you refer to something known, something that is known to the mind, and immediately, the thought goes to the inhabitants of the city and their life connected to the parks.

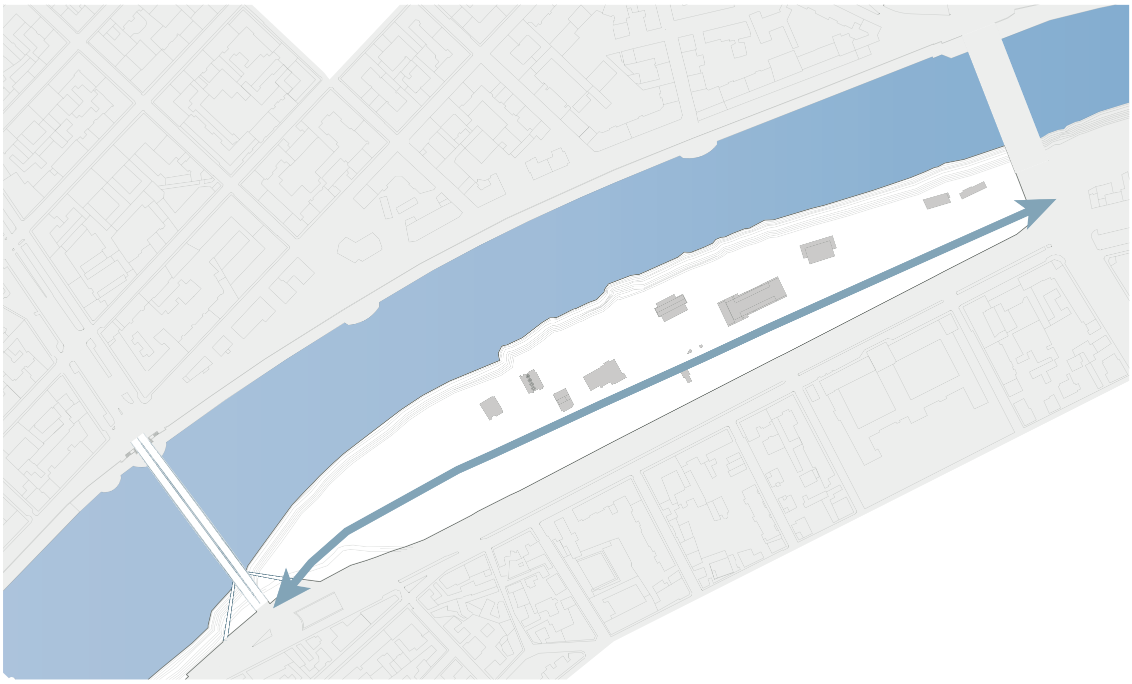
The second sentence has a strong connection with the words “your eyes”: a vice is something negative and rooted in the mind of the owner, by virtue of the possession of the same its removal is difficult and includes the loss of something that does not you want to lose. The stubborn abandonment of the project area, and the competitions that have followed one another over the years with related inapplications, is the demonstration that it is difficult to go beyond what the park has represented, it is difficult to invest resources because they cannot be few and, then, there is the fear.

The fear of change and, at the same time, of a new failure leads to political immobility. My idea of being a designer lies in the pages of this chapter: recognizing the strengths of the city and adapting to them to create something new, but always “son of Turin” which must not be the ultimate solver or even definitive but point starting point for future interventions which, in turn, will be a reason to go further.

Death will come and it has your eyes.
It will be like removing a vice.

SERIES OF PROJECTS THE PARK
concept

A
TOTAL REMOVAL OF PERIMETER RESTRICTIONS AND PRESERVATION ONLY OF THE INFRASTRUCTURE OF THE EX-ZOO



B
MAINTENANCE OF THE EXISTING EXTERNAL PATH IN THE PART OF THE PARK NOWADAYS OPEN TO THE PUBLIC

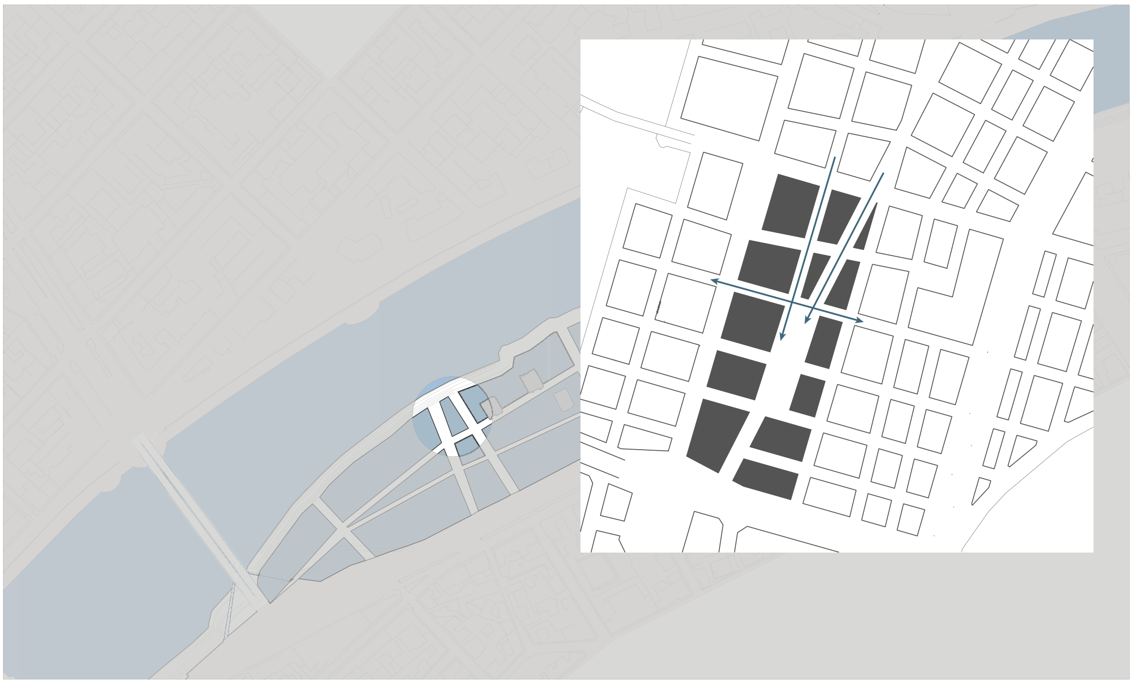
SERIES OF PROJECTS THE PARK
concept

C
REINTRODUCTION OF THE ROUTE THAT CUT THE EX-ZOO LONG, THE NEW PEDESTRIAN WALKWAY IS THE BEGINNING OF THE PATHS

D
CONSTITUTION OF THE CUTTING ROUTES USING THE ROAD AXES OF THE CITY PATTERN UNTIL MEETING THE INVALICABLE LIMIT OF THE RIVER

SERIES OF PROJECTS THE PARK
result

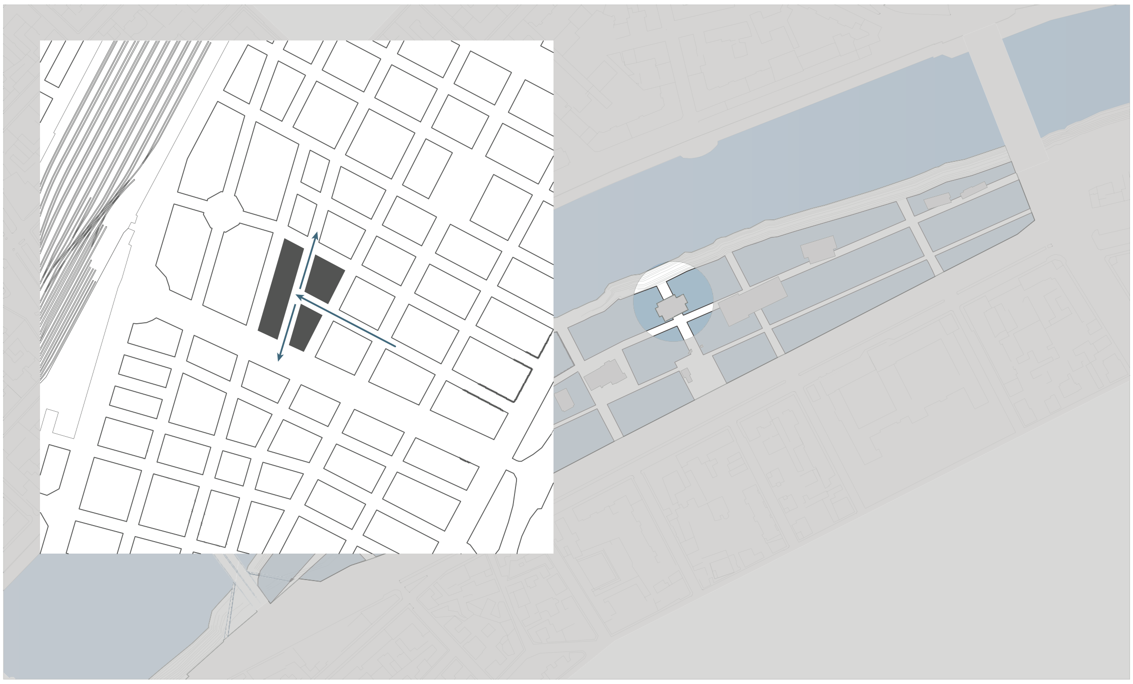
1
THE RESULTING PATH SYSTEM SIMULATES THE MACRO WORLD OF THE CITY OF TURIN IN THE MICROWORLD OF THE PARK



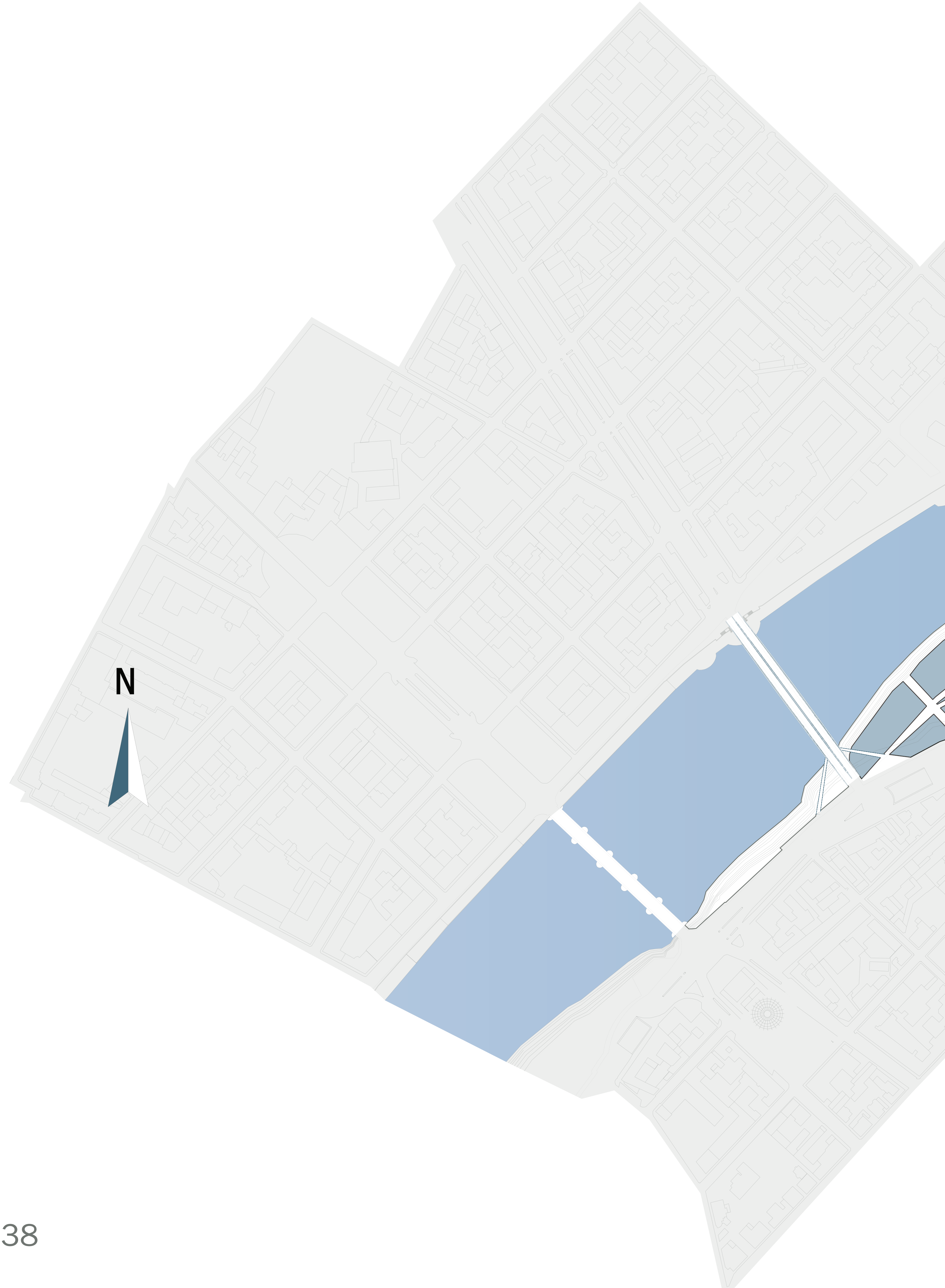
2
THE AXES OF VIA SALUZZO AND VIA MADAMA CRISTINA CONTRASTING ON PIAZZA ARTURO GRAF SHAPE THE BLOCKS

SERIES OF PROJECTS THE PARK
result

3
PIAZZA MADAMA CRISTINA IS THE RESULTING SPACE BETWEEN A SMALLER BLOCK THAN THE OTHERS



4
VIA CESARE LOMBROSO IS INTERRUPTED BY A FACADE OF A BUILDING, THE FACADE IS MONUMENTALIZED BY THE PATH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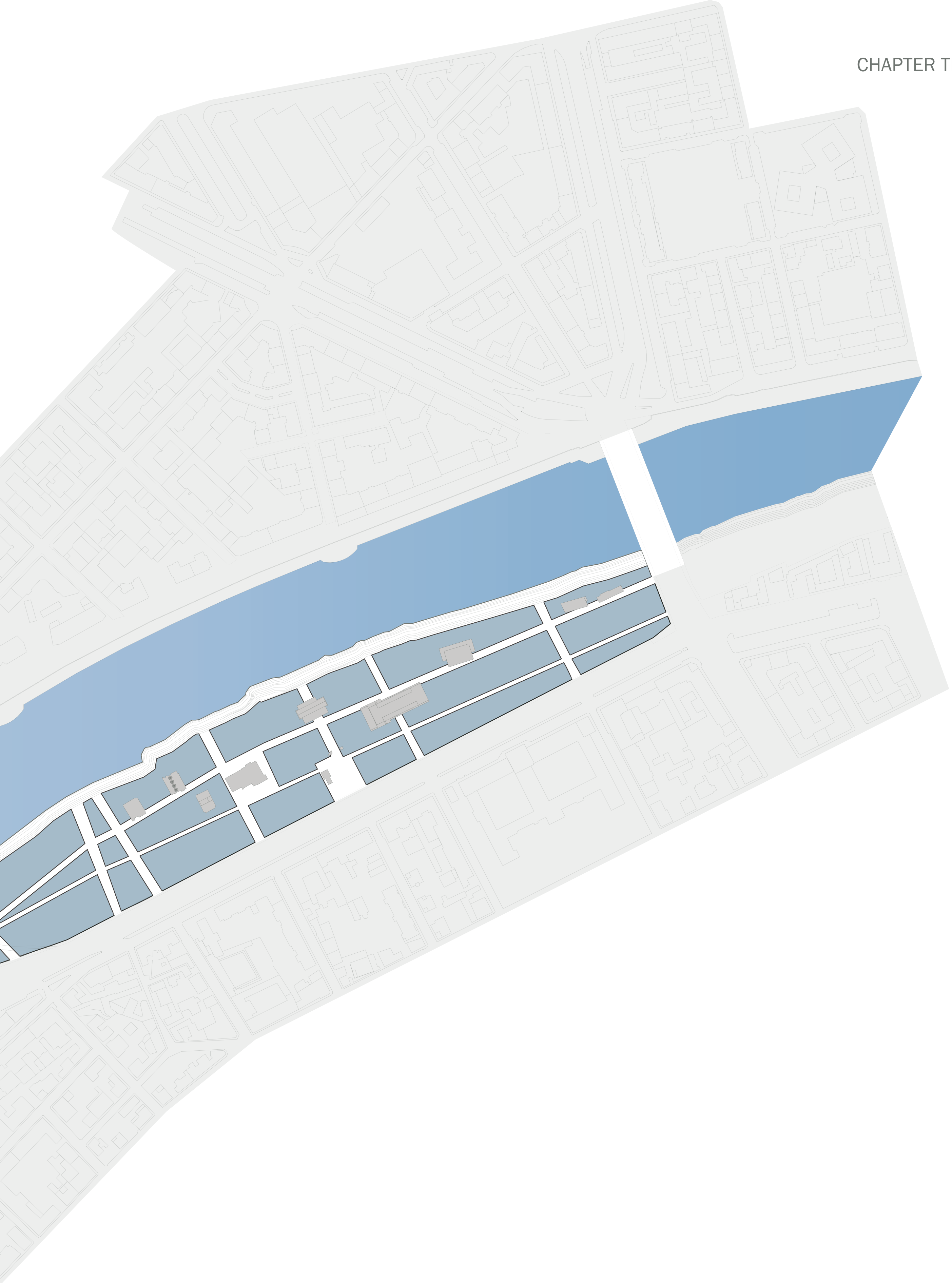
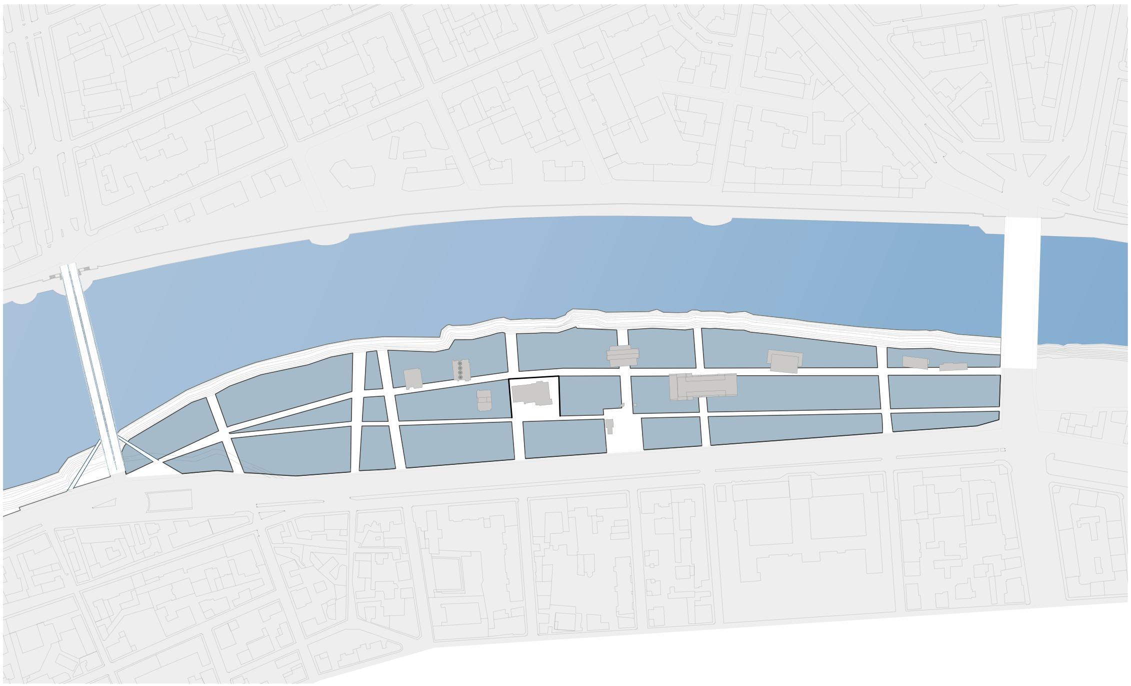


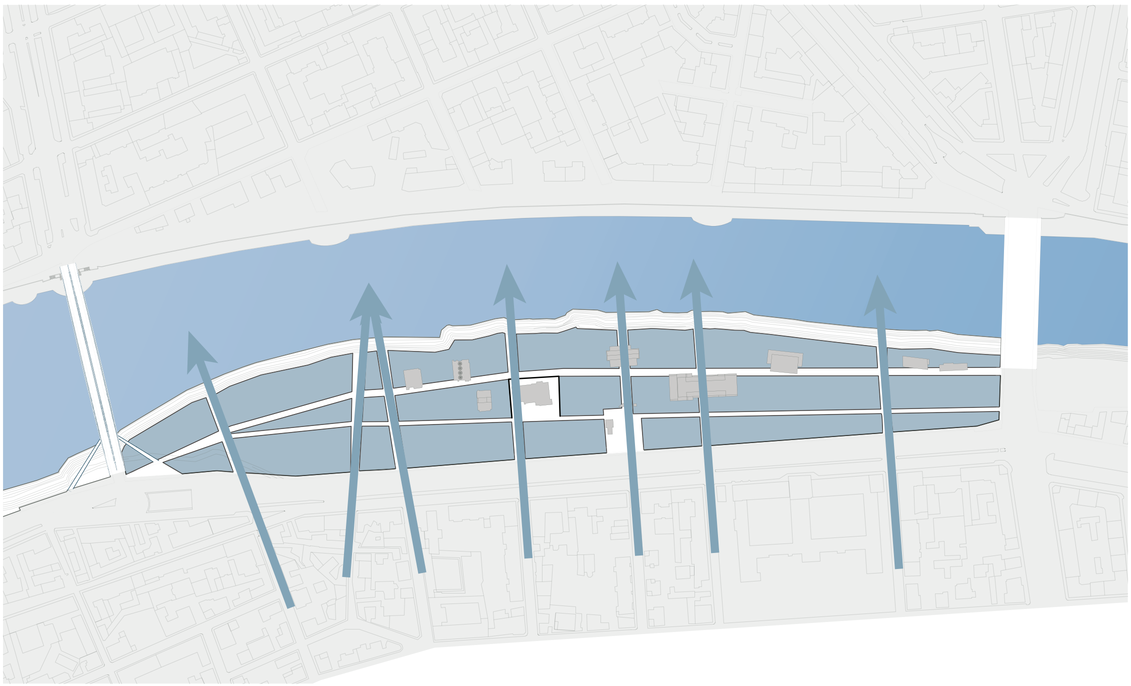
general plan

SERIES OF PROJECTS THE OVERLOOKING TO RIVER
concept



A

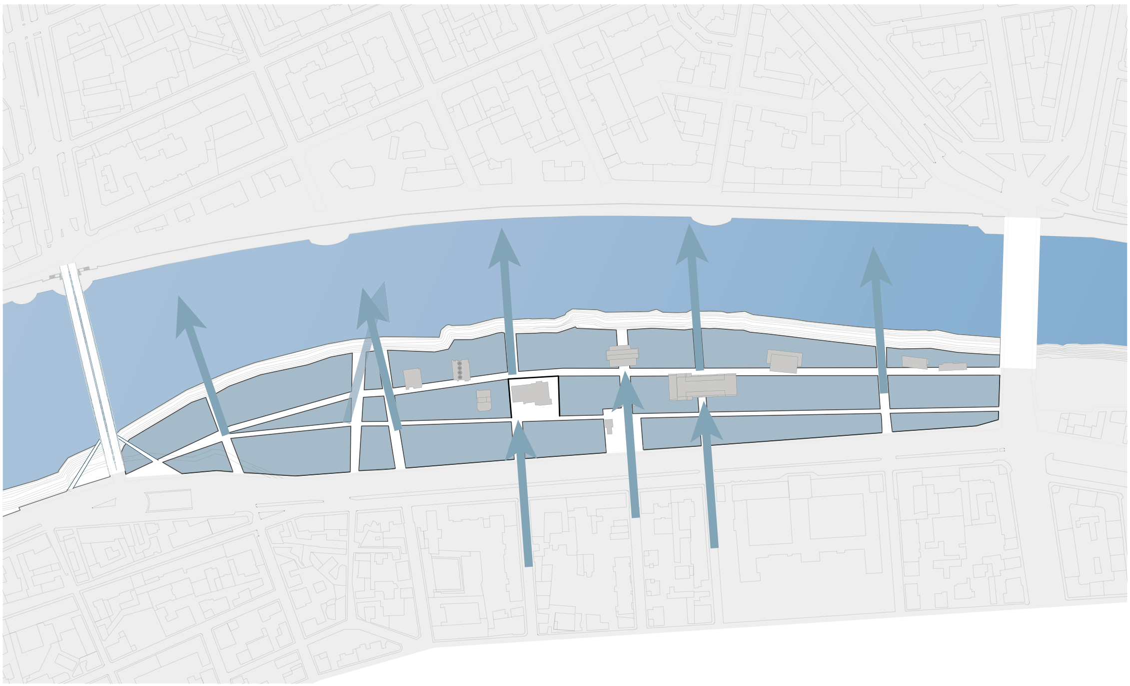
THE GRID, NEW LAYOUT OF THE PARK, INCLUDES OVERLOOKINGS TO THE RIVER, THESE MUST BE DESIGNED CONSIDERING EVERY CASE



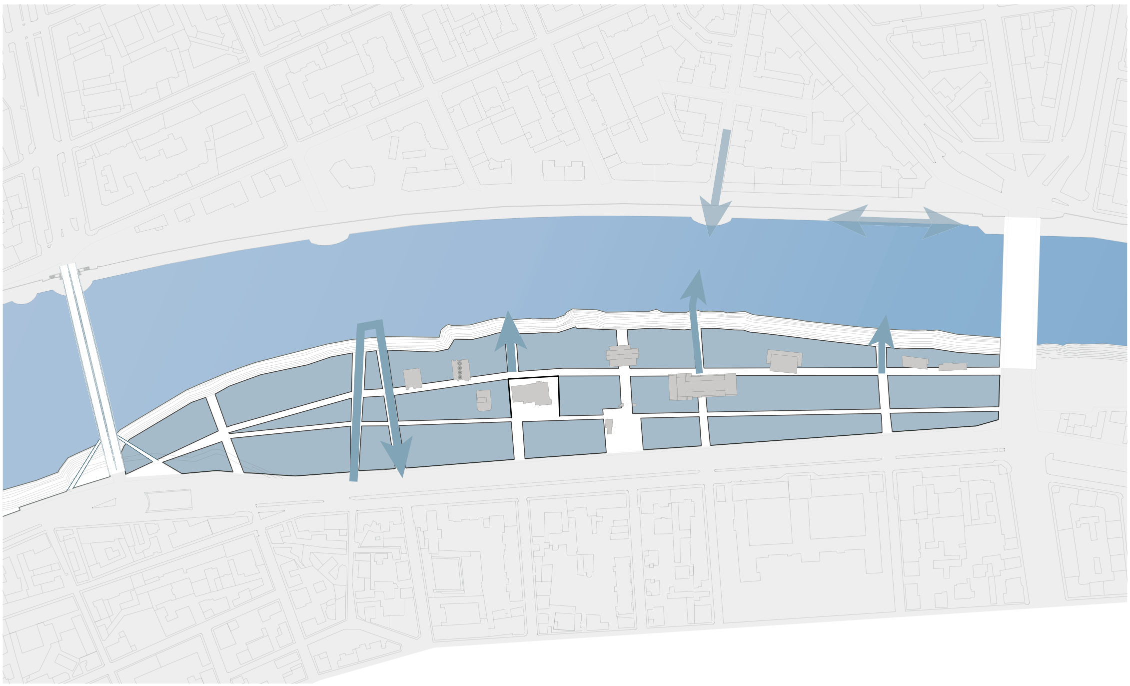
B

THE FIRST AND SEVENTH AXIS HAS NO OBSTACLES, THE SECOND AND THIRD ARE CROSSED, THE REMAINING ARE INTERRUPTED BY BUILDINGS

SERIES OF PROJECTS THE OVERLOOKING TO RIVER
concept

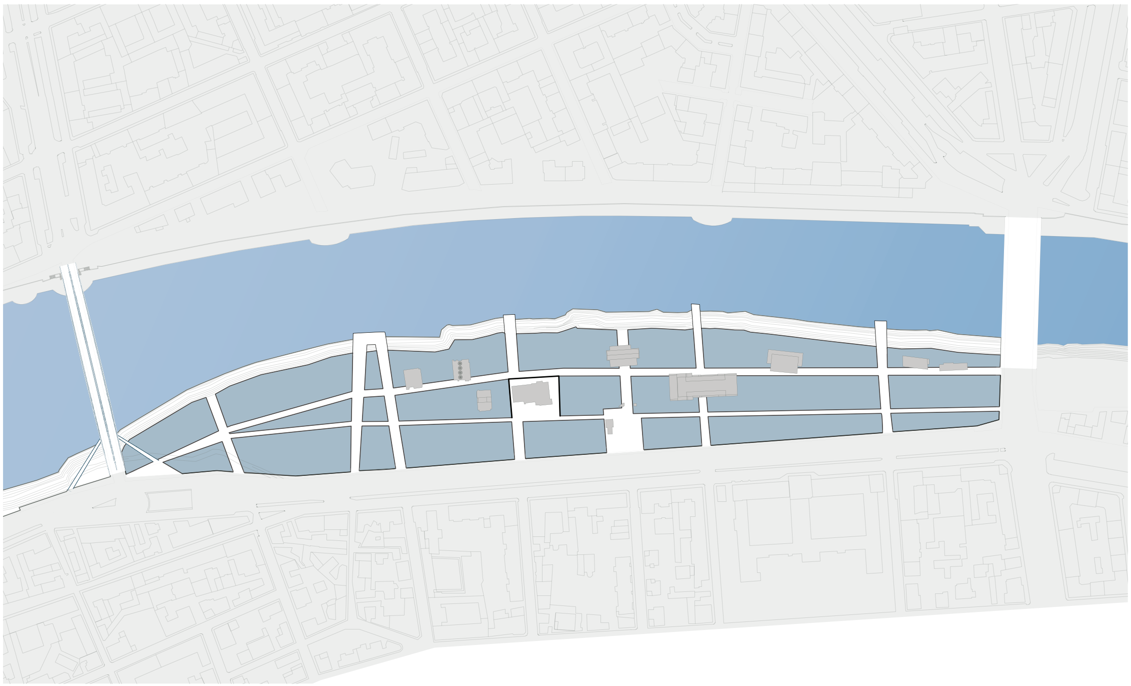


C
THE SECOND AND THIRD COMBINE IN ONE, THE FOURTH AND SIXTH ALLOW A VIEW, CONNECTED WITH PUBLIC AXES, THE FIFTH IS INTERRUPTED

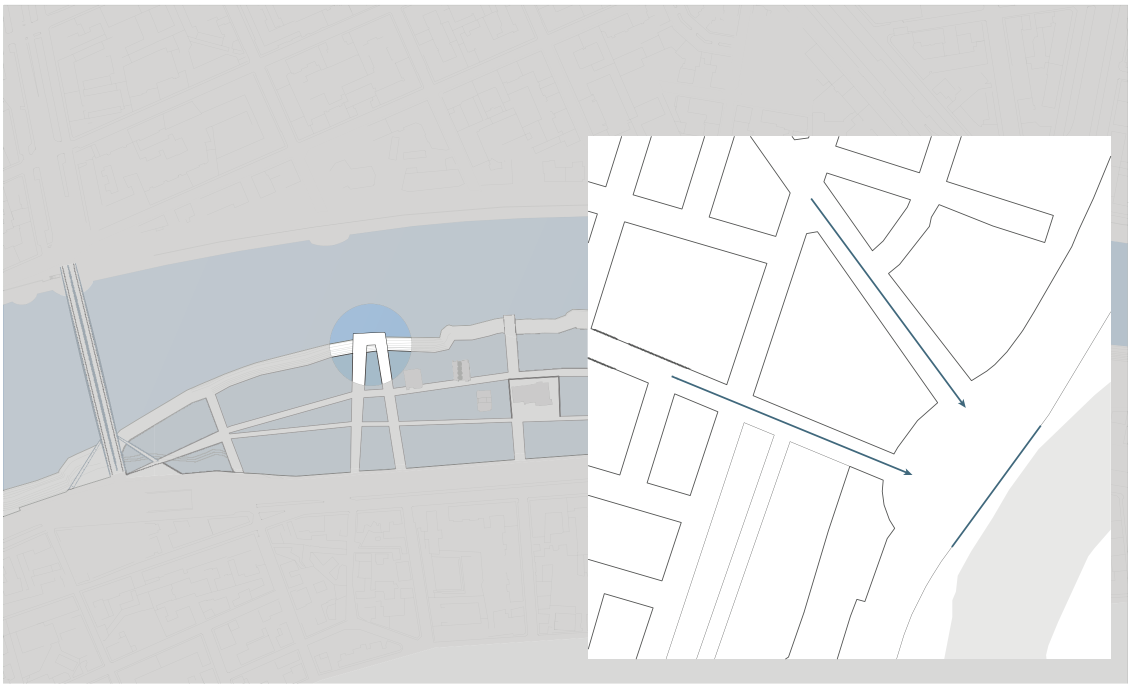


D
THE SECOND AND THIRD FOLLOW THE BROKEN OF THE GRID, THE SIXTH AND SEVENTH CHANGE DIRECTION FOLLOWING THE OPPOSITE SIDE

SERIES OF PROJECTS THE OVERLOOKING TO RIVER
result



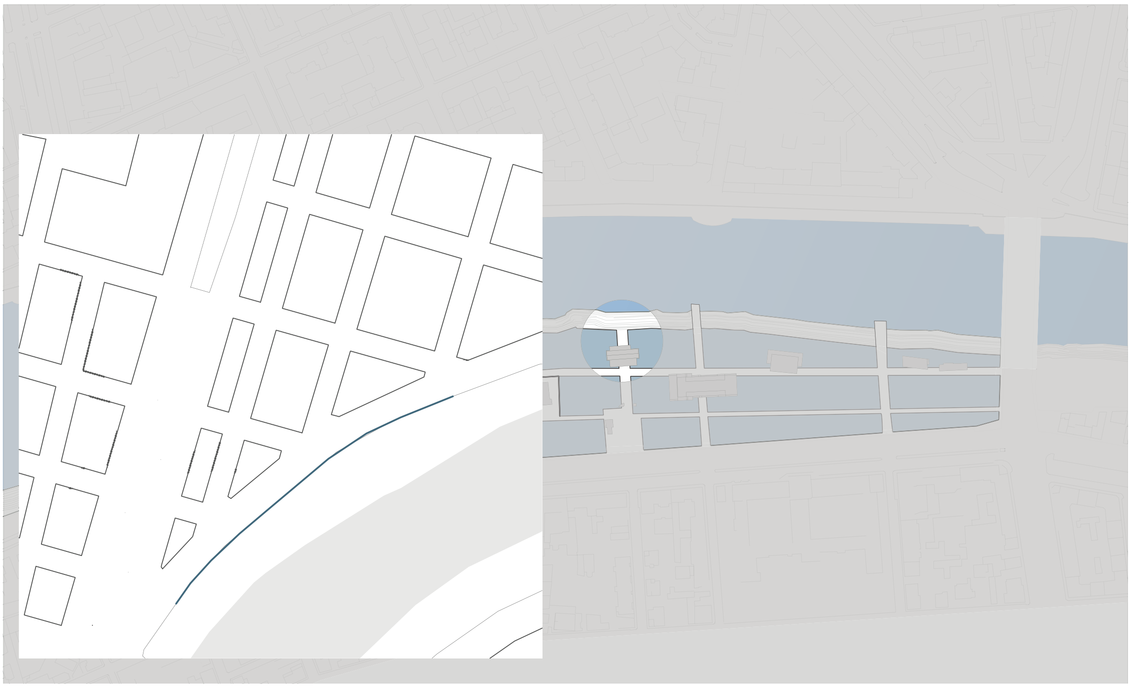
1
THE PATHS OF THE PARK INCLUDE OVERLOOKINGS TO THE RIVER, TYPICAL OF TURIN WHERE THE VIEW POSSIBILITY IS BETWEEN GRID AND RIVER



2
PIAZZALE FRATELLI CEIRANO IS THE CROSSING OF FOUR STREETS, A SQUARE AND A VIEW OF THE RIVER, THE VIEW IS HIGH AND OPEN

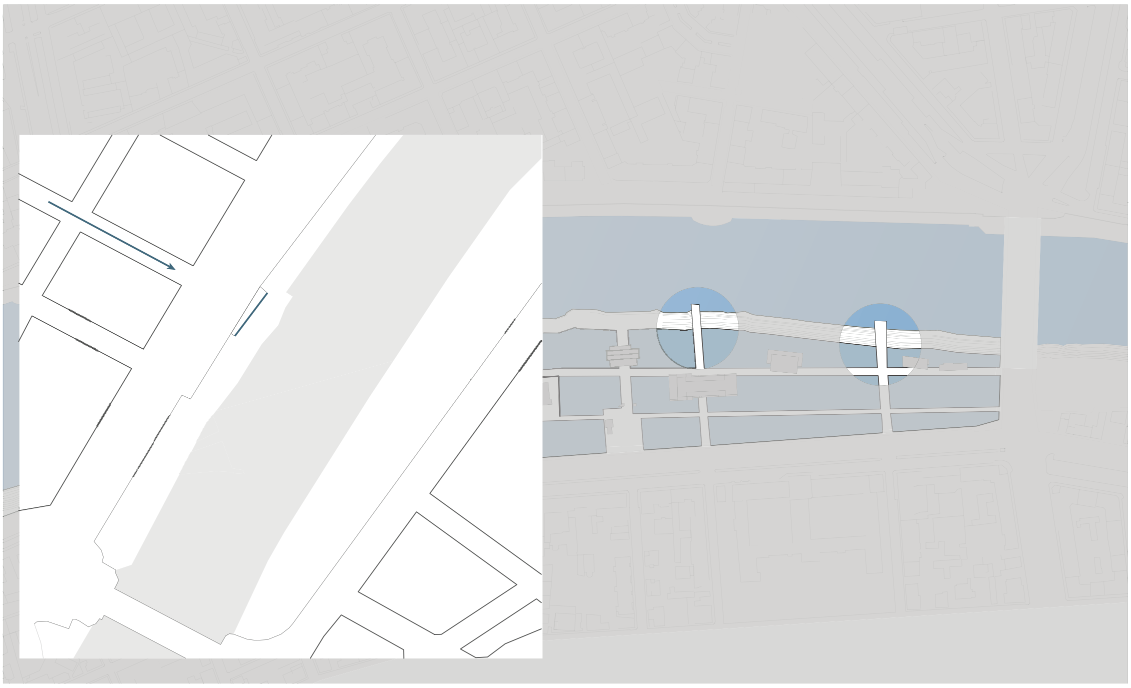
SERIES OF PROJECTS THE OVERLOOKING TO RIVER

result



3

THE PART OF THE RIVER BETWEEN PONTE BALBIS AND PONTE ISABELLA DON'T HAVE RADIAL ROAD AXES TO THE RIVER, THE VIEWS ARE BLOCKED

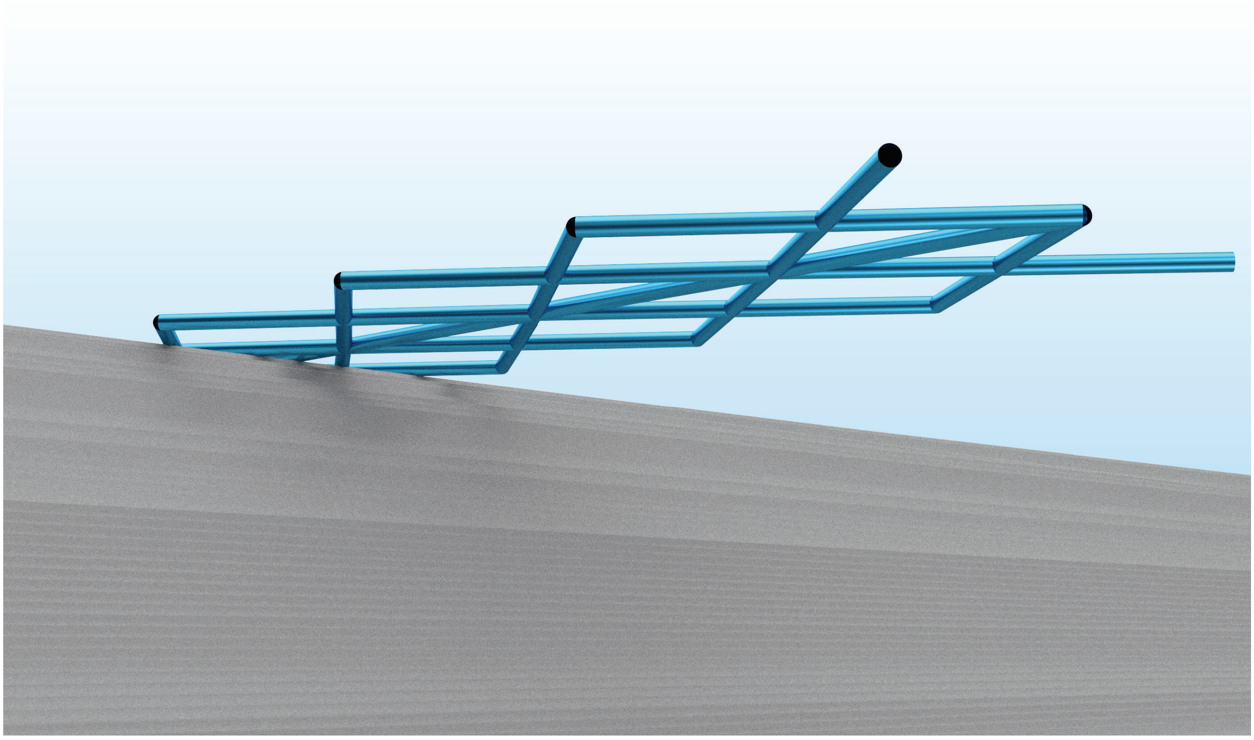


4

THE ANCIENT STAIRCASE, CORRESPONDING TO VIA DEI MILLE, IS PARALLEL TO THE RIVER, NOT PERPENDICULAR TO THE ROAD AXIS

SERIES OF PROJECTS THE OVERLOOKING TO RIVER

structure



first phase
SUPPORT FOR THE FLOOR SURFACE

features

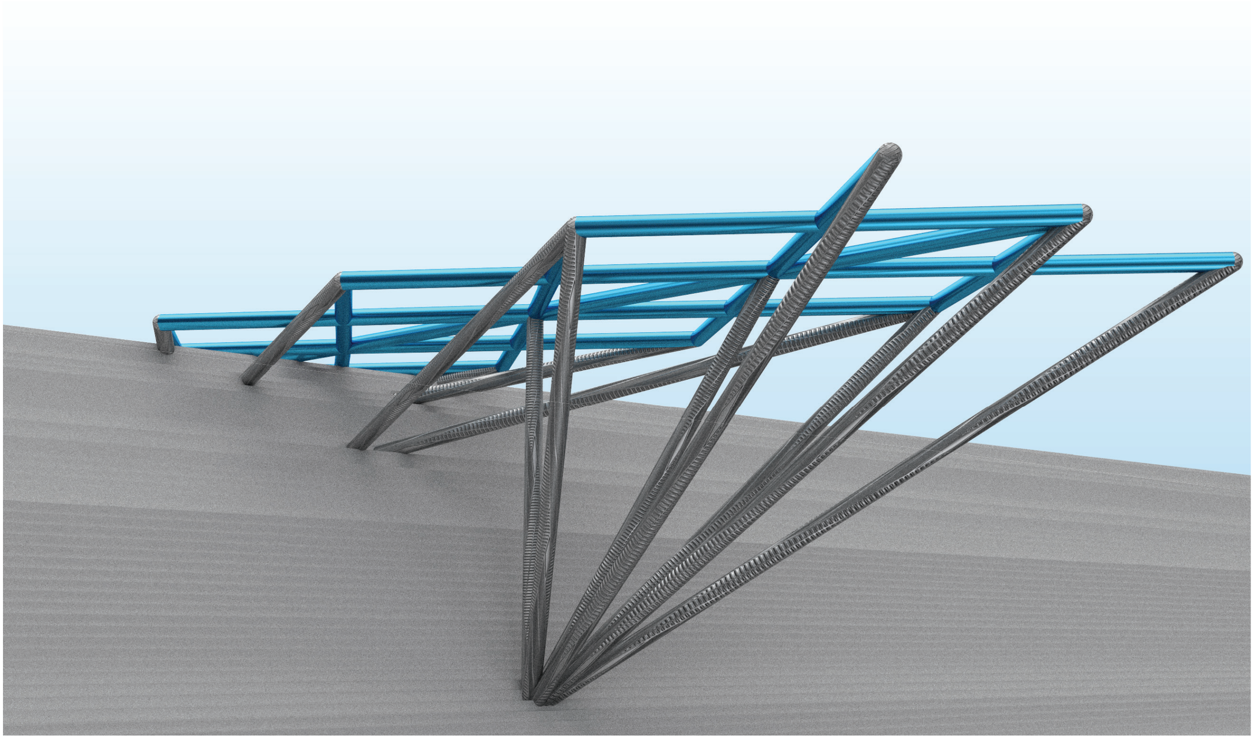
THE SUPPORT STRUCTURE TO THE FLOORED SUPEFICE IS MADE UP OF MAIN BEAMS, THAT SUPPORT THE PREVIOUSLY DEFINED AREA, HELPED BY BRACING TO BE ABLE TO MAKE THE SYSTEM MORE RIGID

Considering the bridge project, the main subject of the whole thesis project, and the river terraces project, their supporting structures have to speak the same compositional laguage. The shapes, explained in the previous passages of the chapter, are defined by geographical needs: the results are irregulare plans that are not simplified with rectangulars.

Following the algorithmic procedures, the process is, again, working by making the structure explicit and by virtue of structural choices the form results.

Defined forms, extensions and limits of the terrace, it is supported with a stiffened structure composed of main beams and bracing.

SERIES OF PROJECTS THE OVERLOOKING TO RIVER
structure



second phase
SUPPORT FOR THE FLOOR STRUCTURE

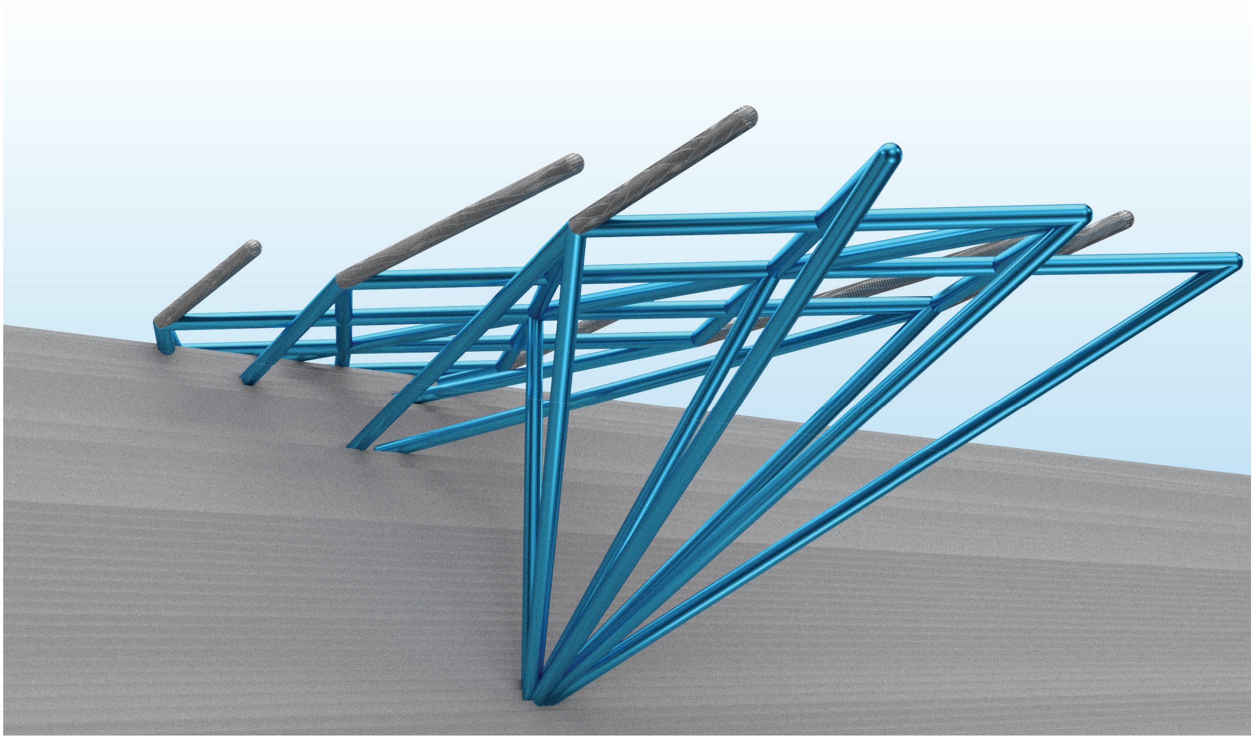
features

THE ENTIRE SYSTEM OF SUPPORTING THE WALKABLE SURFACE IS COMPOSED OF THE BEAMS, PRESENTED IN THE PREVIOUS STEP, REINFORCED BY THE MAIN THOSE AND BY FOOTPRINTS

The floor steel structure, for now considered to be cantilevered, are reinforced with a coffered structure made of tubular steel: a main beam supports the attic placing itself in the center and joining the edge that extends to the ground, to cross the main one there are three more small equidistant from each other and in support of the slab along its short side, discharging the central slla itself.

To increase the stiffness and safety of the support structure, formed by cross beams of different dimensions with an angle of approximately 90 degrees, bracing of equal dimensions are inserted, maintaining the positioning in the plane given by the lower surface of the floor structure. A structure of this type could resist only with high tubular thicknesses.

SERIES OF PROJECTS THE OVERLOOKING TO RIVER
structure



third phase
EXTENSION OF THE SUPPORT POLES TO BE ABLE TO BE FUTURE SUPPORT OF THE PARAPET

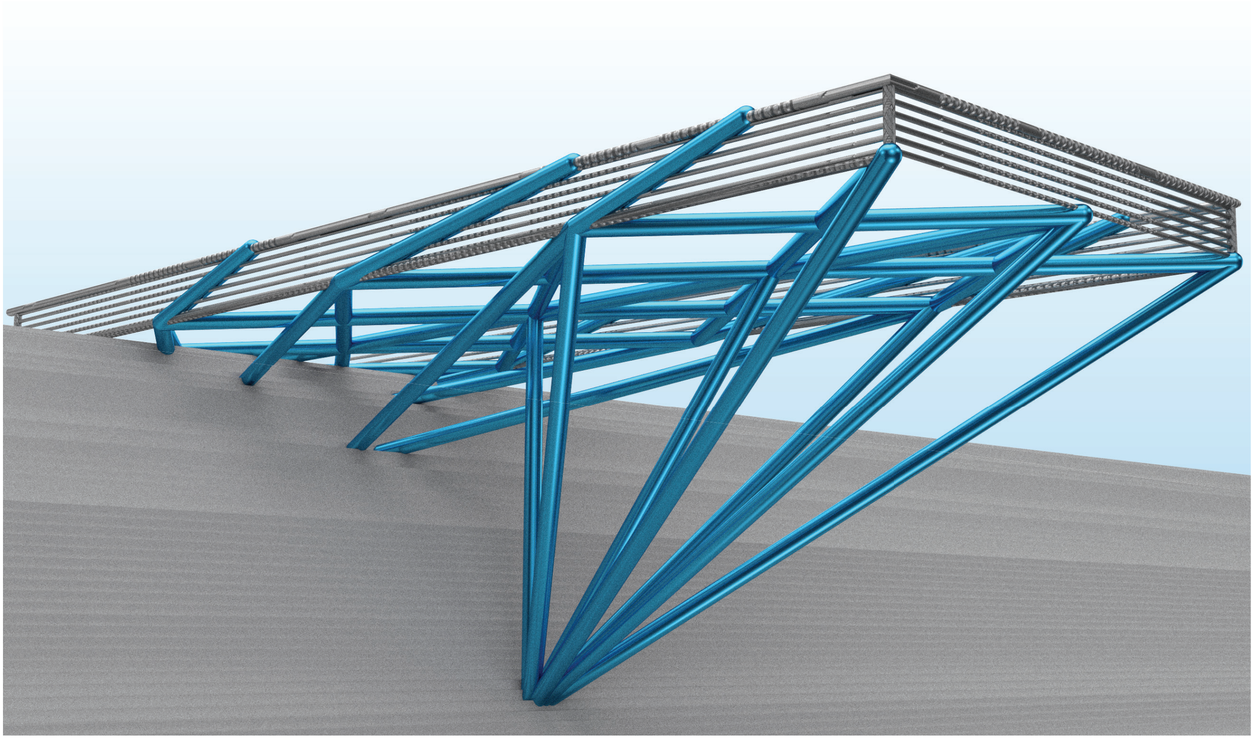
features

THE EXTENSION OF THE SUPPORT PINS, IN ORDER TO BE FUTURE SUPPORTS OF THE PARAPET, ARE RE-ORIENTED TO BE ABLE TO HAVE A FORM OF ORTHOGONAL CONTROL AND NOT INCLINED ACCORDING TO THE DIRECTIONS OF THE POLES

Thus, to maintain the compositional elegance of the steel tubes and to have a direct formal correspondence with the deck structure of the bridge, also in steel, struts are inserted. These collect the weight of the slab from the beams, and from their bracing, and unload it to the ground by stretching their terminal parts towards a single point. Thus sharing the foundation.

To these metal rods positioned in equidistant points and cooperating two by two, they need a stiffening. Their inclination is given by the ground and the same positions of the foundations are given by the same therefore in certain cases there are large inclinations that must receive opposite resistances so as not to open outwards.

SERIES OF PROJECTS THE OVERLOOKING TO RIVER structure



fourth phase
THE STRUCTURES OF THE PARAPETS ARE SUPPORTED BY POLES

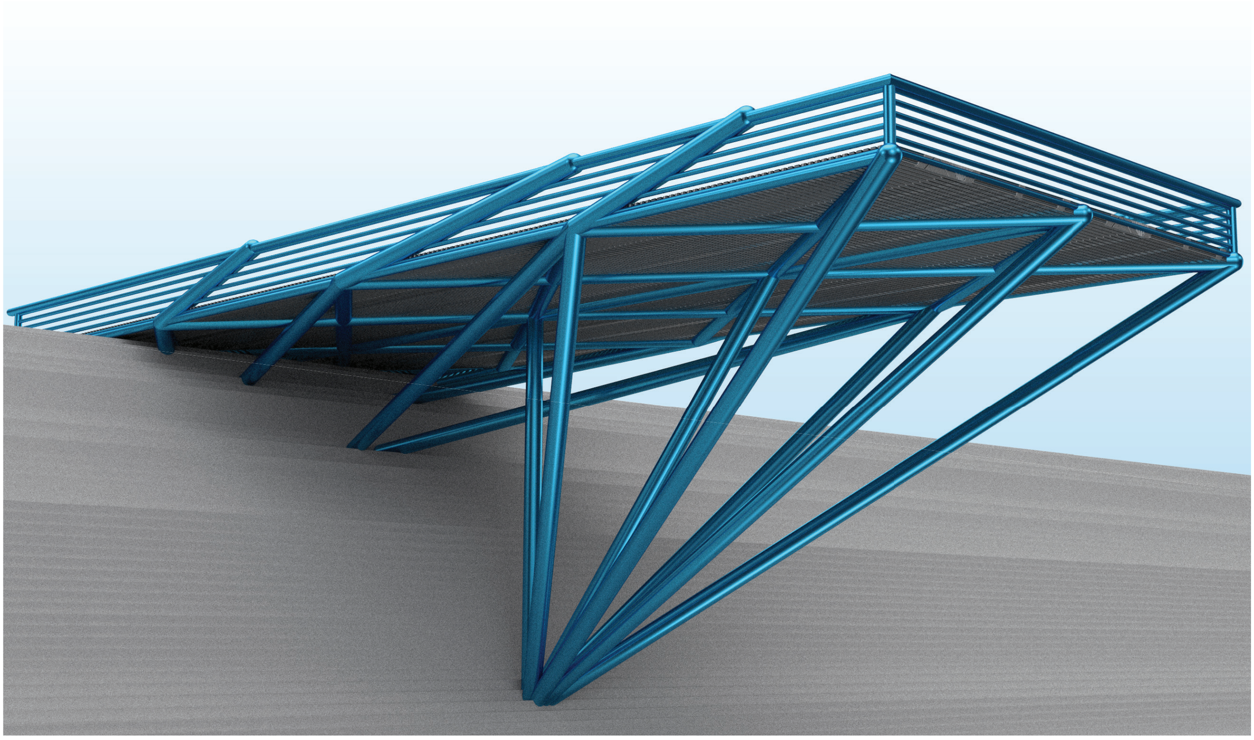
features

THE PARAPETS OF THE TERRACES ON THE RIVER REPLY IN SECTION DIMENSIONS THOSE OF THE BRIDGE, WITH A SUBSTANTIVE THICKNESS OF THE HANDRAIL AND A CONSTANT MSURA OF SMALLER THICKNESSES, ALL THE RODS ARE SUPPORTED BY THE EXTENSIONS OF THE POLES

To maintain the formal aspect consistent with the urban macro-project that has the design of the bridge as its fulcrum, the parapets are designed very similar to the bridge's ones in such a way as to clearly highlight the string course of the floor slab. In reverse arrangement, the same materials as the bridge persist and the "belvedere" function of the overlookings is improved, thanks to transparency.

The outermost part of the terrace cannot be supported by extensions of the rafters, so in order not to have too many and easily deformable walls, columns are inserted at the corners. The highest rods of the parapet are thickened in order to have a better comfort and to replicate the parapet of the bridge.

SERIES OF PROJECTS THE OVERLOOKING TO RIVER structure



fifth phase
THE FLOOR SURFACE MATERIAL

features

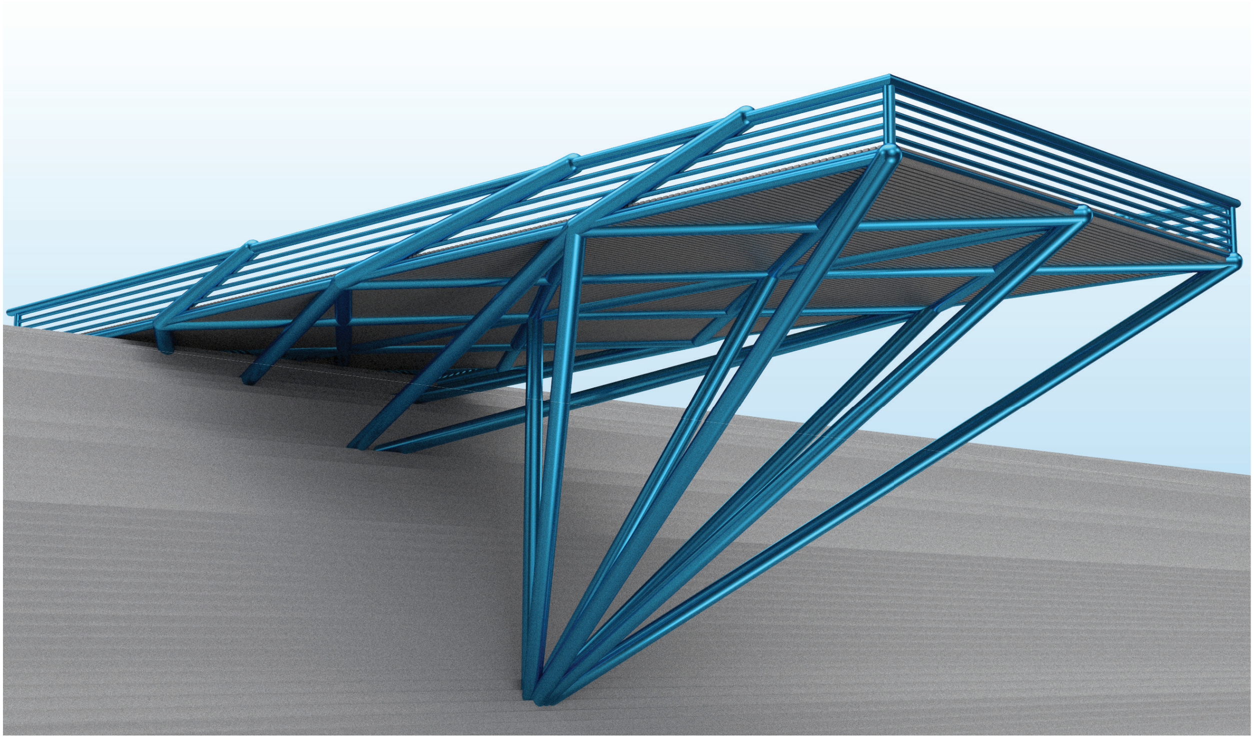
THE FLOOR IS COMPOSED OF A THICK METALLIC GRID IN GRAY STEEL, NATURAL COLOR, THE REPLICATION OF THE MATERIAL CONTRASTS OF THE DECK DECK ALLOWS TO HAVE A SIMILAR LANGUAGE

Again by replicating the conditions imposed in the bridge project, the results of reasoning and procedures that led to an overall project.

The pavement is also made up of a light metal grating that allows the view below of the lattice structures of the terrace deck and of the struts that fall on the ground in a naturalistic context of transition between public park and river.

The structure of the floor supports intersecting all the metal grating slats with a view to having the design of the structure painted in blue steel and the gray grid, in steel with its raw color, visible.

SERIES OF PROJECTS THE OVERLOOKING TO RIVER structure



final result
MORE PROJECTS, ONE LANGUAGE

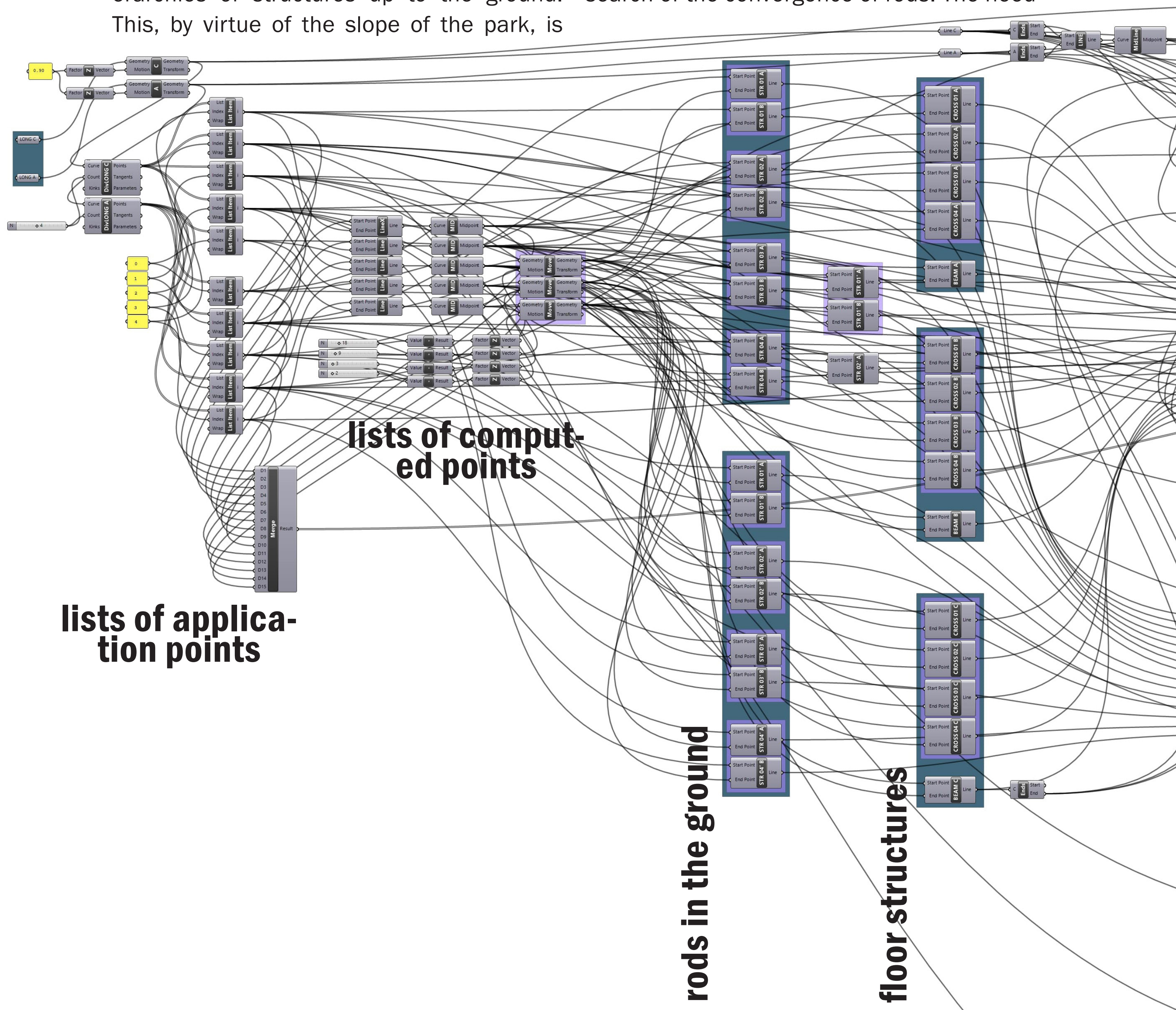
features

THE LIGHT BLUE OF THE SUPPORTING STRUCTURES CONTRAST WITH THE NATURAL TERRITORY BOTH IN SHAPES AND COLORS, THE WALKING FLOOR MAINTAINS THE RELATIONSHIP PRESENTED IN THE BRIDGE PROJECT BOTH FROM THE COMPOSITIVE AND CHROMATIC POINT OF VIEW

THE ENTIRE STRUCTURE, AS IN ALL THE THESIS MACRO PROJECT, COMPLIES WITH THE RULES AND PRINCIPLES OF MINIMUM STRUCTURAL AND COMPOSITIONS OF PARTS THAT LEAD TO THE OPERATION OF A COMPLEX STRUCTURAL SYSTEM.

SITUATIONS SUCH AS PUNTON EXTENSION AND THE MOST COMMON POSSIBLE FOUNDATIONS ARE RESULTS OF A MINUTE STUDY ON GENRATIVE ALGORITHMS AIMED AT DEFINING FORM-FINDING FORMS

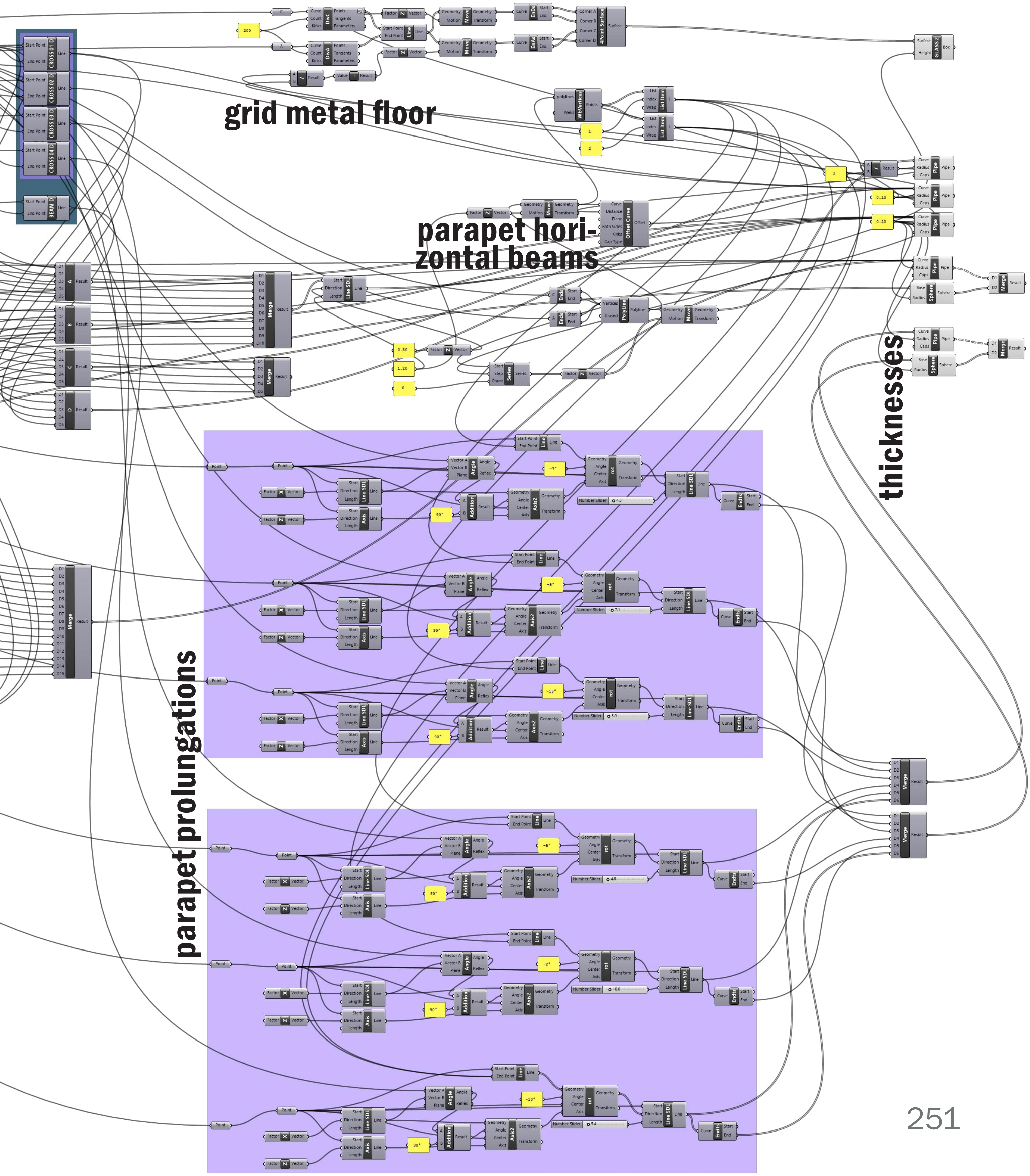
The design of the support structures for the structures, overlookings to the river, was done through a generative algorithm of Grasshopper. Computing the protruding perimeter of the floor surface, the points where the supports to the structure needed to be positioned were identified. Starting from those points you support hierarchies of structures up to the ground. This, by virtue of the slope of the park, is irregular so it was necessary to place numerical sliders that defined points just below the ground, where the foundations were located. The distances of the points have been taken, after the computations of the inferior surfaces, through the constant division of curves, therefore the system has generated equal conditions of resistance of the structure in search of the convergence of rods. The need



algorithm

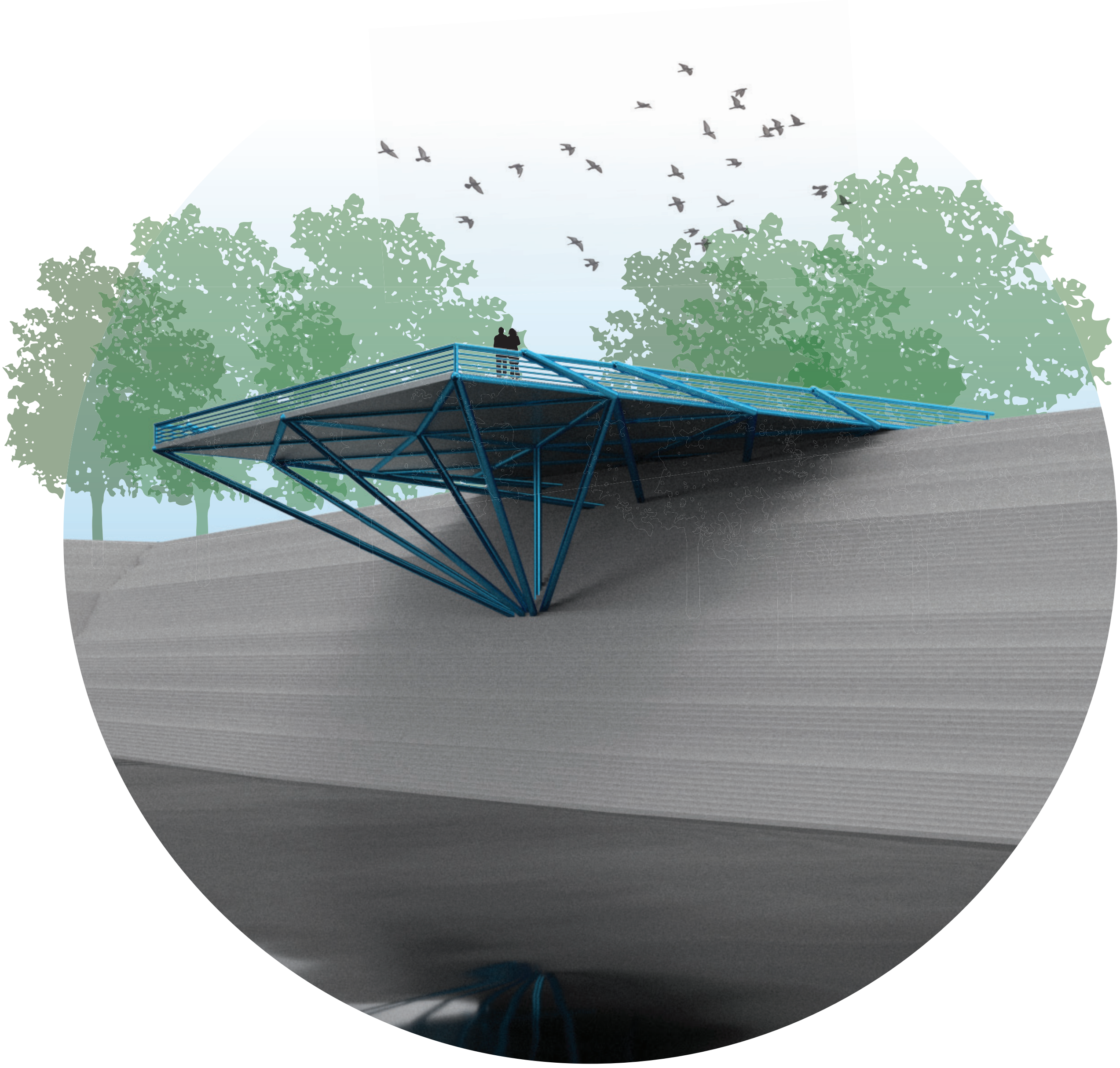
SERIES OF PROJECTS THE OVERLOOKING TO RIVER

for an algorithm in this case is given by the design of four terraces which, for compositional consistency, had to have the same language. Each terrace, however, has very different dimensions and contour shapes, because as explained in the previous pages they are adapted to paths and targeted views. So there is a need for an adaptive parameterization that maintains the same support conditions and the same thicknesses as the permanent structural parts and adapts to the irregular conditions of the ground. Last note, the floor, replicating the ateriality proposed for the bridge, is also parametric and adaptable to both the number of slats and the thickness.



SERIES OF PROJECTS THE OVERLOOKING TO RIVER

parameterization



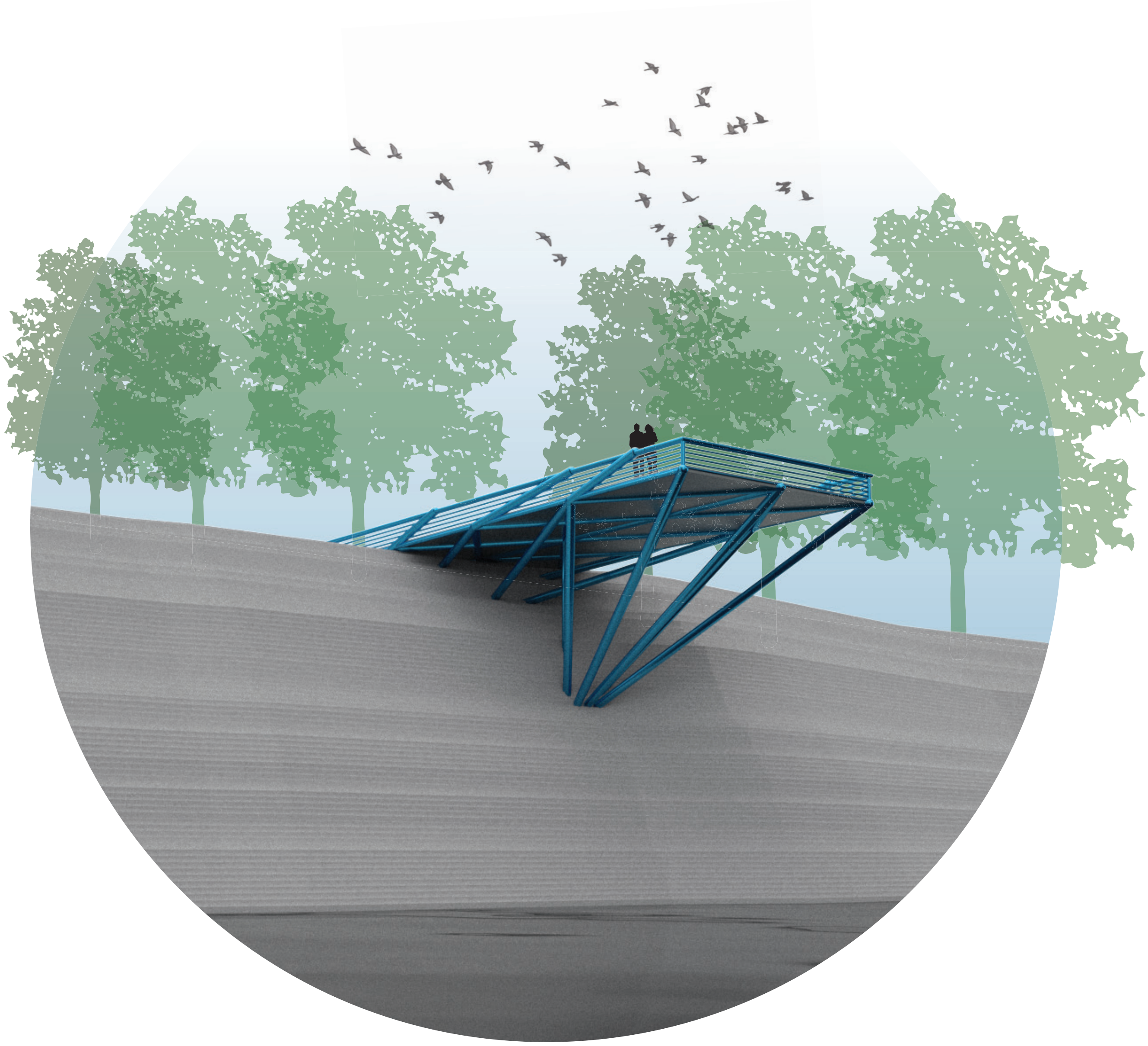
location

SOUTH PART OF THE PARK, OVERLOOKING THE RIVER NEAREST TO THE NEW BRIDGE, THE LARGEST WALKABLE SURFACE

feature

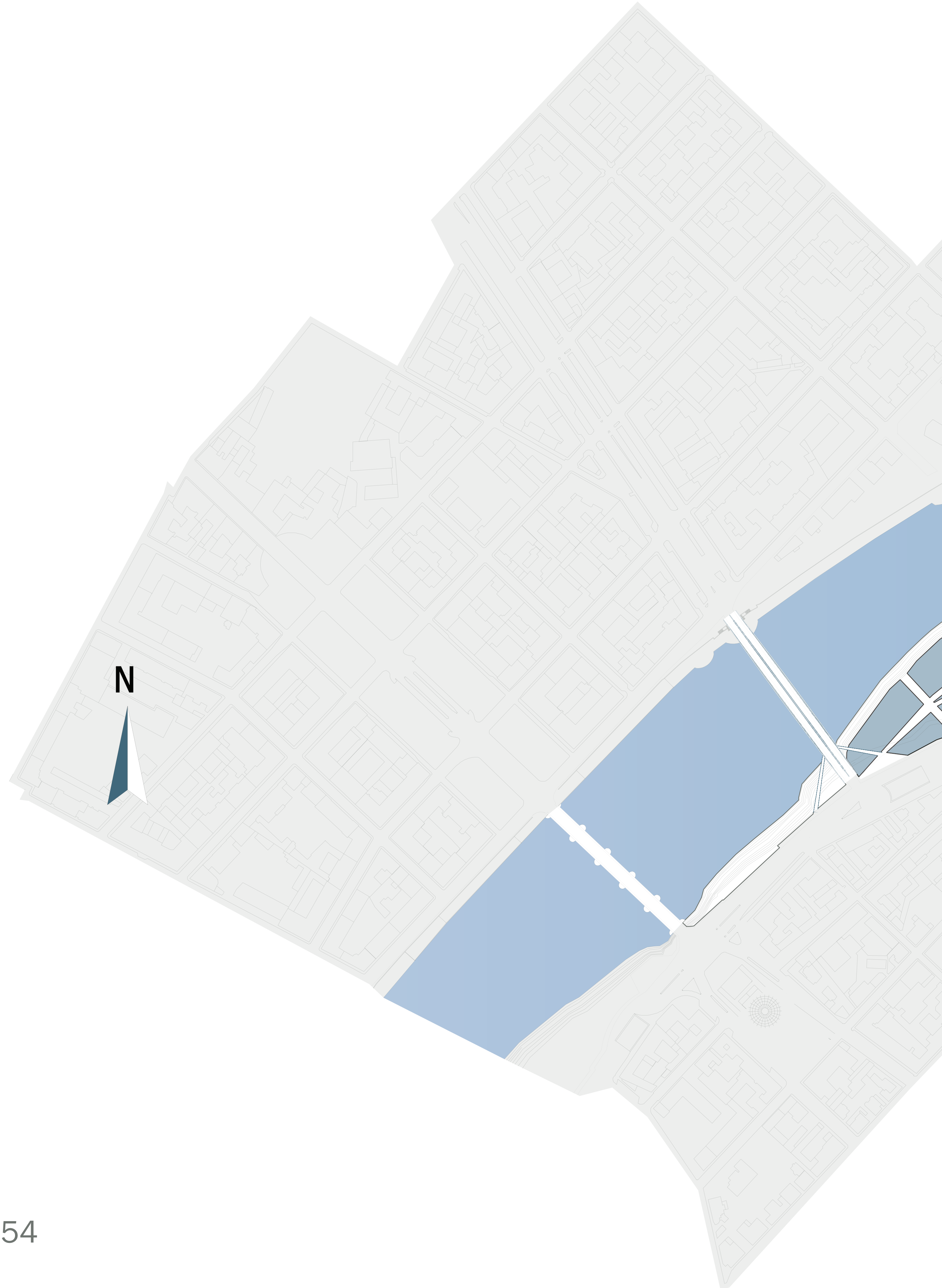
THE TERRACE WITH THE LARGEST WALKABLE SURFACE, THE ALGORITHM, COMPUTING LIMITS AND SIZE OF THE MEMBERS, IMPROVES THE SUPPORT STRUCTURE OF THE FLOOR IN ORDER TO IMPROVE THE SUPPORT

SERIES OF PROJECTS THE OVERLOOKING TO RIVER
parameterization



location
NORTH PART OF THE PARK, OVERLOOKING PLACED AT THE END OF THE PATH, THE MOST PROJECTING ON THE RIVER

feature
THE MOST PROJECTING TERRACE ON THE RIVER NEEDS THE LARGEST ANCHOR POINTS, THE ALGORITHM, COMPUTING THE PERIMETER, DETERMINES POSITIONS IN A NARROW AND LONG SURFACE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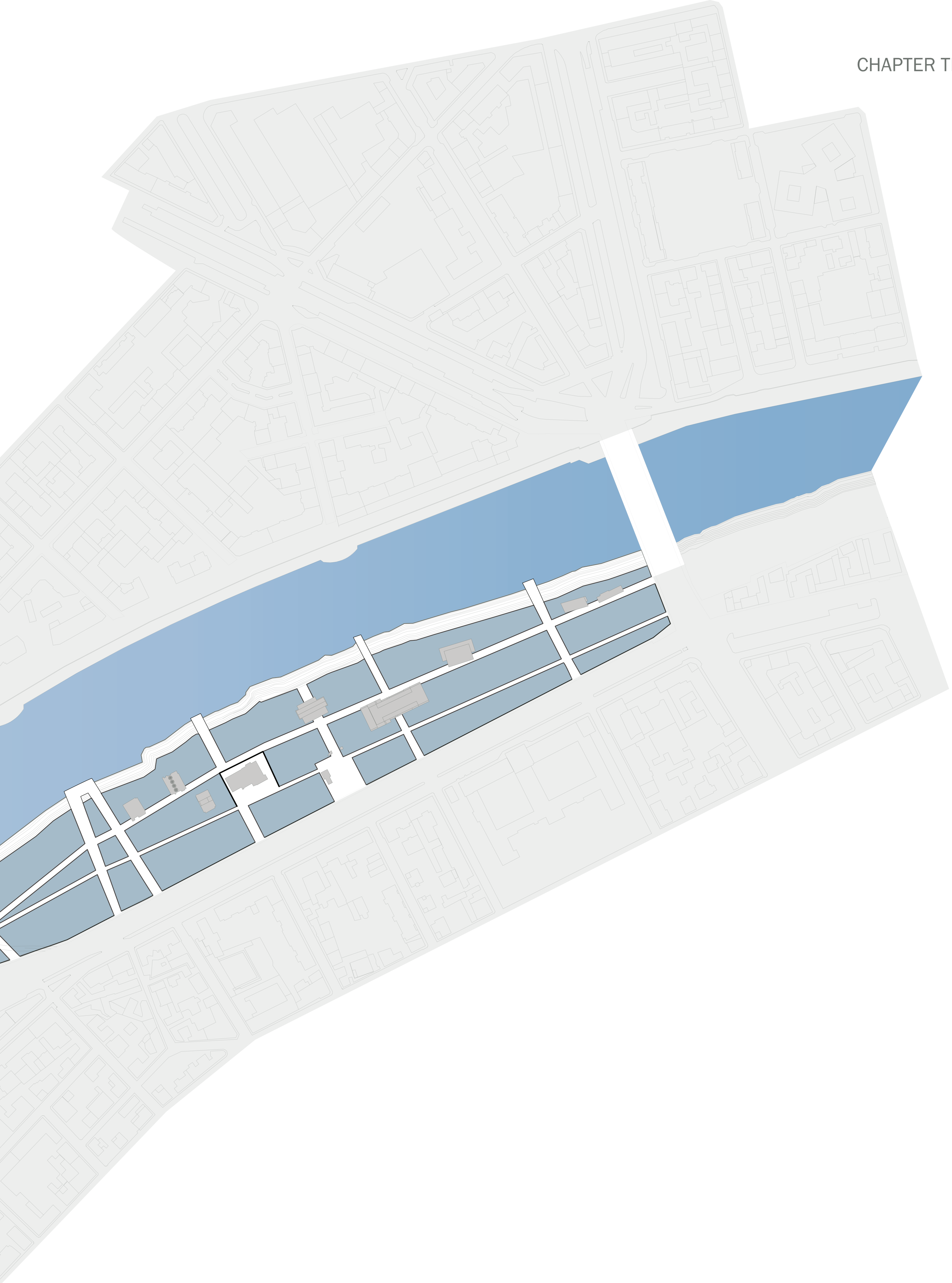
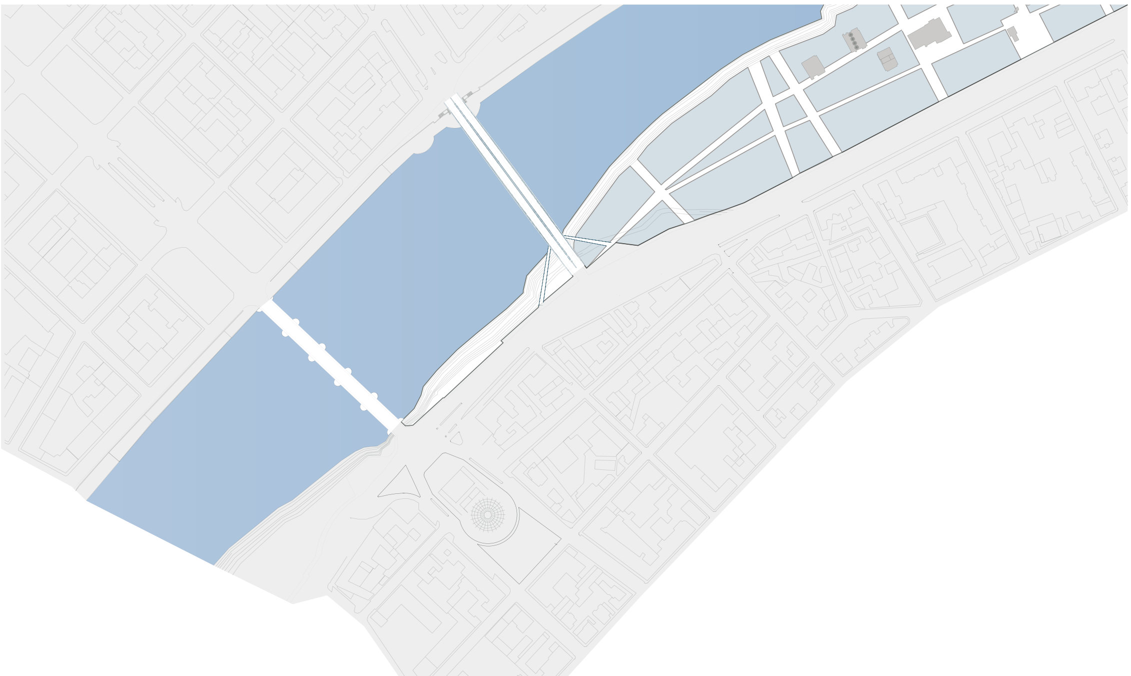
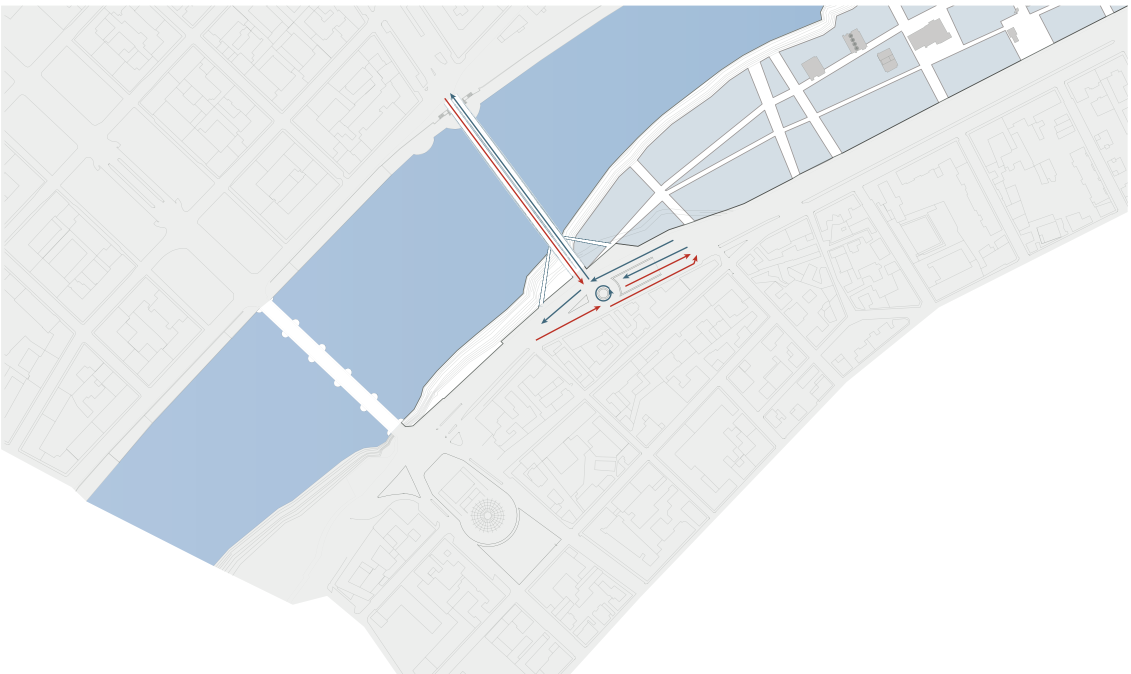


overlooking plan

SERIES OF PROJECTS THE CAR PATHS
new elements

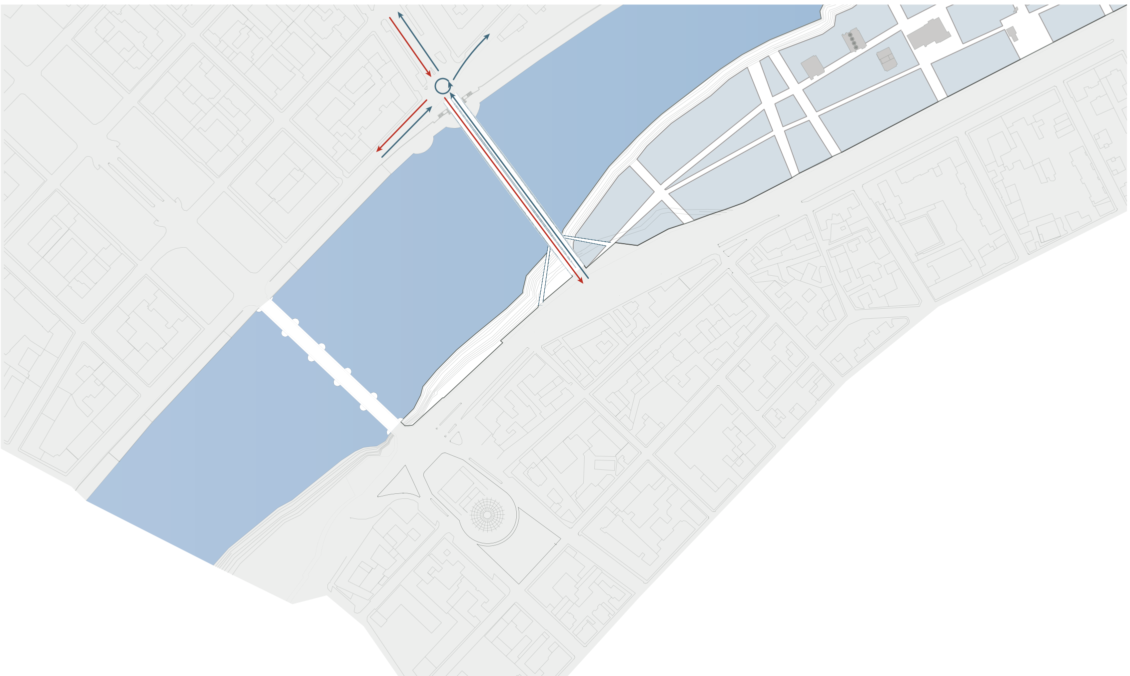


A
THE PRESENCE OF THE NEW BRIDGE NEEDS A DIFFERENT SET-UP OF THE ROAD PATTERN, IN ORDER TO MAXIMIZE ITS FUNCTION



B
THE INTRODUCTION OF A ROUNDABOUT AND AN UNDERPASS ALLOWS TO DIFFERENTIATE THE BRIDGE TRAFFIC FROM THE REST

SERIES OF PROJECTS THE CAR PATHS
new elements

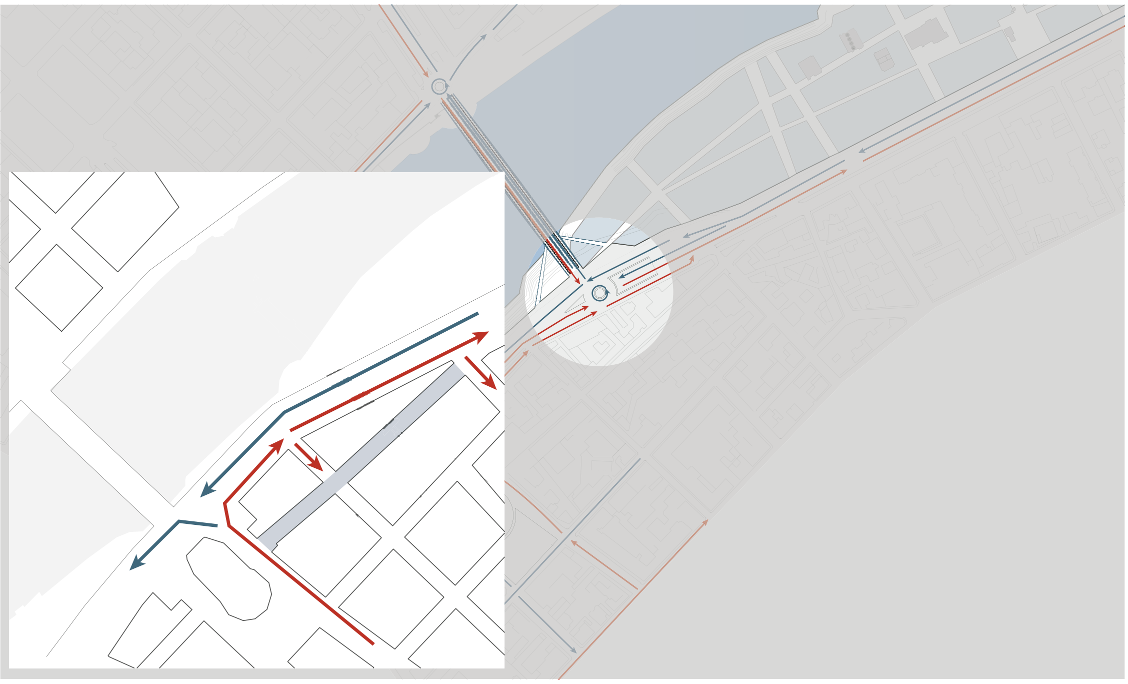


C
CORSO SAN MAURIZIO, EXTENDED, CREATES A CROSSING OF FOUR ROADS, A ROUNDABOUT REDISTRIBUTES THE TRAFFIC

D
THE UNDERPASS OF CORSO CASALE HAS ANOTHER ENTRANCE IN CORSO MONCALIERI, THE OLD BRIDGE AND THE CHURCH BREATHE

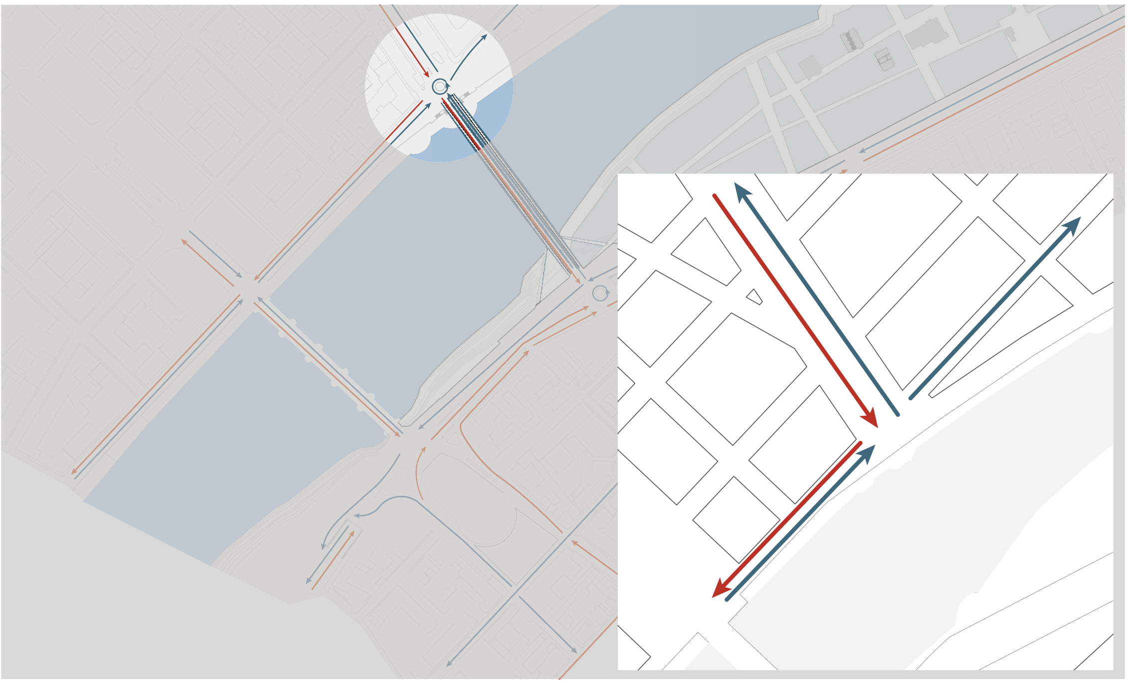
SERIES OF PROJECTS THE CAR PATHS
differences

1
THE NEW BRIDGE AND THE INFRASTRUCTURE SUPPORTING THE ROADS MODIFY THE ROUTES OF THE CITY



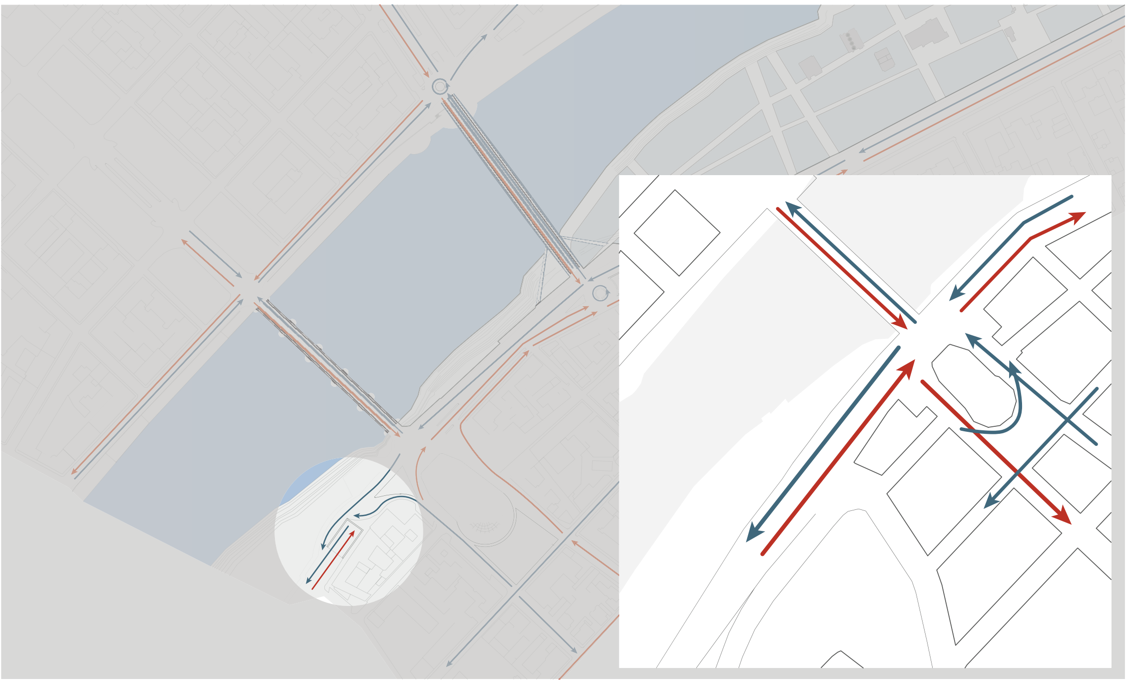
2
THE JOINT CHANGES FROM ONE DOUBLE DIRECTION TO THREE DOUBLE DIRECTIONS: EXISTING PATH, THE NEW BRIDGE, THE UNDERPASS

SERIES OF PROJECTS THE CAR PATHS differences



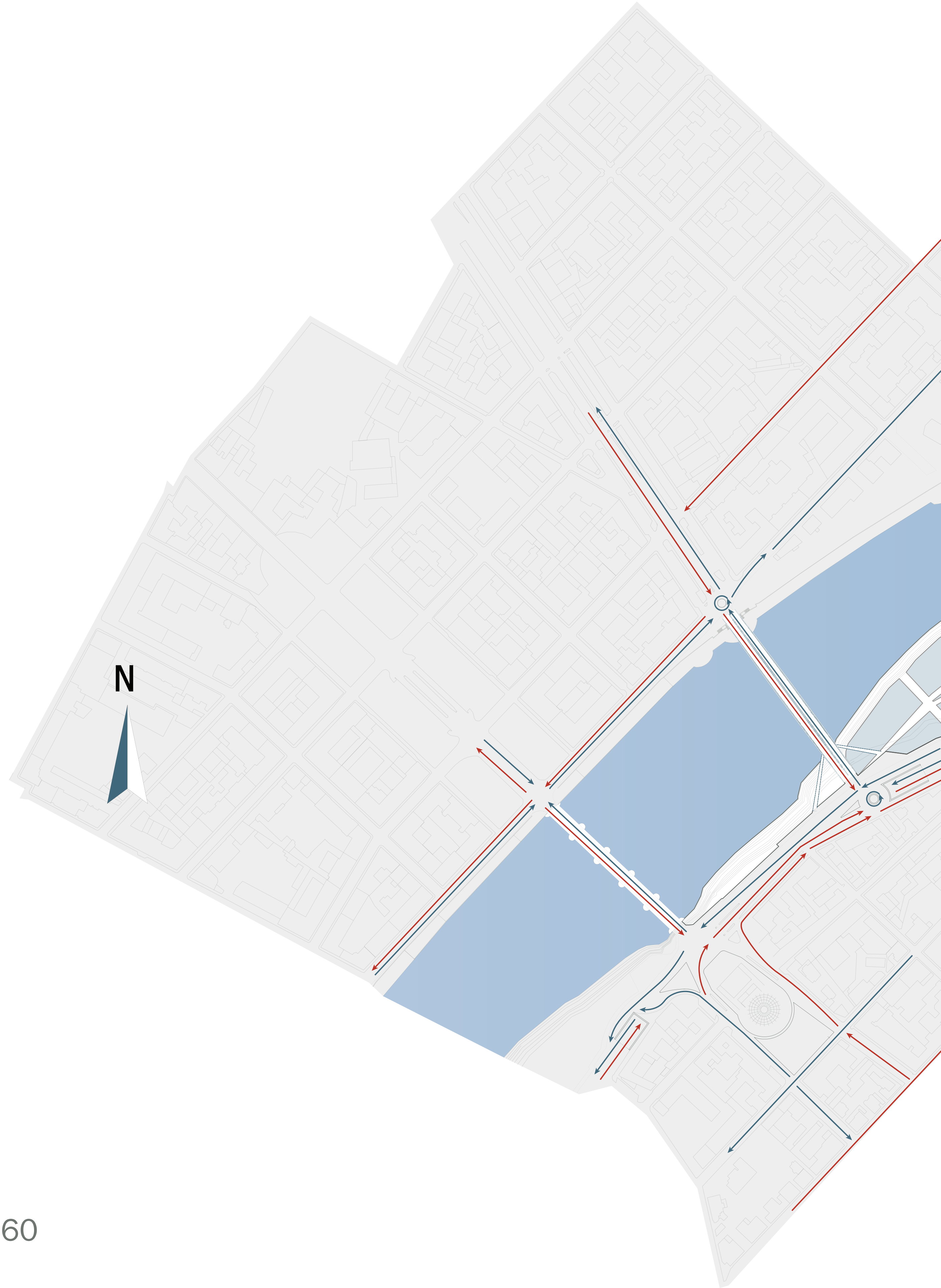
3

THE NEW BRIDGE AND THE ROTONDA IN SUPPORT INCREASE THE USE OF THE AREA, MAKING THE MOVEMENT FASTER



4

THE JOINT LIGHTENES TRAFFIC AROUND THE GRAN MADRE AND ALLOWS TWO CONNECTIONS TO THE OLD BRIDGE: FAST AND SLOWER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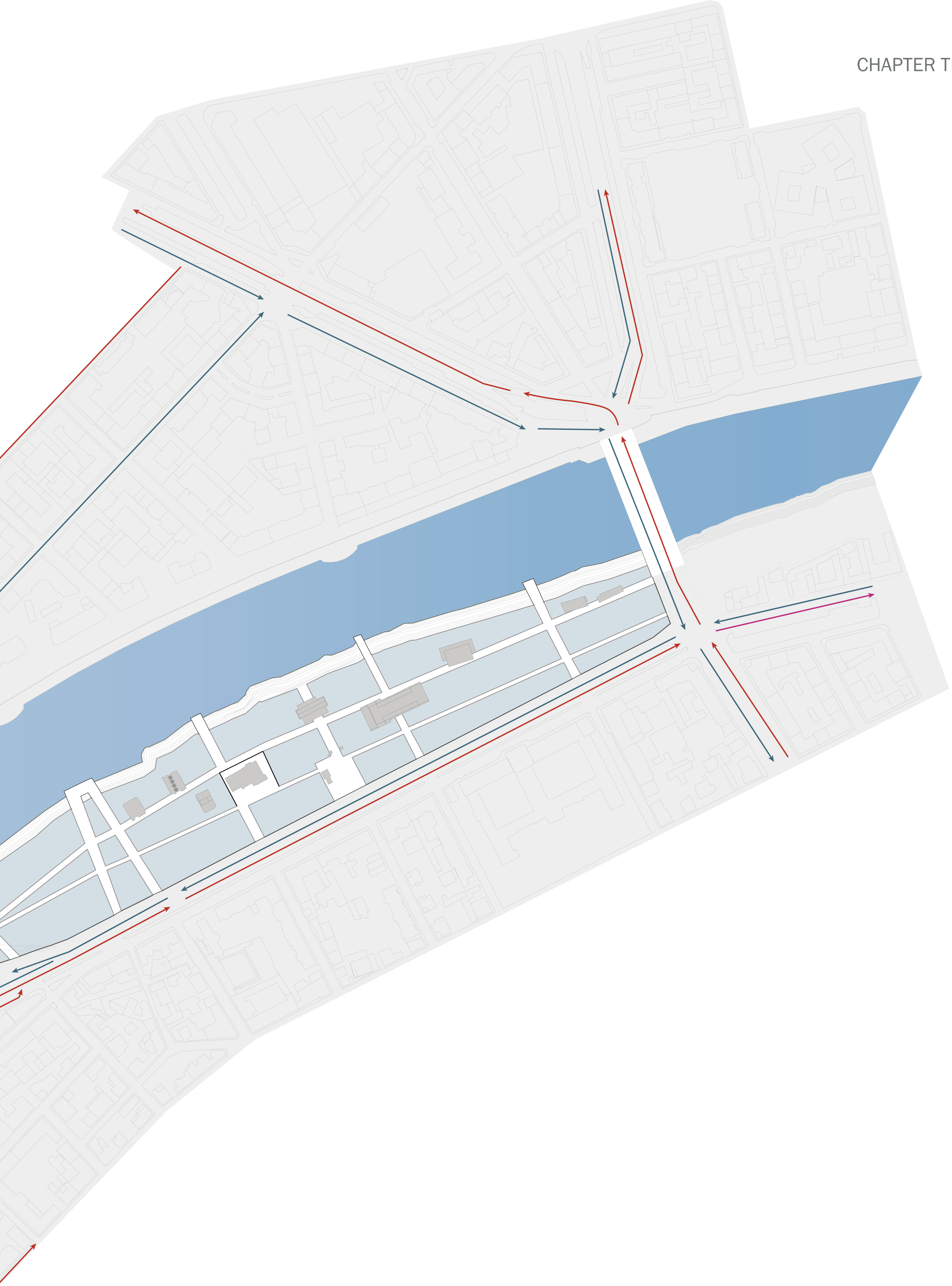
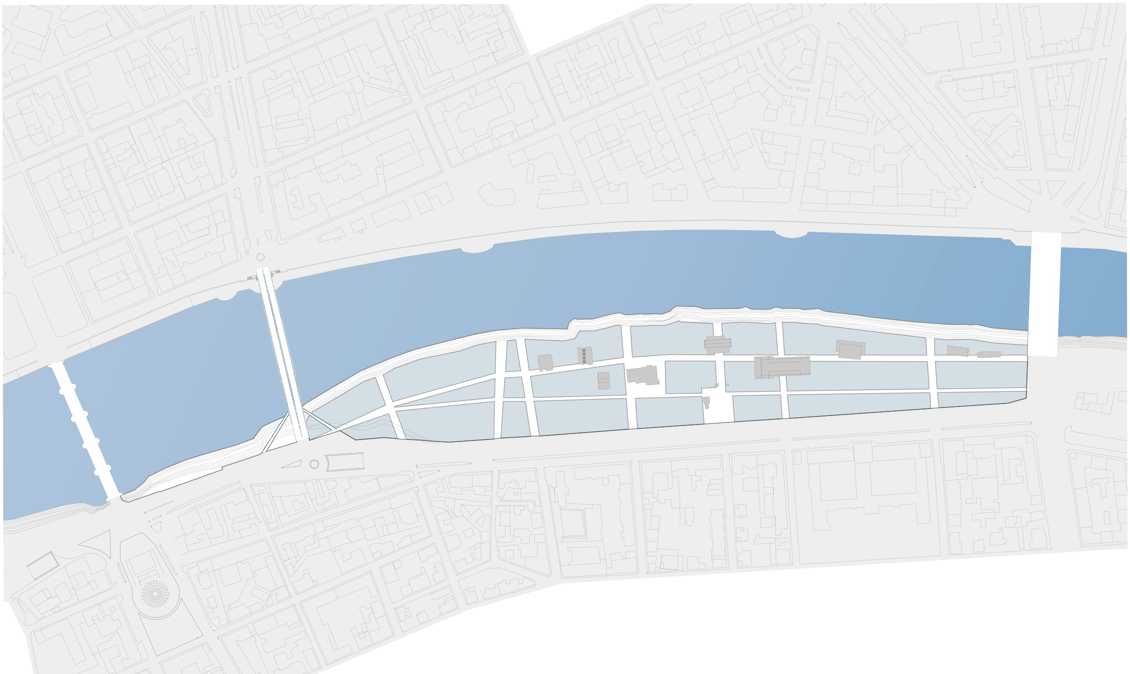


road plan

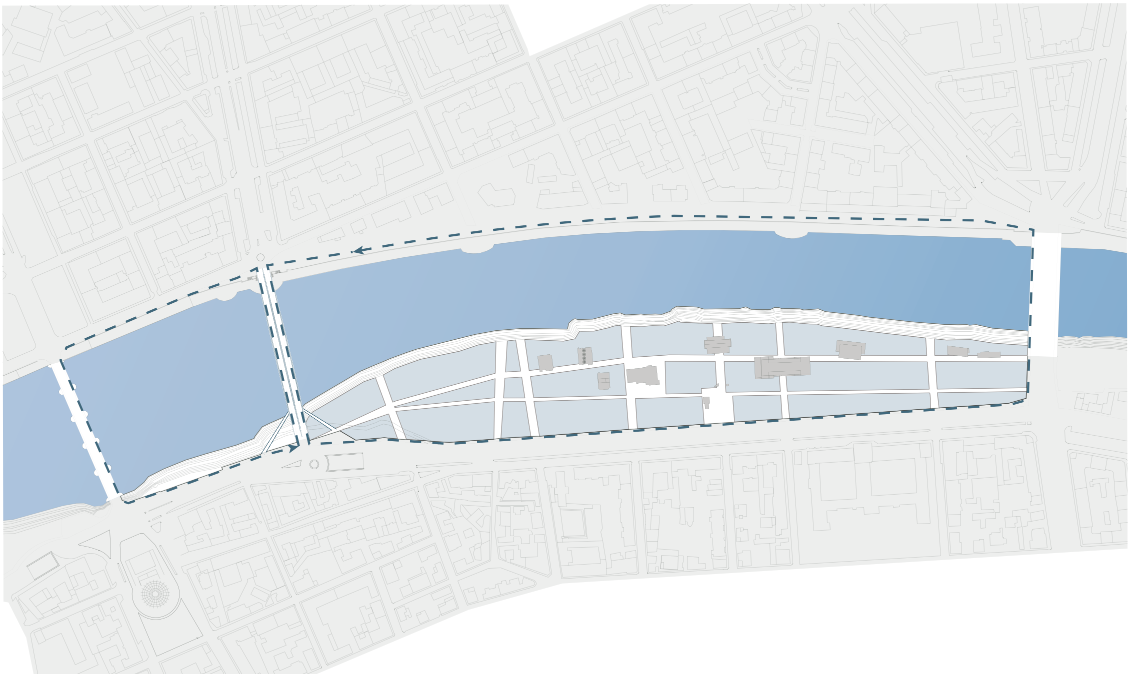
SERIES OF PROJECTS THE PEDESTRIAN PATHS

new routes



A

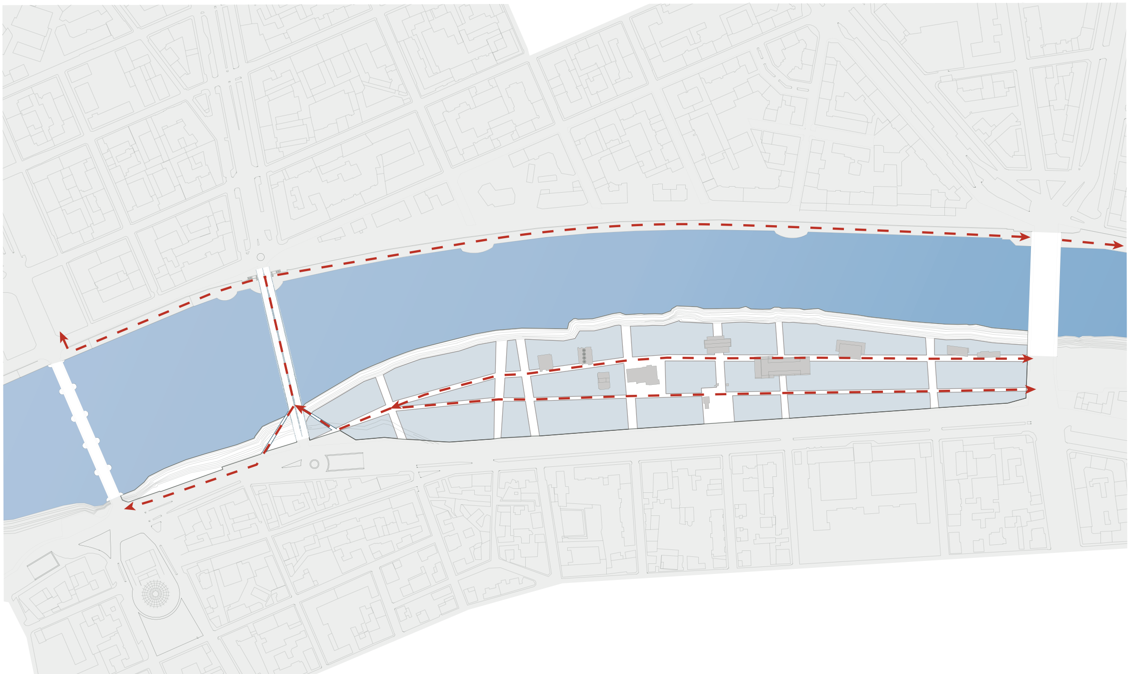
THE BRIDGE IMPROVES THE USE OF THE AREA ALSO FROM THE PEDESTRIAN POINT OF VIEW: THE NEW PATHS OF THE PARK, THE BRIDGE WALKWAY



B

THE SIDEWALKS OF THE BRIDGE CARRIAGES ALLOW YOU TO USE THE BRIDGE ALSO AT ROAD LEVEL

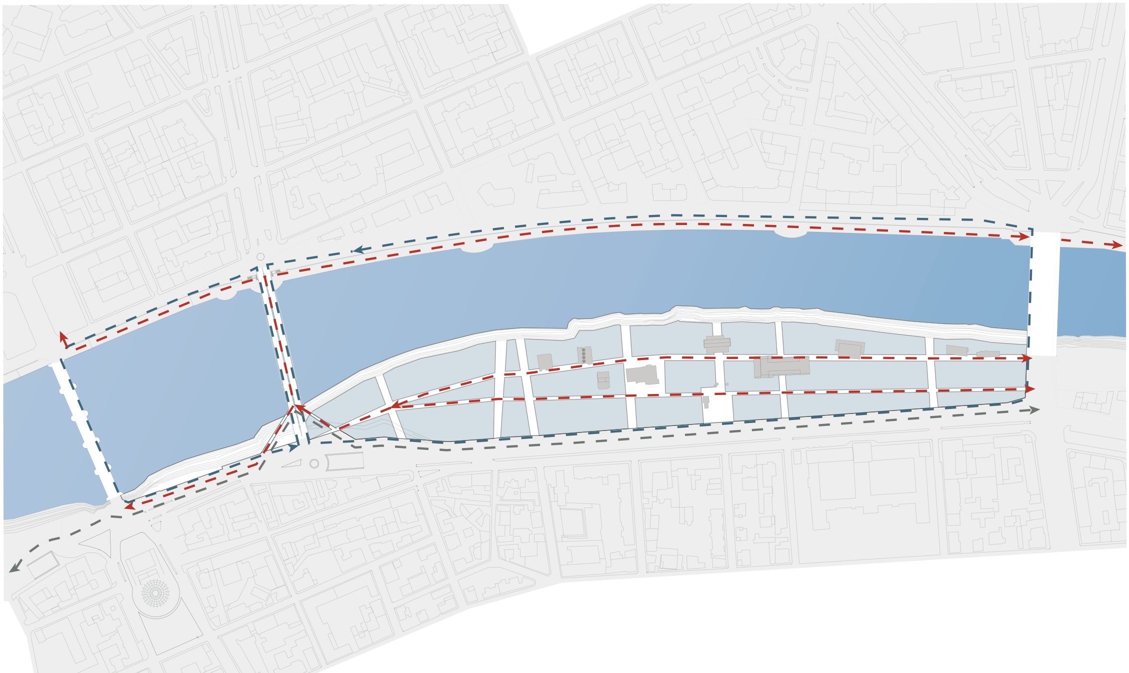
SERIES OF PROJECTS THE PEDESTRIAN PATHS
new routes



C
THE PEDESTRIAN WALKWAY OF THE BRIDGE, WITH THE PRESERVED STAIR, ALLOWS TO CONNECT THE LEVELS BETWEEN MURAZZI AND THE PARK

D
THE FORCING OF THE PEDESTRIAN WALKWAY ALLOWS TO OVERCOME THE CARRIAGE WITHOUT CROSSING THE ROAD IN THE PASSAGE OF CARS

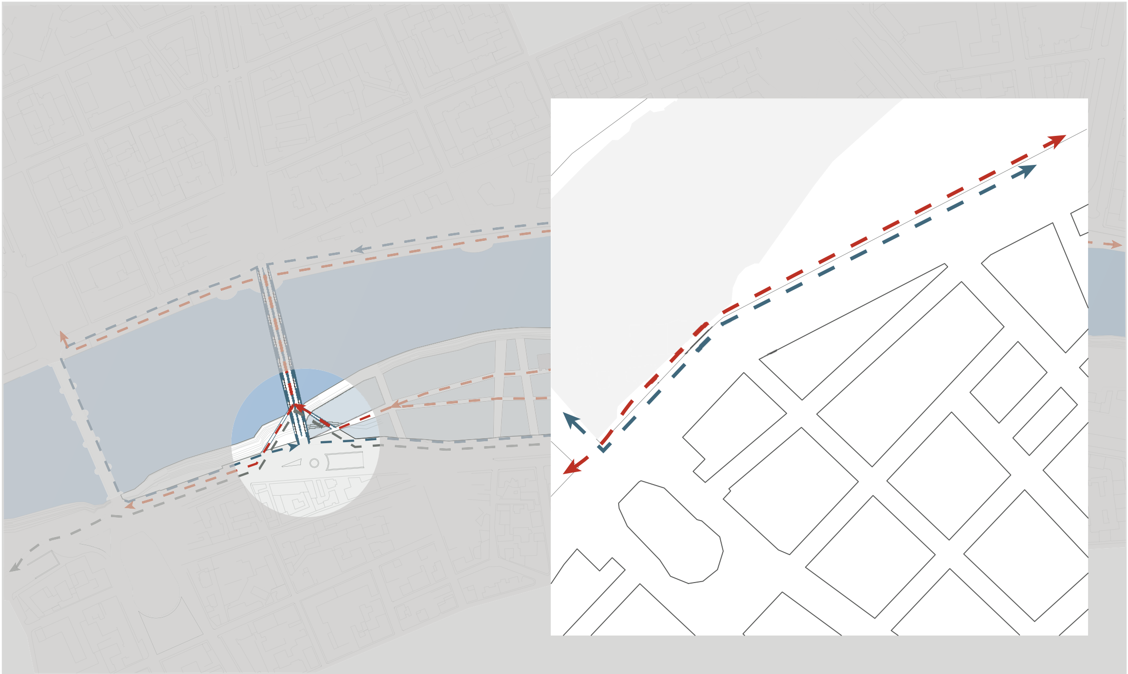
SERIES OF PROJECTS THE PEDESTRIAN PATHS differences



1
THE NEW BRIDGE ALLOWS TO THE PEDESTRIAN PUBLIC TO USE THREE LEVELS: THE LEVEL OF THE CITY, MURAZZI AND THE WALKWAY

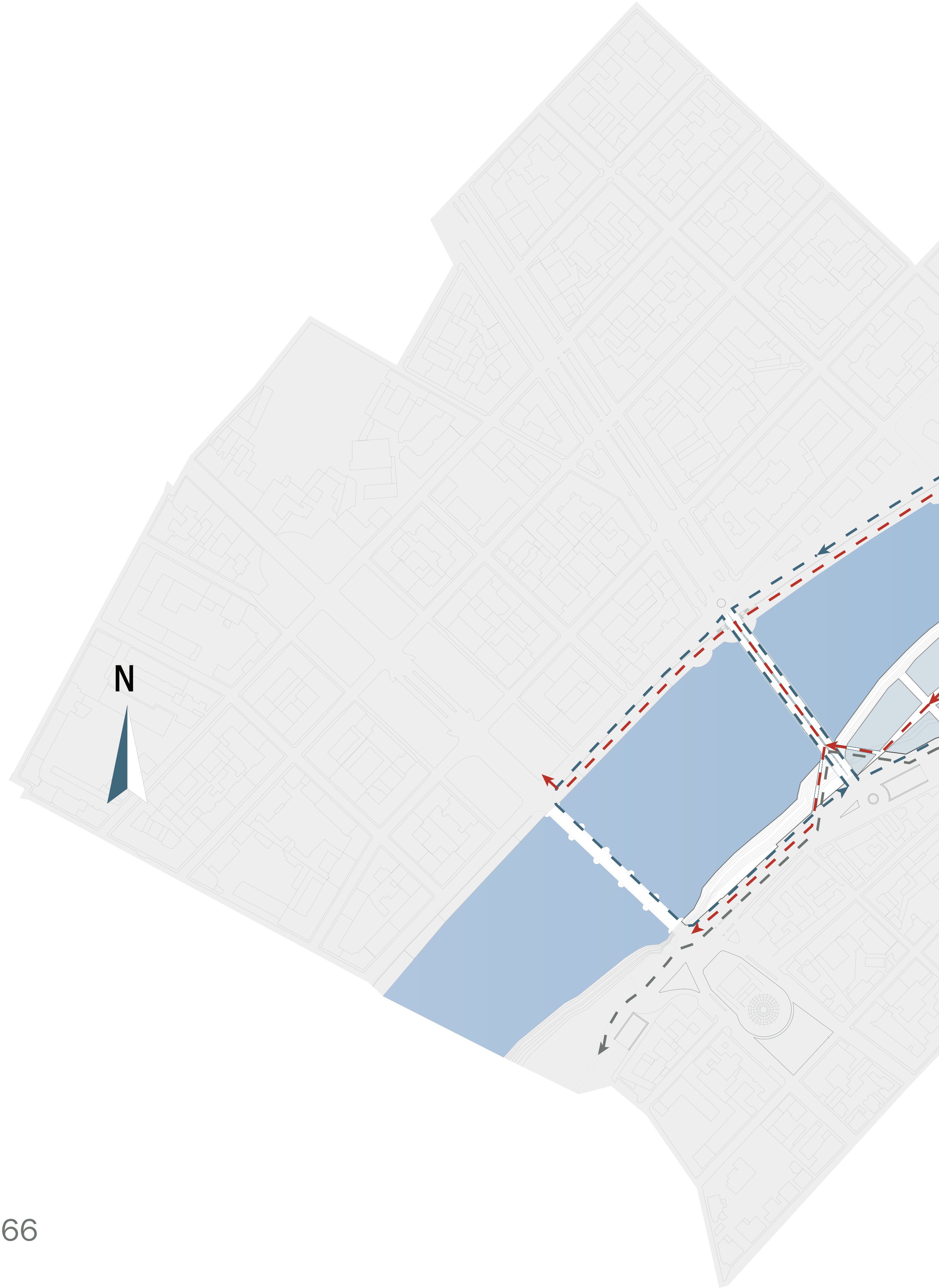
2
THE NEW ARRANGEMENT OF THE PARK'S DISTRIBUTION ALLOWS TO USE DIFFERENT PATHS WALKING

SERIES OF PROJECTS THE PEDESTRIAN PATHS differences



3
THE COMPLEX SYSTEM OF ROUTES, IN EASTERN PART OF THE BRIDGE, ALLOWS TO FACILITATE THE FLUXES OF PEOPLE

4
IN THE WESTERN PART OF THE BRIDGE, THE LEVELS ARE INTERCONNED, NOWADAYS TO CROSS THE RIVER IT IS NECESSARY A BRIDGE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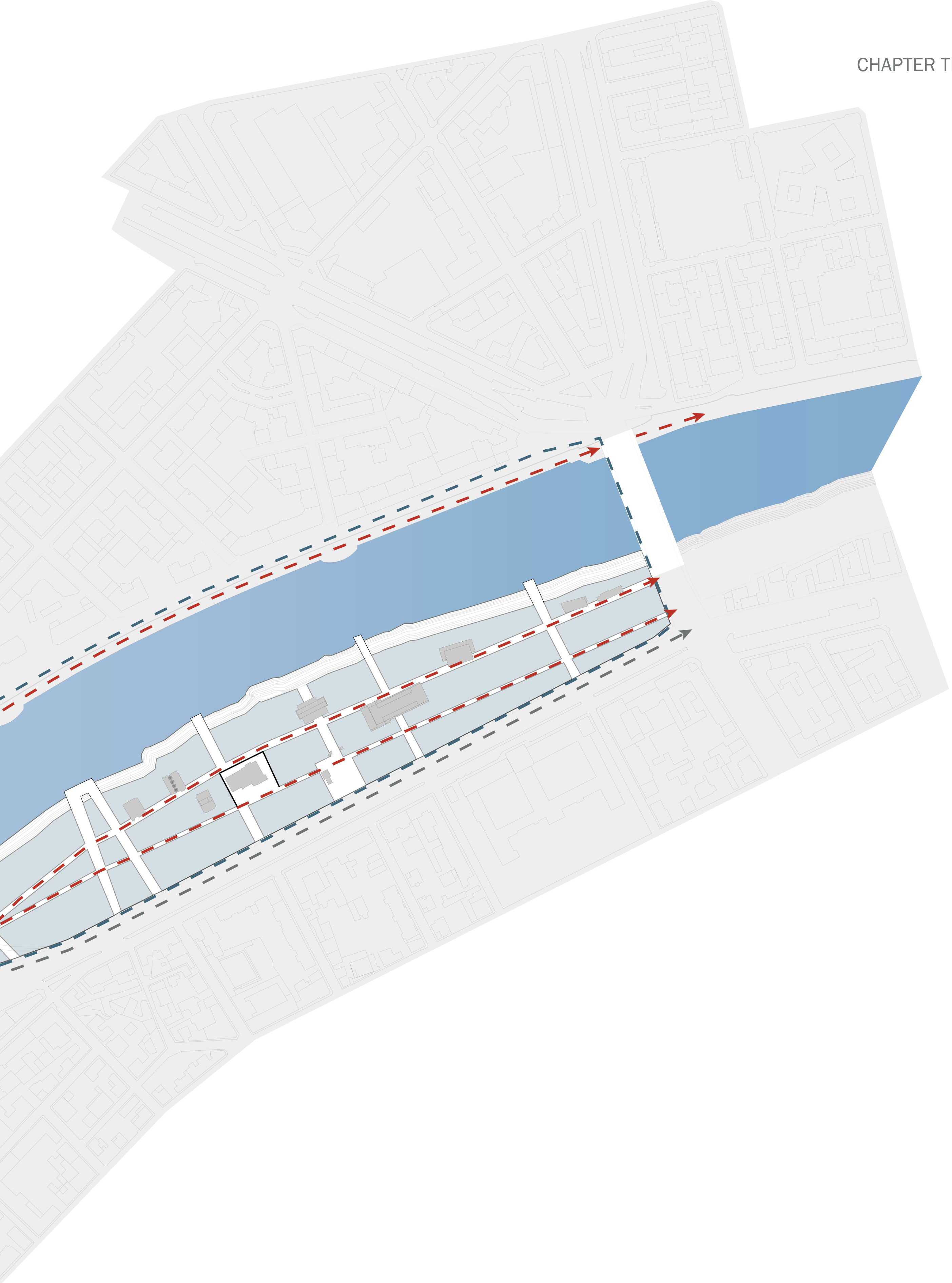


path plan

SERIES OF PROJECTS THE EXISTING BUILDINGS

Library Geisser

photo source
article “La biblioteca “Geisser” chiuderà per due anni: al via il progetto di riqualificazione” | date Saturday 04 January 2020
link <https://www.torinoggi.it/2020/01/04/leggi-notizia/argomenti/attualita-8/articolo/la-biblioteca-geisser-chiudera-per-due-anni-al-via-il-progetto-di-riqualificazione.html>

PUBLIC LIBRARY GEISSER

The construction site for the renovation was to begin on 7 January 2020 and suspend the activities of the library until February 2022. Due to the Covid-19 emergency, the start of work has been postponed but the projects have already been approved and will take place.

The redevelopment intervention is part of the European program “PON Metro 2014-2020” to promote sustainable urban development: the goal is to achieve the minimum energy performance requirements, reduce consumption and promote the safety of workers and users.

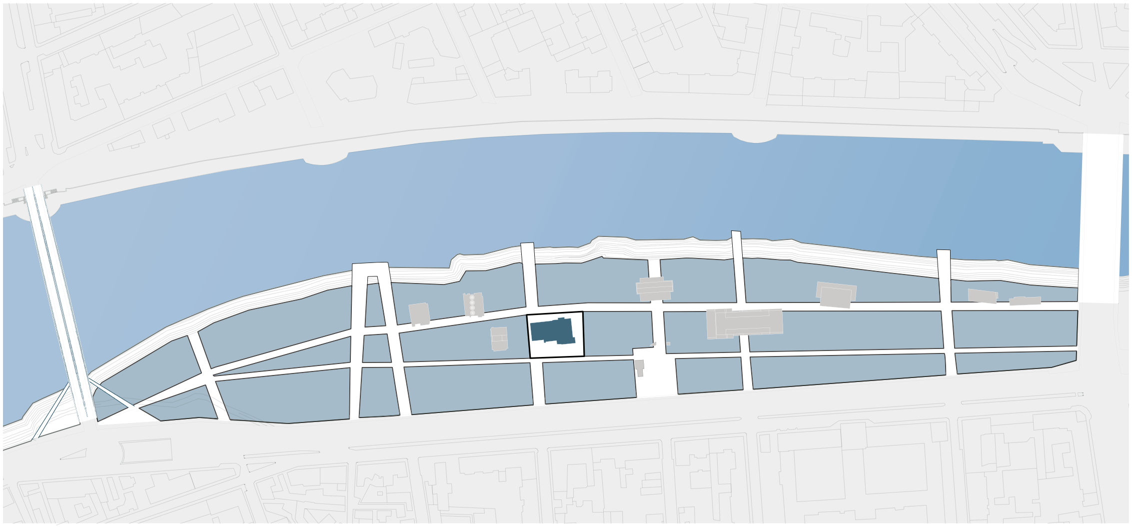
The building, of 590 square meters, has been the seat of the library since the early 1970s, but its construction dates back to the 1950s, as the original seat of the “Provincial Butchers Association”. Its position inside the park, even if central and with a public function, has always been disconnected from the activities of the park: the fences isolate it, the use of the park for library users is possible only by exiting it. The park project allows any decision the library managers take:

- if they had to maintain the private sense of the building by keeping the gates, the block of the grid that includes the structure can be circumnavigated and the green would frame it by inserting it and enhancing it from a visual point of view

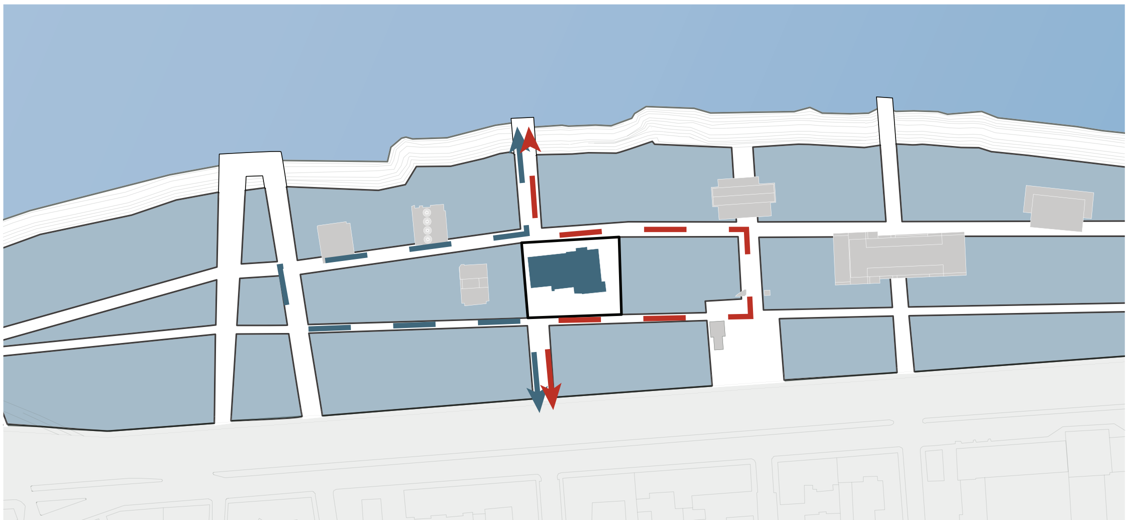
- if they were to decide to make the space inside the library enclosures public, the grid would allow the permeability of the area by connecting the building to the flows of people on two sides, with four sides of public green and privileged access to the new ones overlooking the river

Considering the conditions of the park nowadays it is understandable the closure of the structure for safety reasons. But, considering the function of the building, the idea of a park that the new bridge suggests and its central position, ideal, both for improving the condition of users and for being one of the development points of the total redevelopment of the Park Michelotti, is to make the use of the library’s external spaces as public as possible.

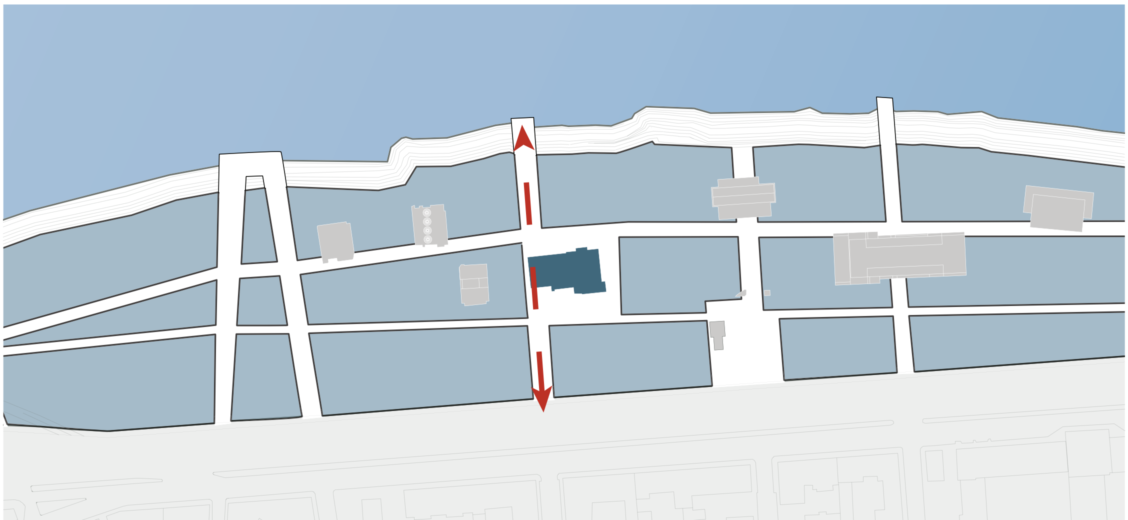
SERIES OF PROJECTS THE EXISTING BUILDINGS



POSITION IN THE PARK



PRIVATE OPTION PATHS



PUBLIC OPTION PATHS

SERIES OF PROJECTS THE EXISTING BUILDINGS
MIMAT museum

photo source
article "All'ex rettilario del Michelotti sorgerà il Museo Internazionale della Marionetta" | date Tuesday 16 June 2020
link <https://www.torinoggi.it/2020/06/16/leggi-notizia/argomenti/attualita-8/articolo/allex-rettilario-del-michelotti-sorgera-il-museo-internazionale-della-marionetta.html>

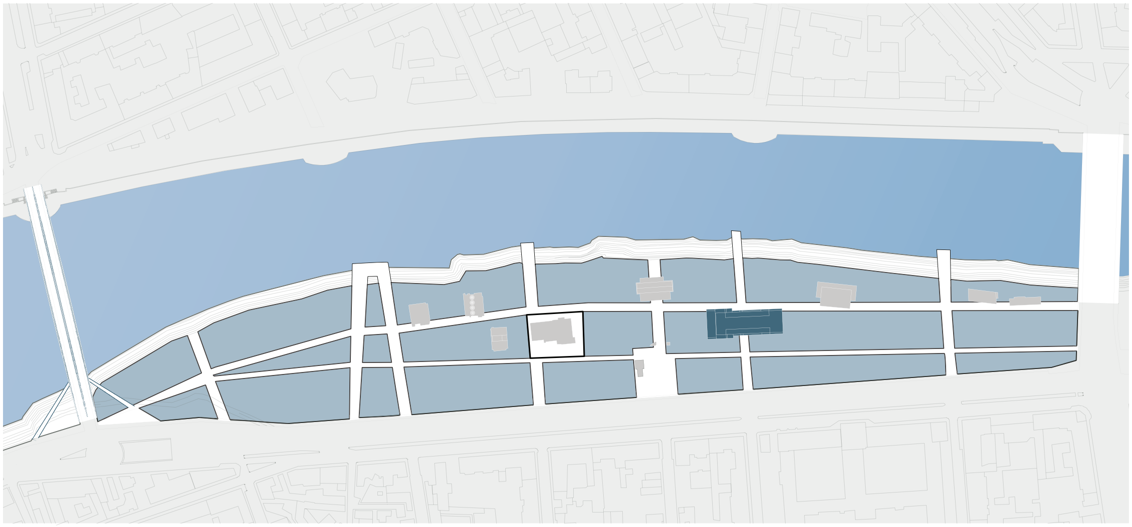
PROJECT MIMAT MUSEUM

The park's most prestigious architecture, the subject of numerous redesigning initiatives that have never been carried out over the years, seems to have found its next function. The Venturelli reptile house will become a great center of culture. The adaptive reuse project was presented in June 2020: the AGST association, manager of all the activities of the Compagnia MarionetteGrilli, is committed to creating projects and works for MIMAT, the international puppet museum. The permit provides for the recovery of the building to be used for theatrical and museum activities promoted by the association, through a complex refurbishment project.

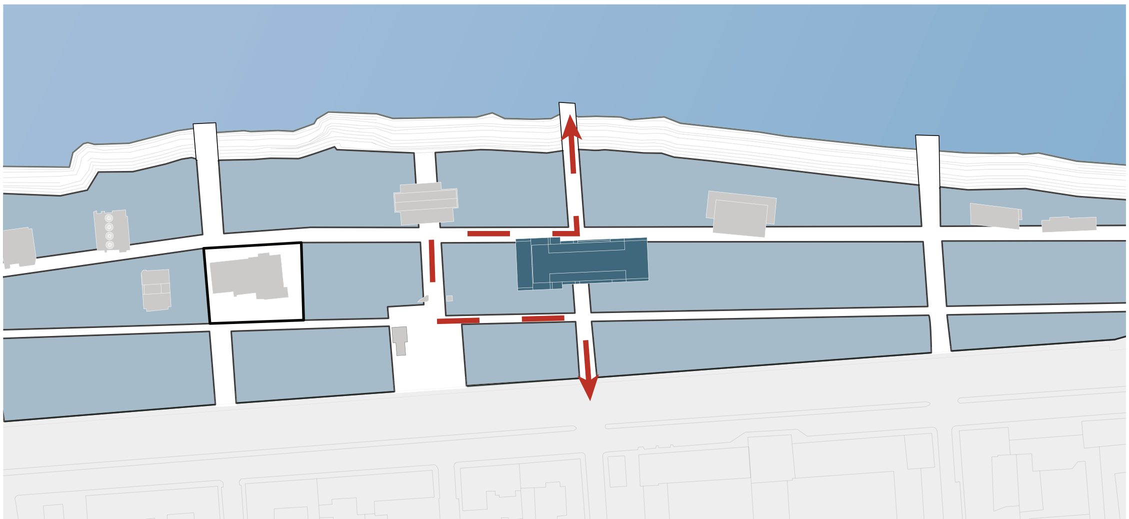
The works will start in 2021 and will contribute to the construction of a green building, built with sustainable materials and the almost complete conservation of the existing building. The aim is to redevelop Parco Michelotti, develop the use of sustainable projects and stop the deterioration of the ex-zoo's reptile house. According to the project presented, inside it will find: permanent exhibition of puppets from the Grilli collection with tour itineraries, exhibition area for temporary exhibitions on puppetry, theater room for puppet and marionette shows with 120 seats, classrooms used for laboratory, classrooms for restoration, study area with library, video library and documentation center, bar, café and book shop.

Observing the drawings of the project, the main entrance to this cultural center will maintain its original position, making the part immediately adjacent to the side public. As for the other sides it is incomprehensible and the absence of plants doesn't help. But, considering the position and functions of the new building, adding also the vaunted sustainability of the intervention, the building should be fully integrated into the park. Making the air around the new MIMAT public would allow it to have multiple entrances and exits, favor different paths for the different types of customers of the structure and make the cafeteria a service for the whole park and not just for museum visitors or spectators of the theater.

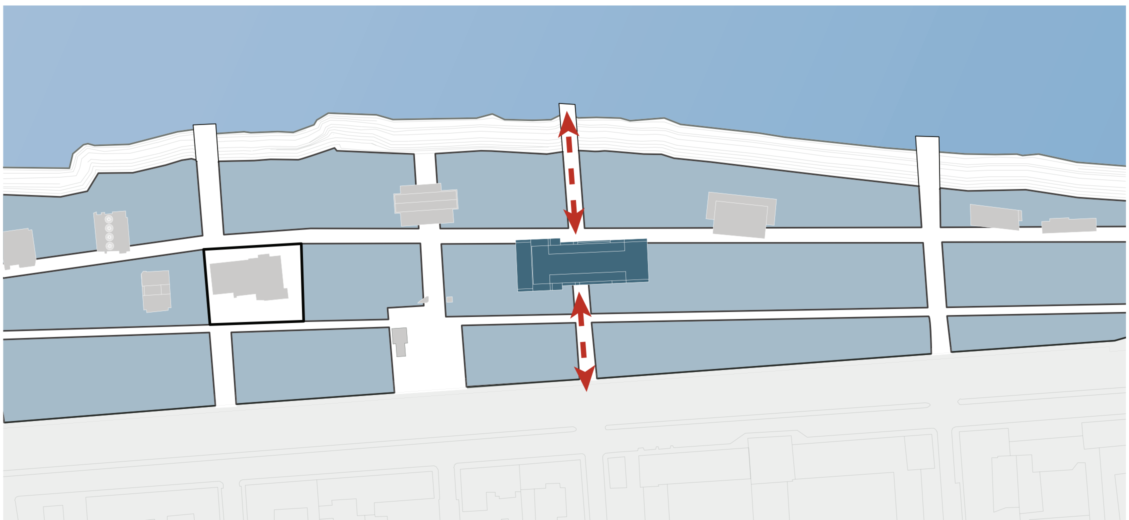
SERIES OF PROJECTS THE EXISTING BUILDINGS



POSITION IN THE PARK



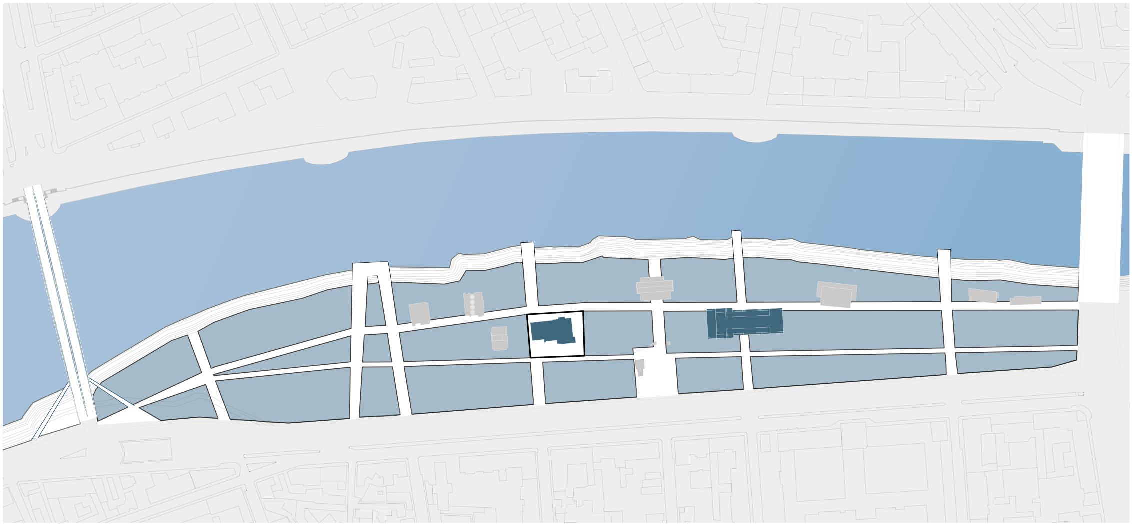
PRIVATE OPTION PATHS



PUBLIC OPTION PATHS

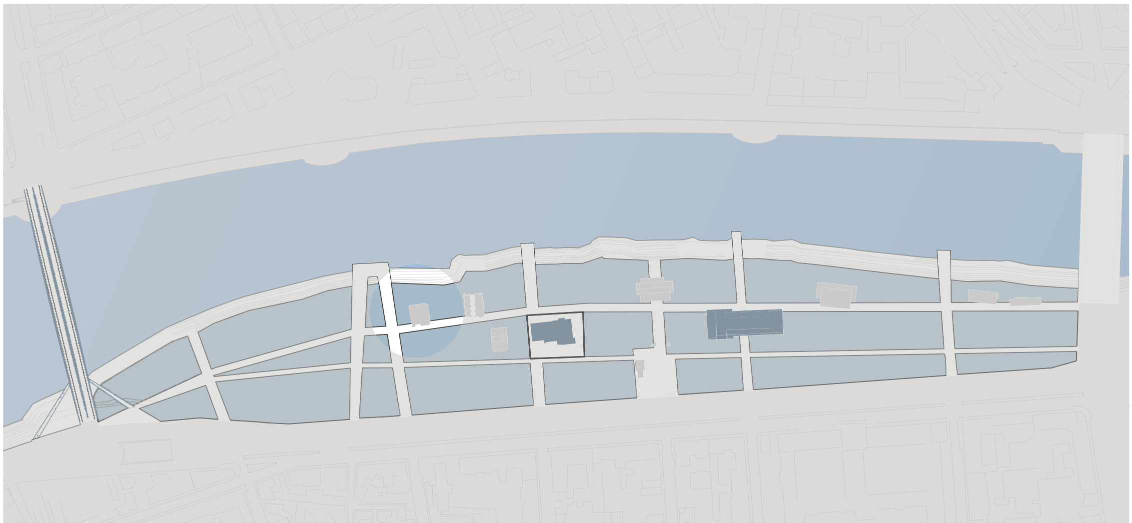
SERIES OF PROJECTS **THE EXISTING BUILDINGS**

future



IDEA OF PARK

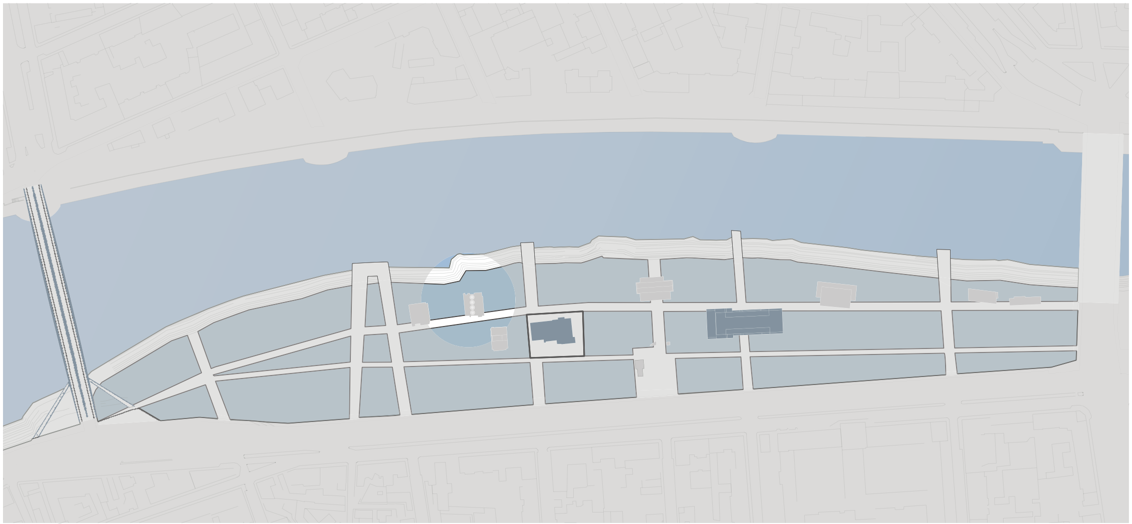
Considering the new function of Venturelli's reptile house, the restoration of the Geisser library and the obvious interest in wanting to have more public space in the park instead of the current decay: Parco Michelotti is increasingly taking the shape of an urban park with various functions. The reference is found again in Turin: the Parco del Valentino. The park is green, within the urban pattern, central in the city. They are privileges that allow various situations and not a single function.



HOUSE OF THE TIGER

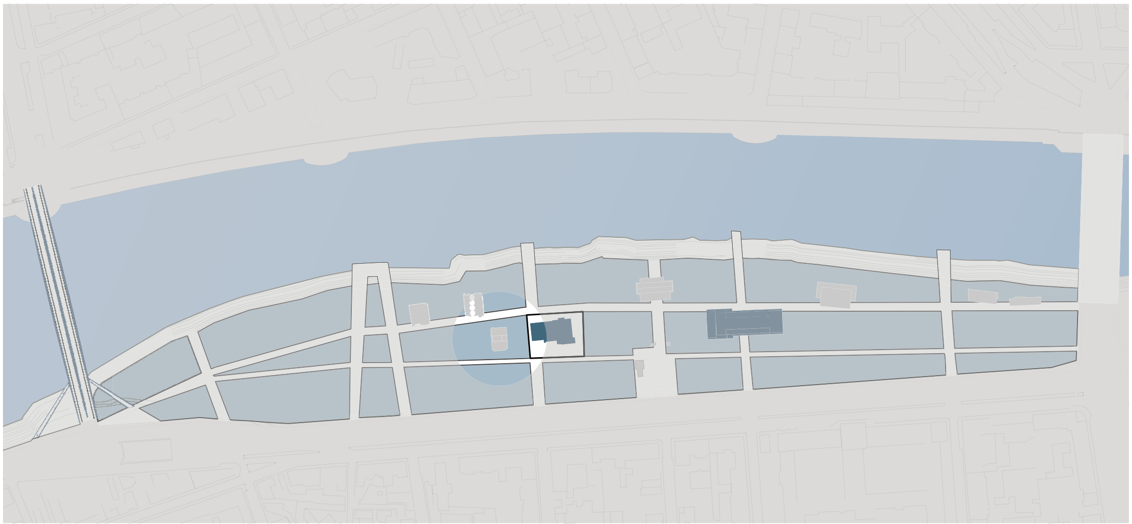
Following the reasoning linked to the Valentino Park, within it we find different situations: from cultural and institutional buildings such as universities and museums, to sports activities related to the river and playgrounds, discotheques and refreshment areas up to to large public spaces open all day and those closed at night. The tiger house is the first building to be found when arriving from the walkway and the paths of the new bridge, it has a privileged position: placing an edge on the path shows its presence.

SERIES OF PROJECTS **THE EXISTING BUILDINGS**
future



HOUSE OF POLAR BEARS

A little further on, the polar bear house has dimensional and positional characteristics very similar to the tiger house but inspires a less public future redevelopment project, slightly more secluded, not central in the park and a stretch that goes towards the river which is very steep. Or it could be a free pavilion and be filled temporarily: the Parco del Valentino hosts large temporary events, city-related activities and international events. Again, it is not necessary to find a permanent function.

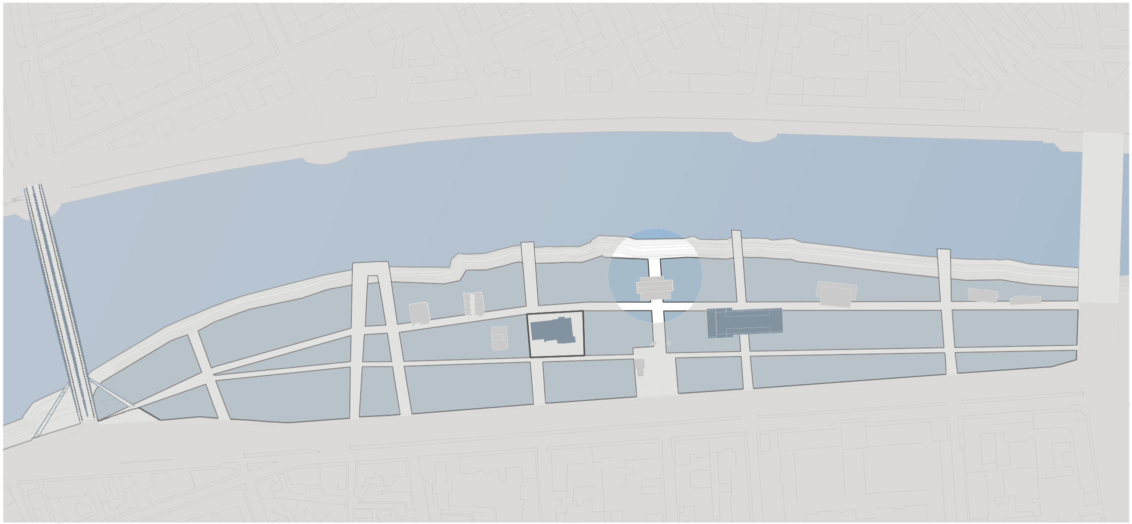


HOUSE OF MONKEYS

The monkey house is located in an isolated situation but relatively close to all the paths and the bridge: Among the trees of Parco Michelotti and in front of the fences of the Geisser library it is possible to give it many functions . With the park regeneration project, the first step towards the total renewal, it was planned to demolish all the ancillary structures to the zoo buildings: vast, external fences, concrete constructions that reproduced the habitats are now degraded dangerous and useless to the future of the park.

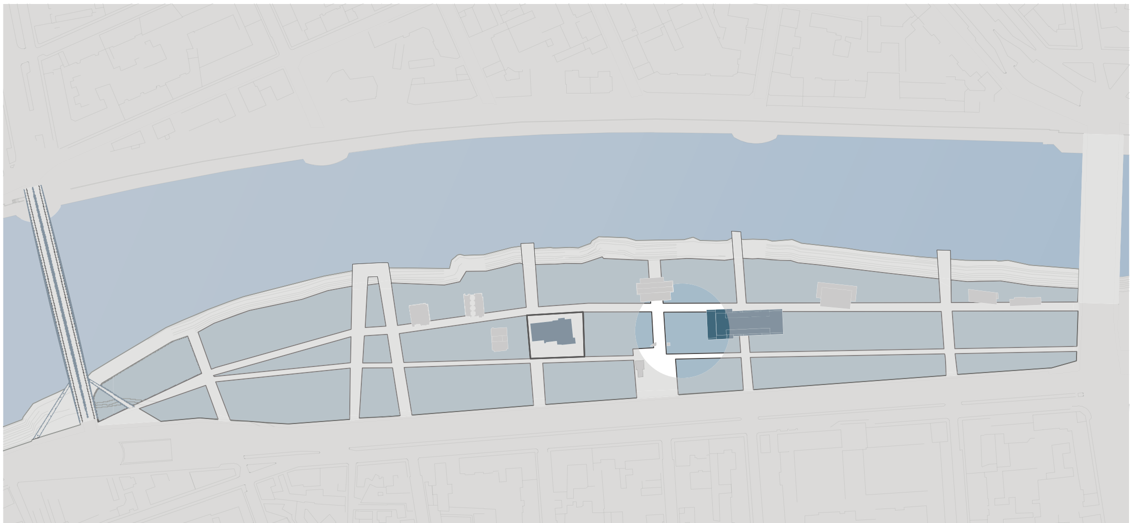
SERIES OF PROJECTS THE EXISTING BUILDINGS

future



HOUSE OF THE GIRAFFES

The house of the giraffes is in an optimal position for less public functions: it has the entrance in front of that of the reptile house and in line with the widening where the parking lot is located, it is directly connected in its rear part with a path that leads to the river, it too can be for the exclusive use of the new function of the architecture itself. Then, the main facade, made by a large opening on one of the paths but compared to it is like the churches: recessed, less visible from near but more visible from far.

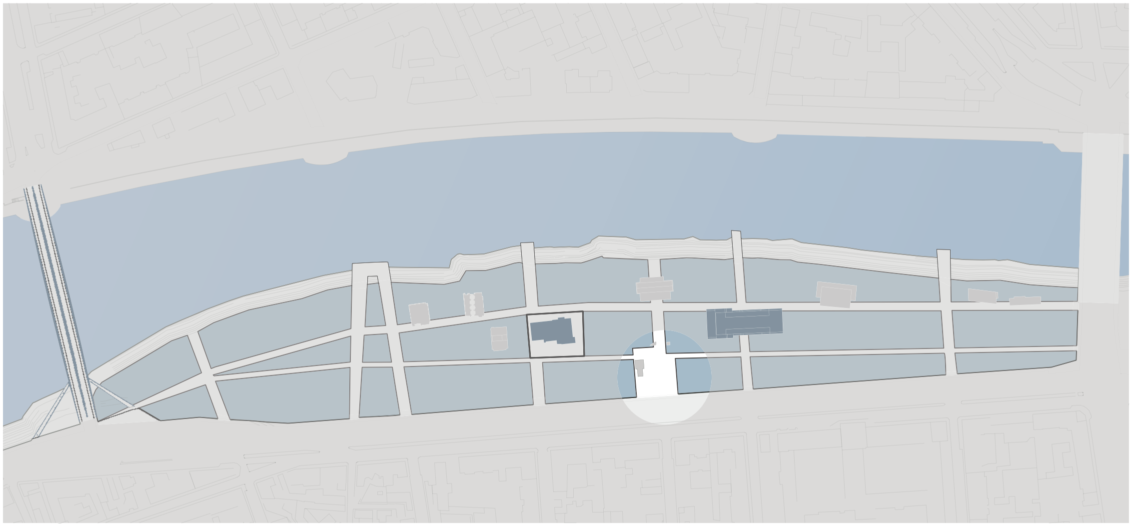


EX-ZOO ENTRANCE

The entrance to the zoo are two monolithic structures in reinforced concrete, one of the two was the ticket offic. Preserving these two structures without a function than the function of their existance is a wise choice according to my way of experiencing places. Leaving a direct memory of what the park has been like for a long time allows you to have respect for the city. Preserving even the graffiti can be a warning to make the park no longer return to the conditions of decay in which it still is today.

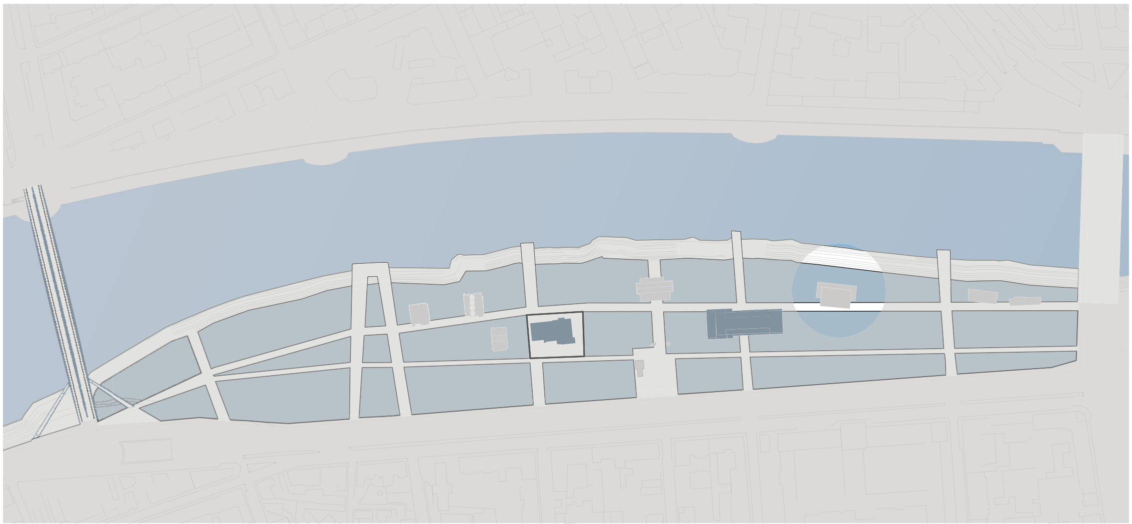
SERIES OF PROJECTS **THE EXISTING BUILDINGS**

future



“FUORI DALLO ZOO”

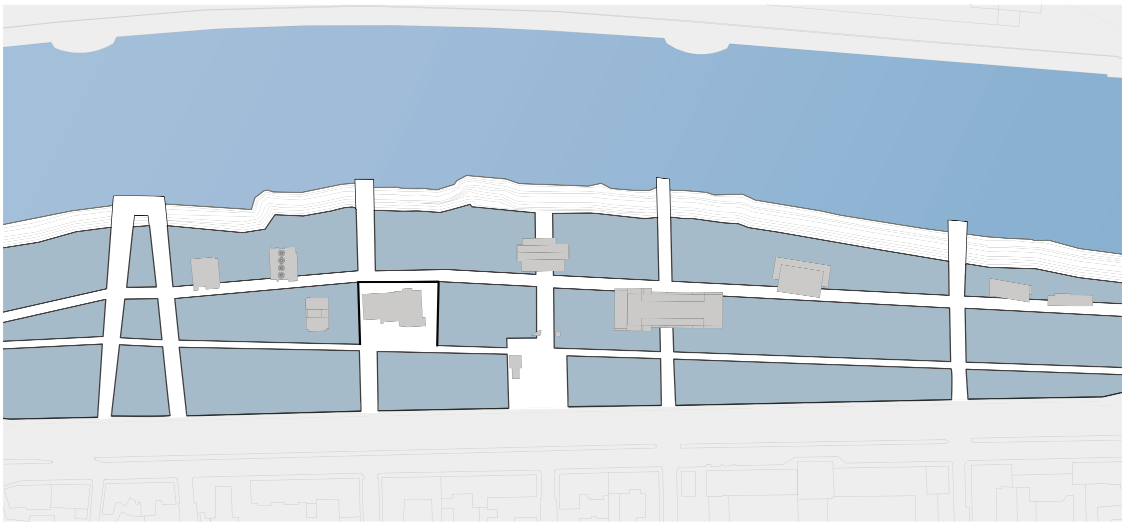
“Fuori dallo Zoo” is the name of a refreshment point present in what is now a parking lot and that the redevelopment project of the park, promoted by the degree thesis, eliminates to create a continuity of the paths and greenery within the park itself . This refreshment point, in accordance with my future idea of a park, must continue to exist but increasing the level of quality, currently poor. The location is ideal: near many buildings of the park between, close to the paths, in a part of the park where green is interrupted.



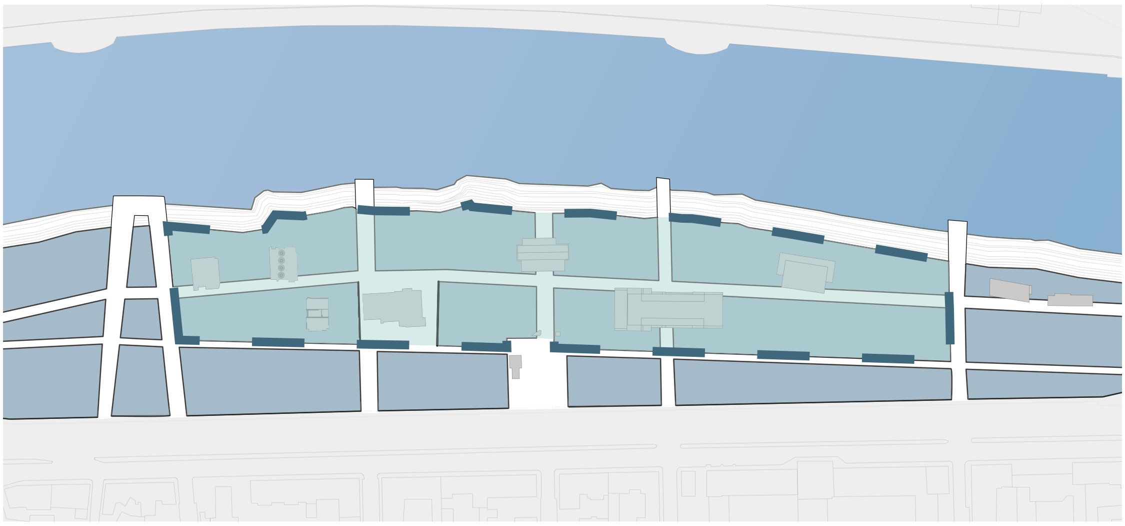
HOUSE OF THE HIPPOS

The house of the hippopotamus is isolated from the other buildings of the park, but it has its peculiarities: the second largest after the reptile house, around it there is a large space for possible extensions or the possibility of activities related to it but to be done outdoors, then, the building is equidistant with two overlookings of the river and with the front parallel to a pedestrian path in the park. Private or public, temporary or permanent like every single piece of the future Parco Michelotti.

SERIES OF PROJECTS THE CENTRAL STOA
concept

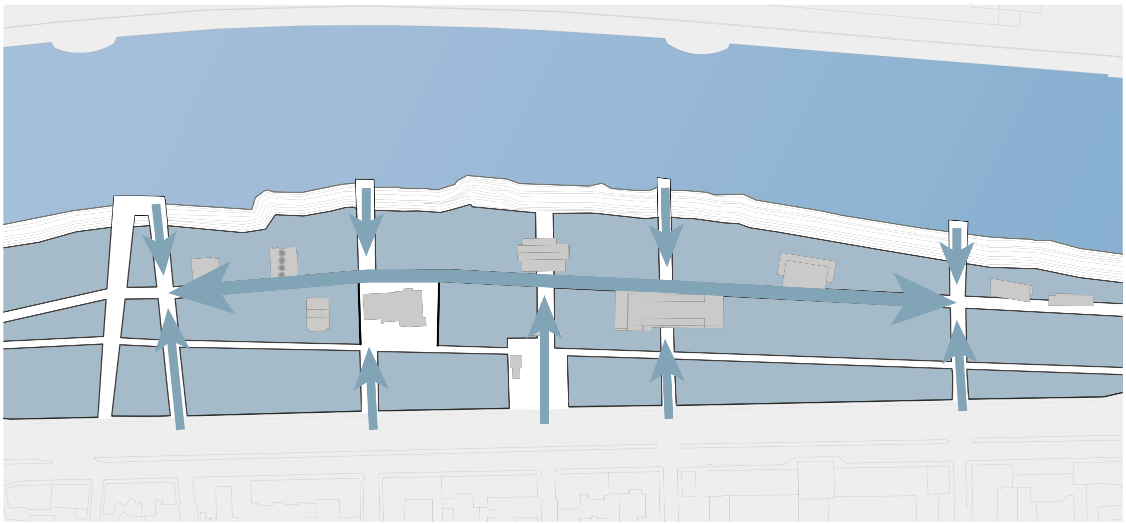


A
THE INFRASTRUCTURES ARE DISCONNECTED BETWEEN THEM, PEOPLE NEED PSYCHOLOGICAL AND PHYSICAL REFERENCE POINTS OF THE SPACE



B
THE AREA, WHERE THE INFRASTEUCTURES OF THE EX-ZOO ARE FOUND, IS A PORTION OF PARK, ITS HEART

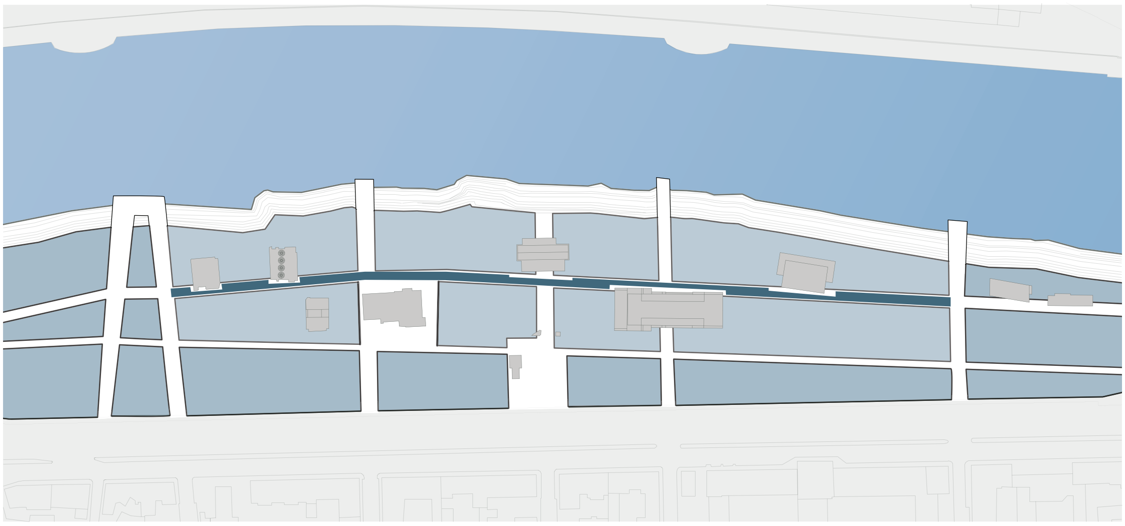
SERIES OF PROJECTS THE CENTRAL STOA
concept



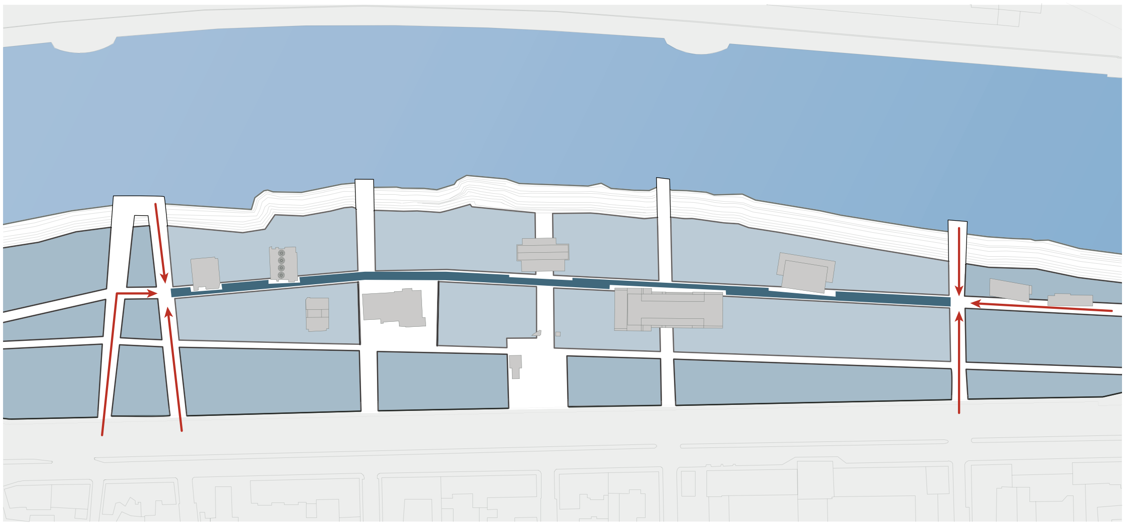
C
THE MAIN PATH SIZES THE AREA INTO TWO PARTS AND DIVIDES THE ARCHITECTURES AND THE ROUTES IN TWO DIFFERENT SETS

D
PLACE AN OBJECT THAT CONNECTS ALL THE STRUCTURES OF THE PARK, THEY MUST SCULPT THEIR PRESENCES ON IT

SERIES OF PROJECTS THE CENTRAL STOA
result



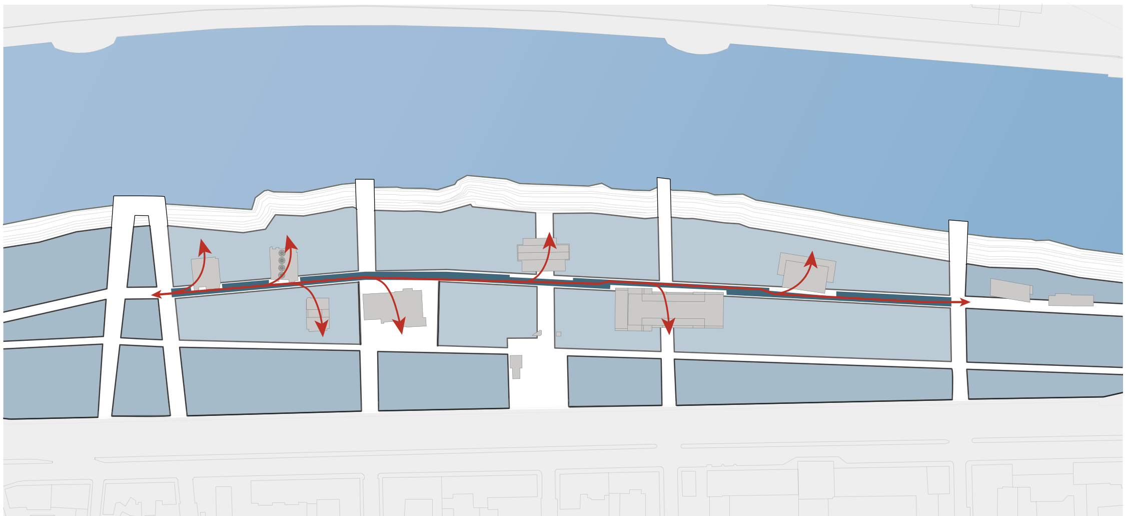
A
THE STOA REPRESENTS A LONG PORCH THAT MAKES PART OF THE MAIN PATH COVERED, SETTING RULES FOR FUTURE RESTORATIONS



B
THE TWO MAIN ACCESSES REACHING THE CROSSINGS OF THE VARIOUS PATHS ALLOW THE PARK USERS TO PERCEIVE THE ARCHITECTURES

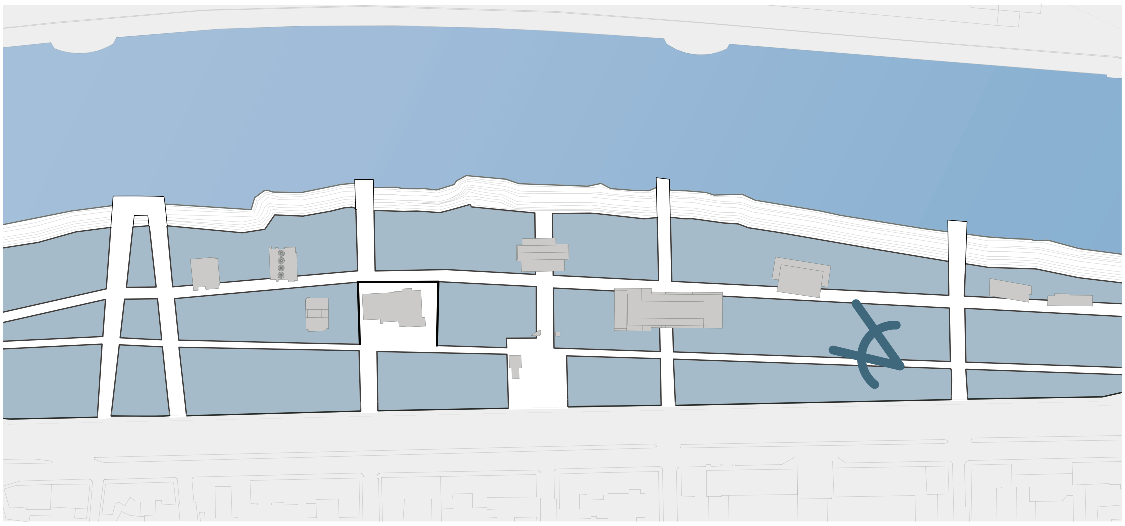
SERIES OF PROJECTS THE CENTRAL STOA
result

C
ALONG THE FULL LENGTH, PEOPLE GUARANTEED A COVERED PASSAGE, EVEN IN THE RESTINGS, THE SMALLER ONE COVERS A SPAN OF 1.20m

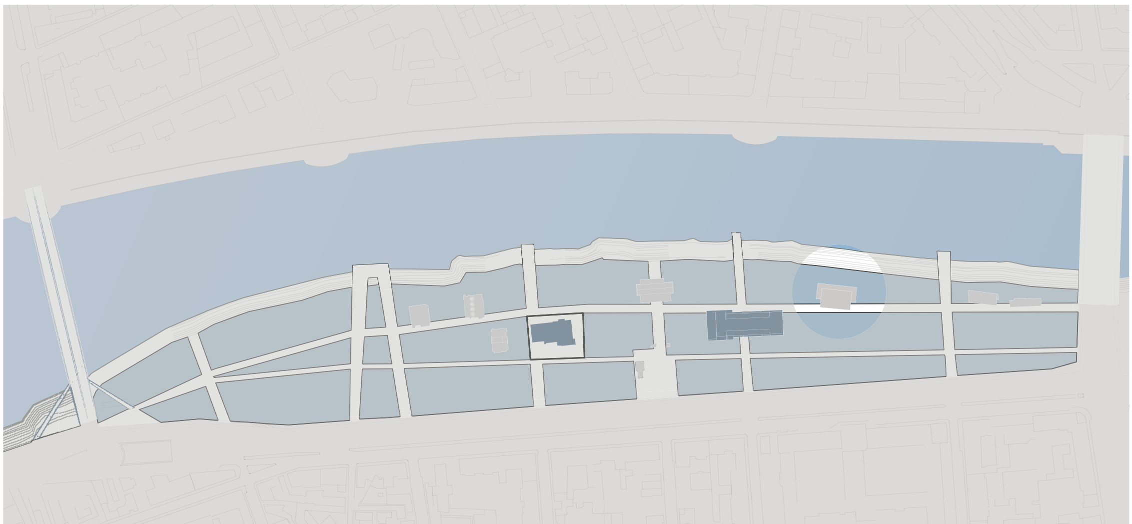


D
FROM THE STOA ACCESS TO THE VARIOUS ARCHITECTURES MUST BE GUARANTEED, THE PATH IS THE CENTER OF THE PARK'S REDEVELOPMENT

SERIES OF PROJECTS THE EXISTING BUILDINGS
future



VIEW POSITION



IN THE VIEW

HOUSE HIPPOS REPTILARY

SERIES OF PROJECTS THE CENTRAL STOA
views

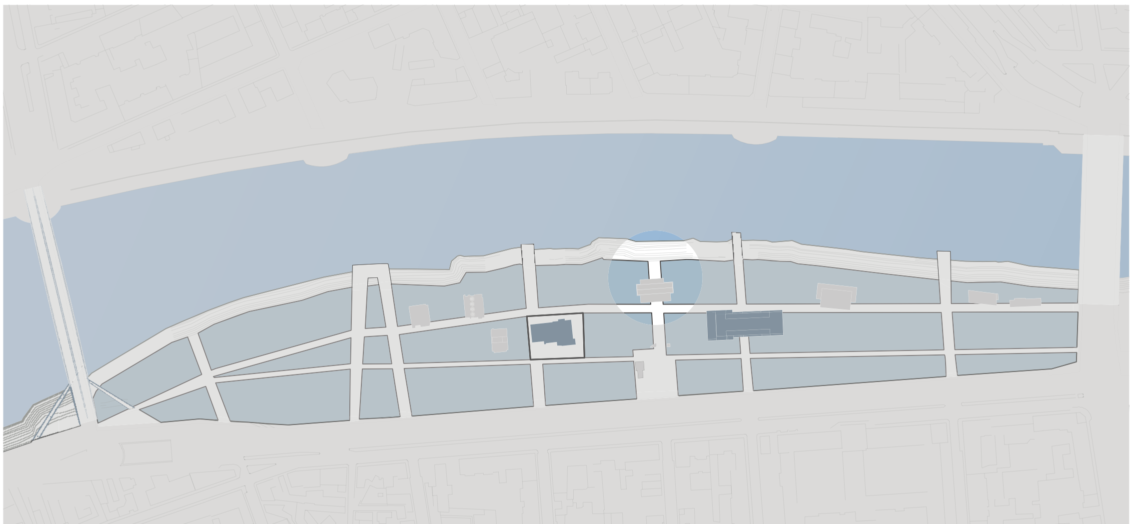
location
NORTH PART OF THE PARK, GREEN AREA BETWEEN THE BACK OF THE REPTILARY AND THE HOUSE OF THE HIPPO

features
THE STOA IS A FIL ROUGE THAT GIVES TOGETHER ALL THE INFRASTRUCTURE OF THE PARK IN A LINEAR AND PERMABLE WAY

THE STOA IS A CONTNUOUS PORCHED PATH, THE PITCH OF THE COLUMNS, LIKE THEIR DIAMETER, IS CONSTANT ALONG THE ENTIRE LENGTH

SERIES OF PROJECTS THE EXISTING BUILDINGS
future

VIEW POSITION



IN THE VIEW

HOUSE GIRAFFES
REPTILARY
GEISSER LIBRARY

SERIES OF PROJECTS THE CENTRAL STOA
views

location

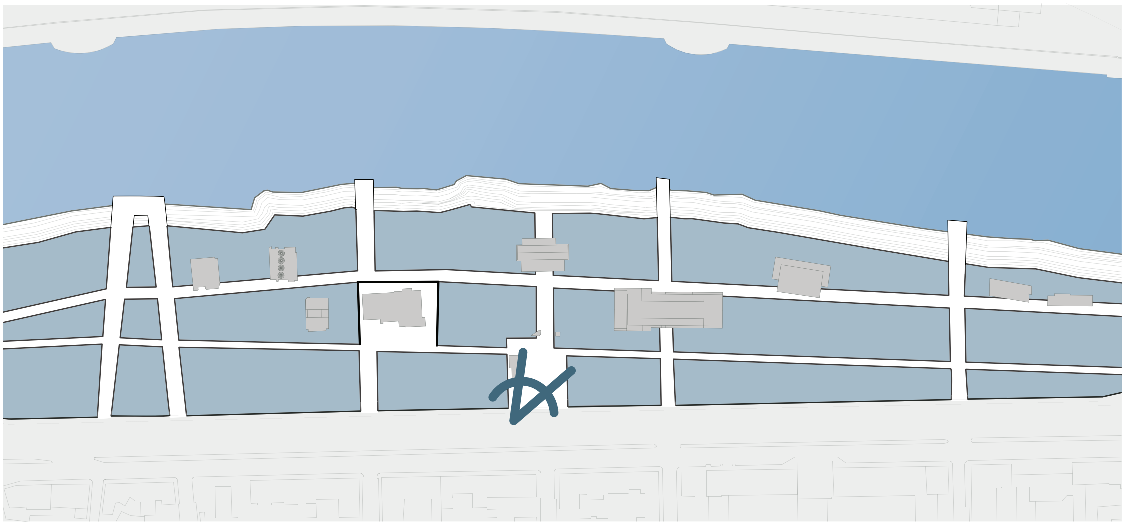
NORTH PART OF THE PARK, GREEN AREA BETWEEN THE NORTH SIDE OF THE GIRAFFE HOUSE AND THE REPTILARY SIDE TOWARDS THE RIVER

features

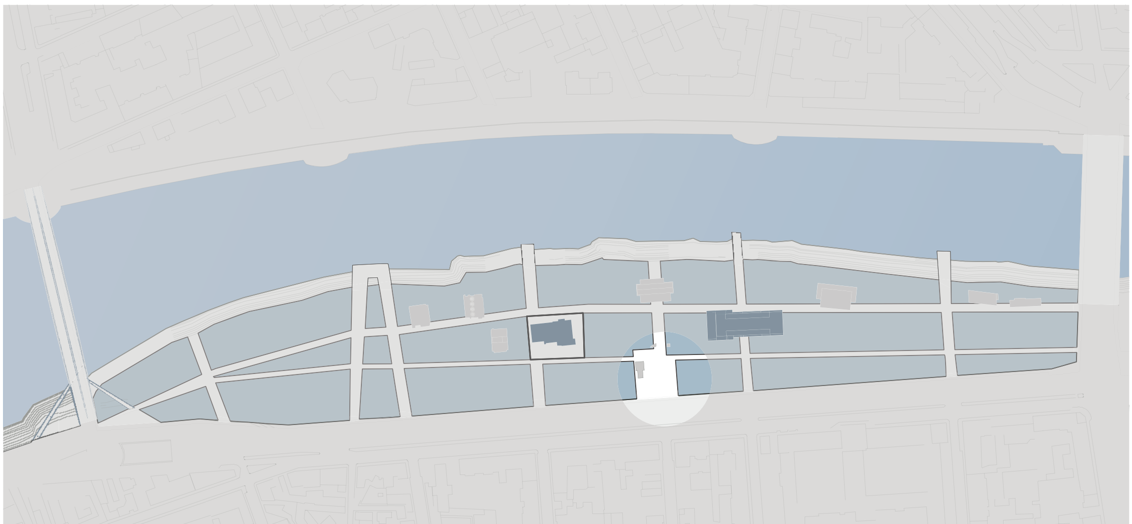
THE STOA IS ARCHITECTURE, ITS POSITION AND ITS SHAPE MODIFY THE SPACE INFLUENCING THE FUTURE INTERVENTIONS

THE STOA AND ARCHITECTURES SURROUND GREEN SPACES, PORTIONS OF PARK, WHERE ACTIVITIES CAN BE CONTAINED WITHOUT DISPERSION

SERIES OF PROJECTS THE EXISTING BUILDINGS
future



VIEW POSITION



IN THE VIEW

ZOO ENTRANCE REPTILARY

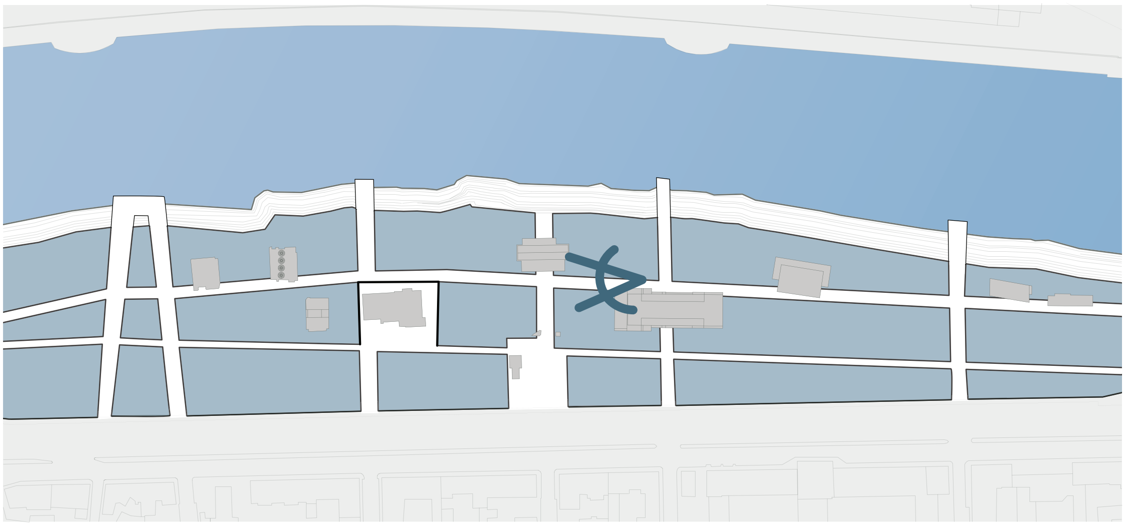
SERIES OF PROJECTS THE CENTRAL STOA
view

location
CENTRAL PART OF THE PARK, SPACE DELIMITED BETWEEN THE ENTRANCE TO THE ZOO, THE CAFETERIA AND PORTIONS OF GREEN

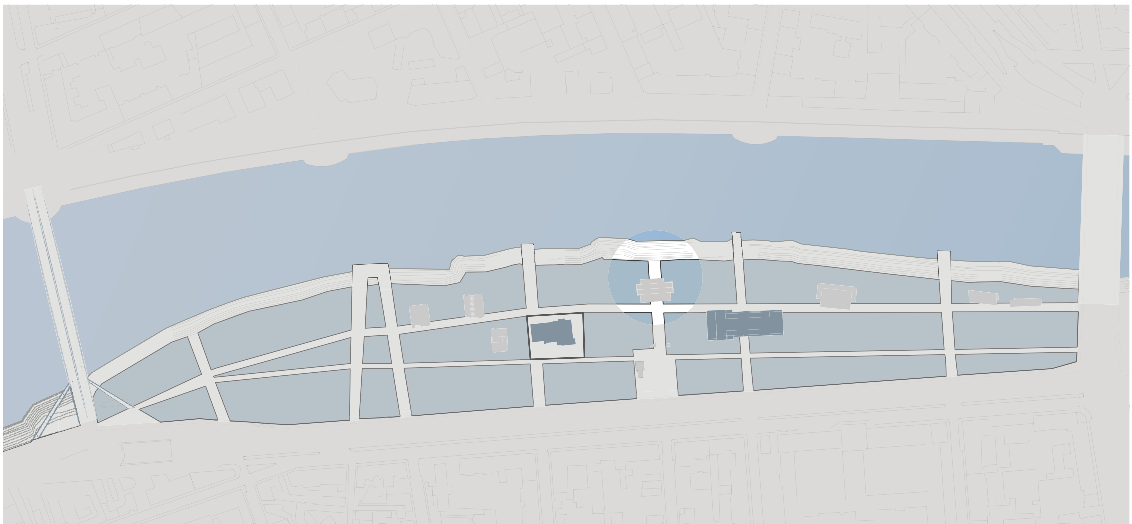
features
THE STOA IS A SIMPLE AND LINEAR STRUCTURE THAT HAS THE PRIDE OF BEING VISIBLE FROM DIFFERENT POINTS OF THE AREA, THE PEOPLE WHO WALK THROUGH AONO ATTRACTION TO OTHERS OUTSIDE

THE STOA IS SHELTER FOR ANYONE AND ACCESSORY OF ALL STRUCTURES

SERIES OF PROJECTS THE EXISTING BUILDINGS
future



VIEW POSITION

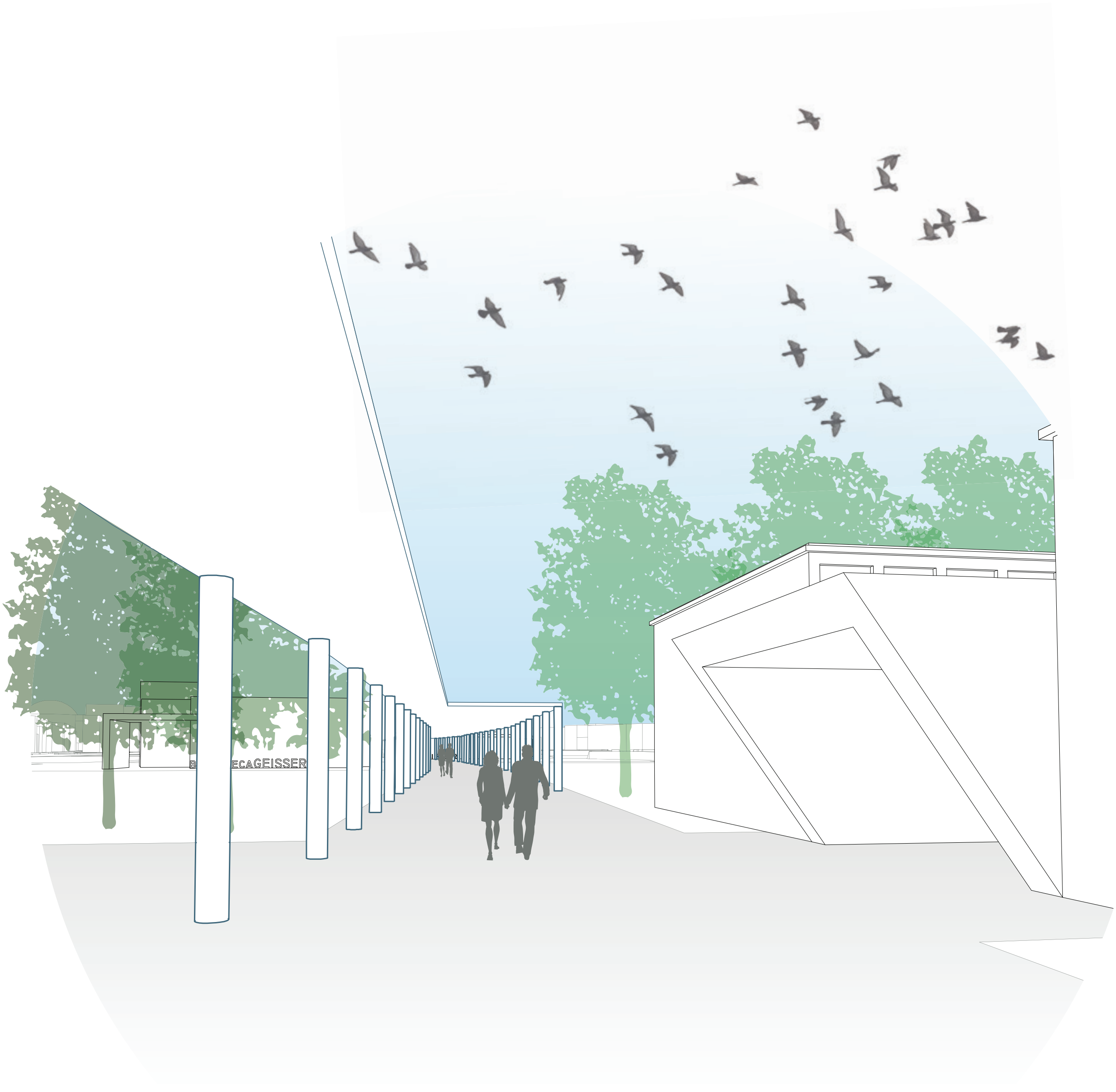


IN THE VIEW

HOUSE GIRAFFES
GEISSER LIBRARY

SERIES OF PROJECTS **THE CENTRAL STOA**

view



location

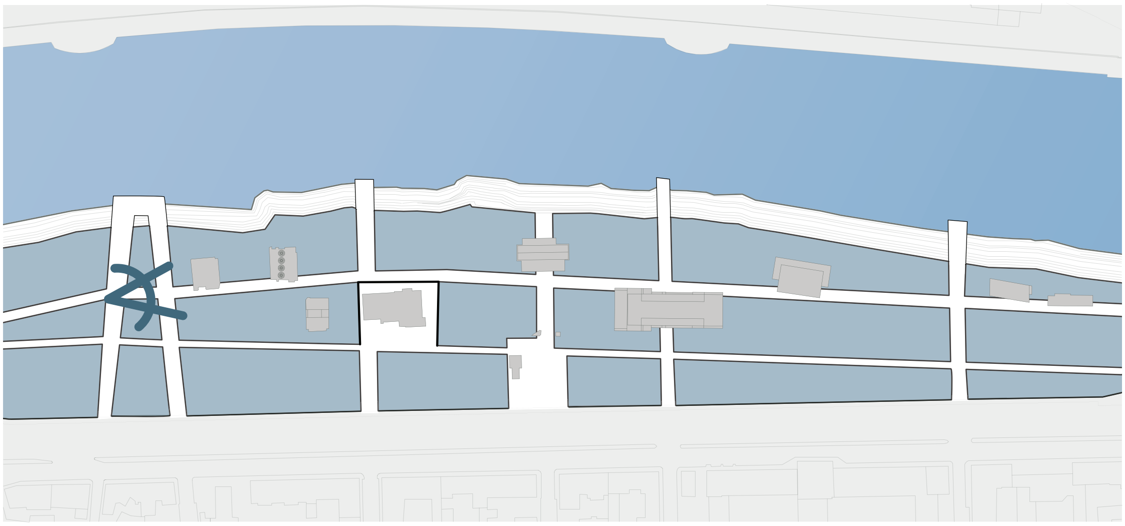
CENTRAL PART OF THE COVERED ROUTE, CORRESPONDING WITH THE ENTRANCE TO THE GIRAFFE HOUSE COMING FROM THE NORTH

features

THE STOA ALLOWS THE ROUTE BOTH COVERED ALONG ITS EXTENSION, AND IN UNCOVERED PORTIONS, WHICH ARE IN CORRESPONDENCE WITH THE ENTRANCES OF THE PRESERVED STRUCTURES OF THE PARK

STOA HAS A HEIGHT LOWER THAN ALL STRUCTURES, EMPHASIZING THEM

SERIES OF PROJECTS THE EXISTING BUILDINGS
future



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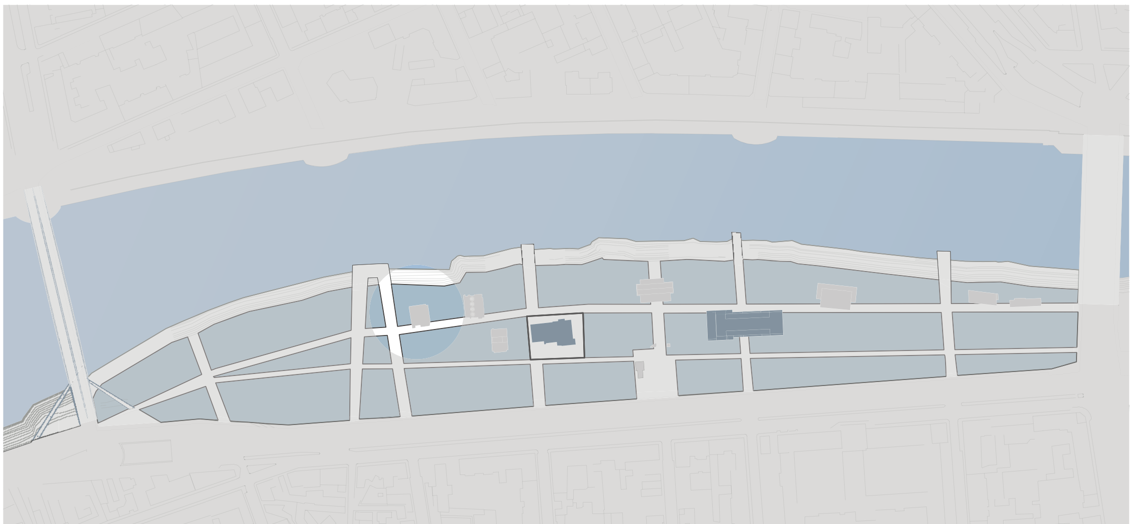


IN THE VIEW

HOUSE TIGER
GEISSER LIBRARY

SERIES OF PROJECTS THE CENTRAL STOA
view

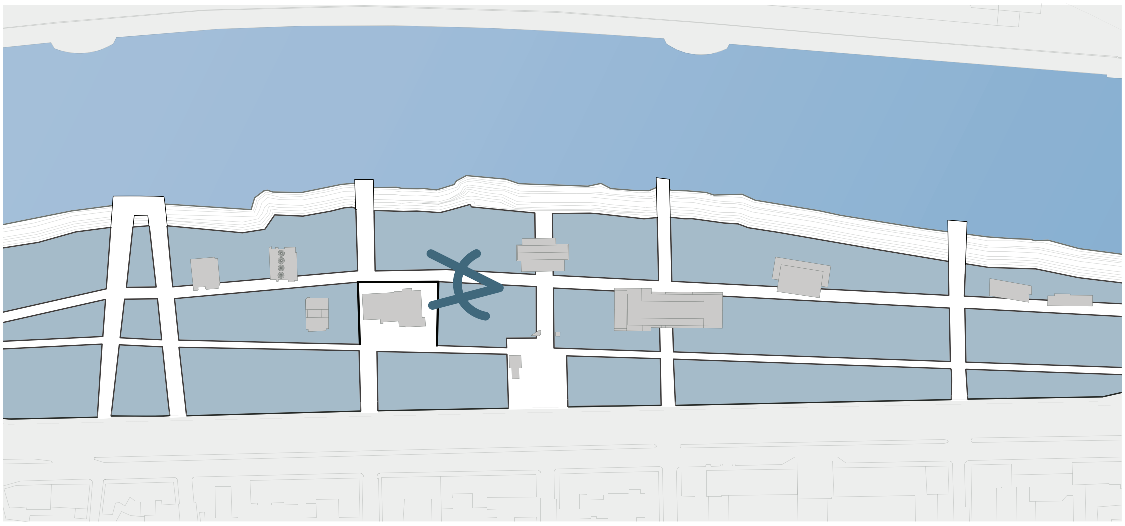
location
SOUTH PART OF THE PARK, MAIN ENTRANCE OF THE COVERED PATH, NEAR THE HOUSE OF THE TIGER

features
THE STOA LIMITS ALL FUTURE EXPANSION OF THE PRESERVED STRUCTURES AT LEAST AS TO VOLUMETRIC CHANGES AND PERSPECTIVE DIFFERENCES, TO MAINTAIN THE FORMAL APPEARANCE OF THE ARCHITECTURE

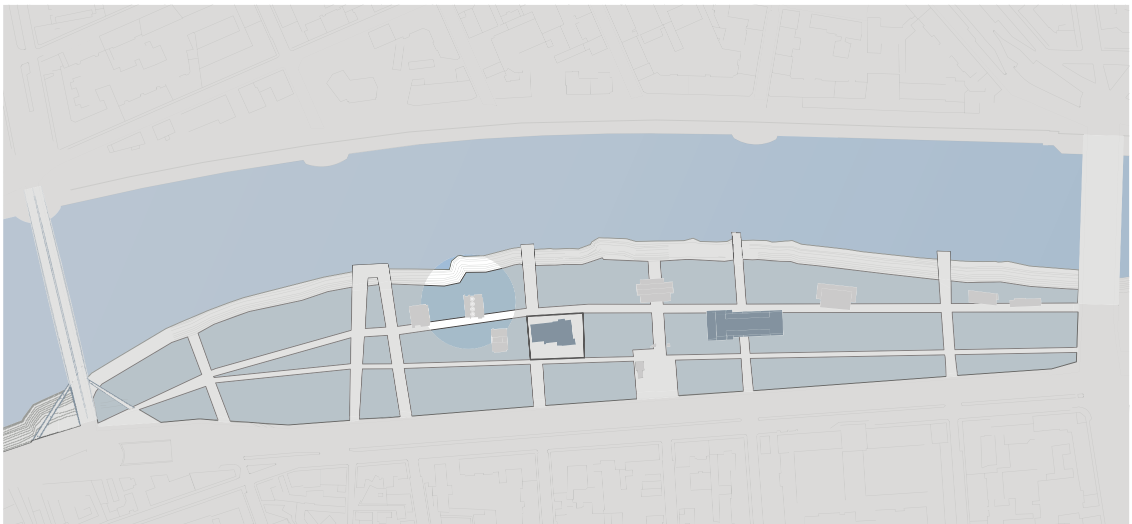
THE STOA HAS AN ANONYMOUS BUT VISIBLE MAIN ENTRANCE

SERIES OF PROJECTS THE EXISTING BUILDINGS

future



VIEW POSITION



IN THE VIEW

HOUSE BEARS
HOUSE MONKEYS

SERIES OF PROJECTS THE CENTRAL STOA

view

location

SOUTHERN PART OF THE PARK, CROSSING OF THE PATHS, COMING FROM THE NORTH THE HOUSE OF MONKEYS AND POLAR BEARS ARE VISIBLE

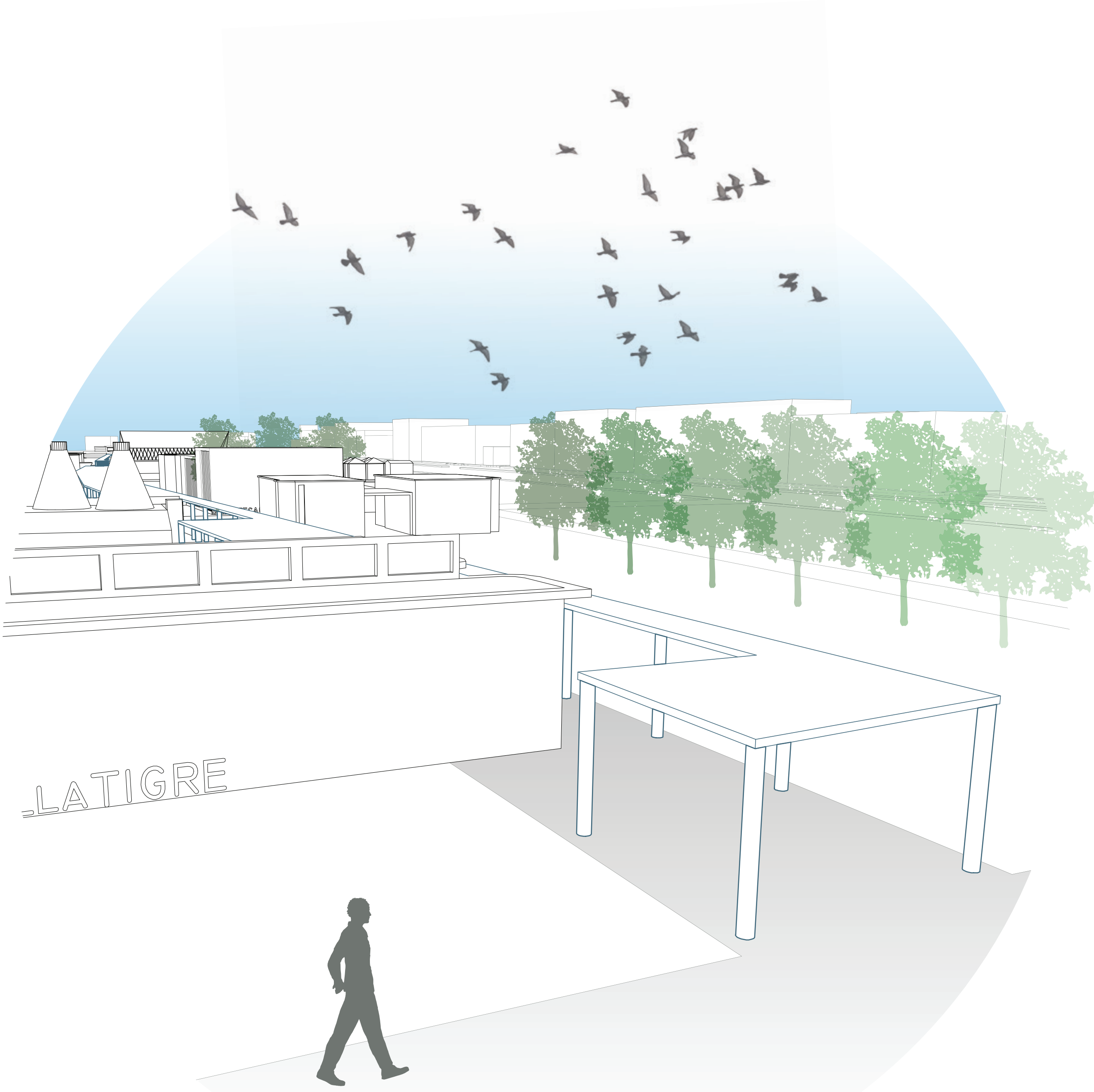
features

THE STOA IS NOT A PERFECTLY STRAIGHT PORCH BUT FOLLOWS THE LINE GIVEN BY THE PATH OF THE GRID, TYPICAL OF ITALIAN CITIES IS NOT TO SEE THE END OF A PATH, INVOLVING AND DECEIVING THE DISTANCES

LA STOA IS A WAY TO EXPERIENCE THE PARK, STAYING OR WALKING

SERIES OF PROJECTS THE CENTRAL STOA

alternatives



location

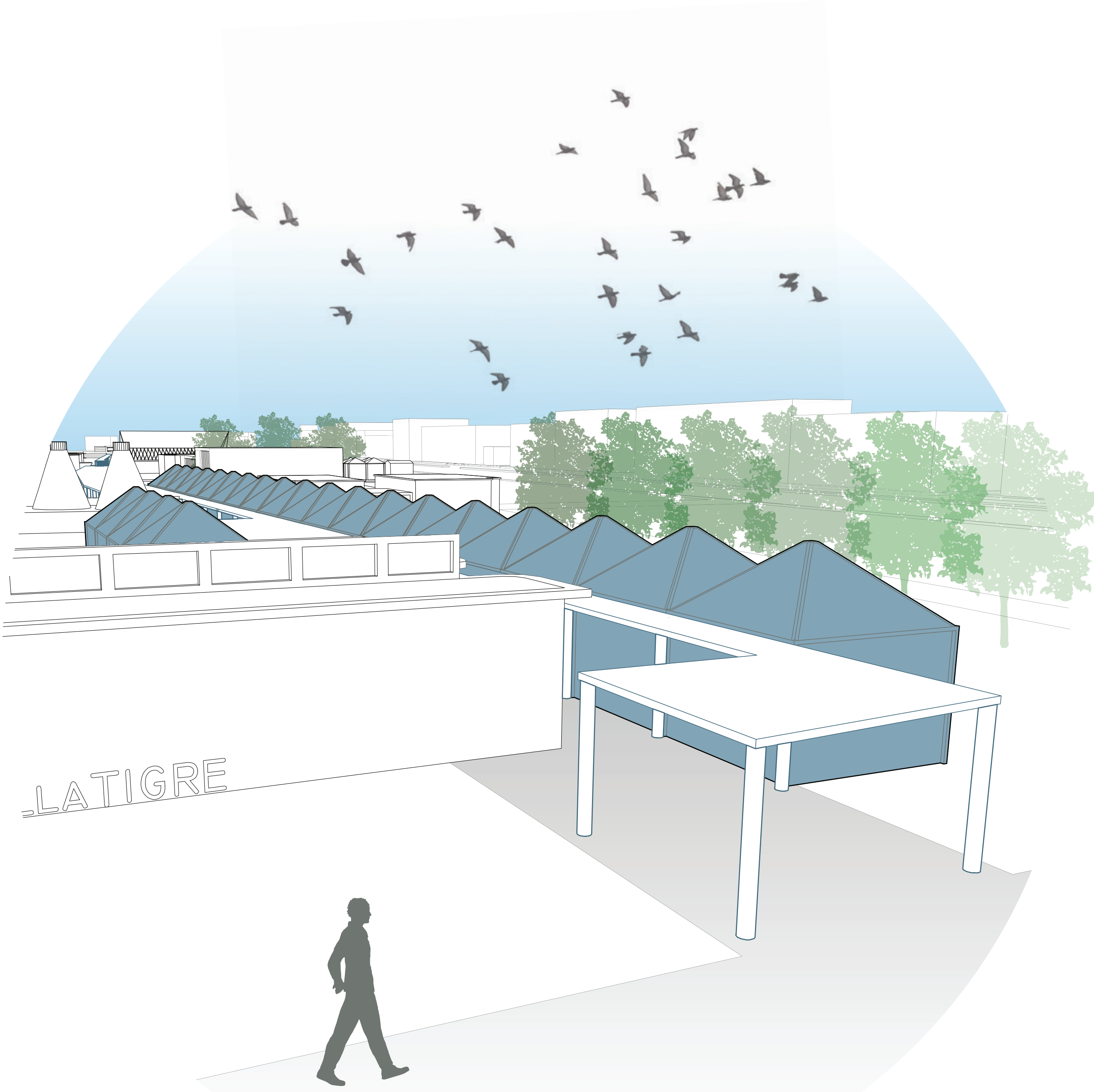
SOUTH PART OF THE PARK, MAIN ENTRANCE OF THE COVERED PATH, NEAR THE HOUSE OF THE TIGER

features

TTHE STOA IS COMPOSED BY COLUMNS, THE THIN COLUMNS REPRODUCE THE RHYTHM OF THE TREES, INDICATE THE WAY TO THE USERS OF THE PARK AND BLOCK THE CEMENTIFICATION IN THE AREA

THE STOA HAS BEEN DESIGNED WITH PRECISE RULES

SERIES OF PROJECTS THE CENTRAL STOA alternatives



location

SOUTHERN PART OF THE PARK, CROSSING OF THE PATHS, COMING FROM THE NORTH THE HOUSE OF MONKEYS AND POLAR BEARS ARE VISIBLE

features

THE STOA HAS COLUMNS DISTANCED BY A PRECISE DIMENSION, 5m, THIS DIMENSION CAN BE A PORTAL THAT REPEATS FOR THE INSTALLATION OF STRUCTURES FOR TEMPORARY EVENTS HOSTED IN THE PARK

THE STOA IS A FLEXIBLE ARCHITECTURE AT THE DISPOSAL OF THE PARK

SERIES OF PROJECTS THE CENTRAL STOA
alternatives

location

CENTRAL PART OF THE PARK, FROM THE TERRACE ON THE RIVER, THE REETILARY IS VISIBLE ON ITS LONG SIDE

features

THE STOA GIVES THE DIRECTION TO MOVEMENTS INSIDE THE PARK, LIMITS INTERVENTIONS ON EXISTING STRUCTURES, IS REFERENCE POINT FOR PARK USERS AND DEFINES A STYLE

THE STOA, AS AN ACCESSORY, LIVES THE LIFE OF ARCHITECTURE

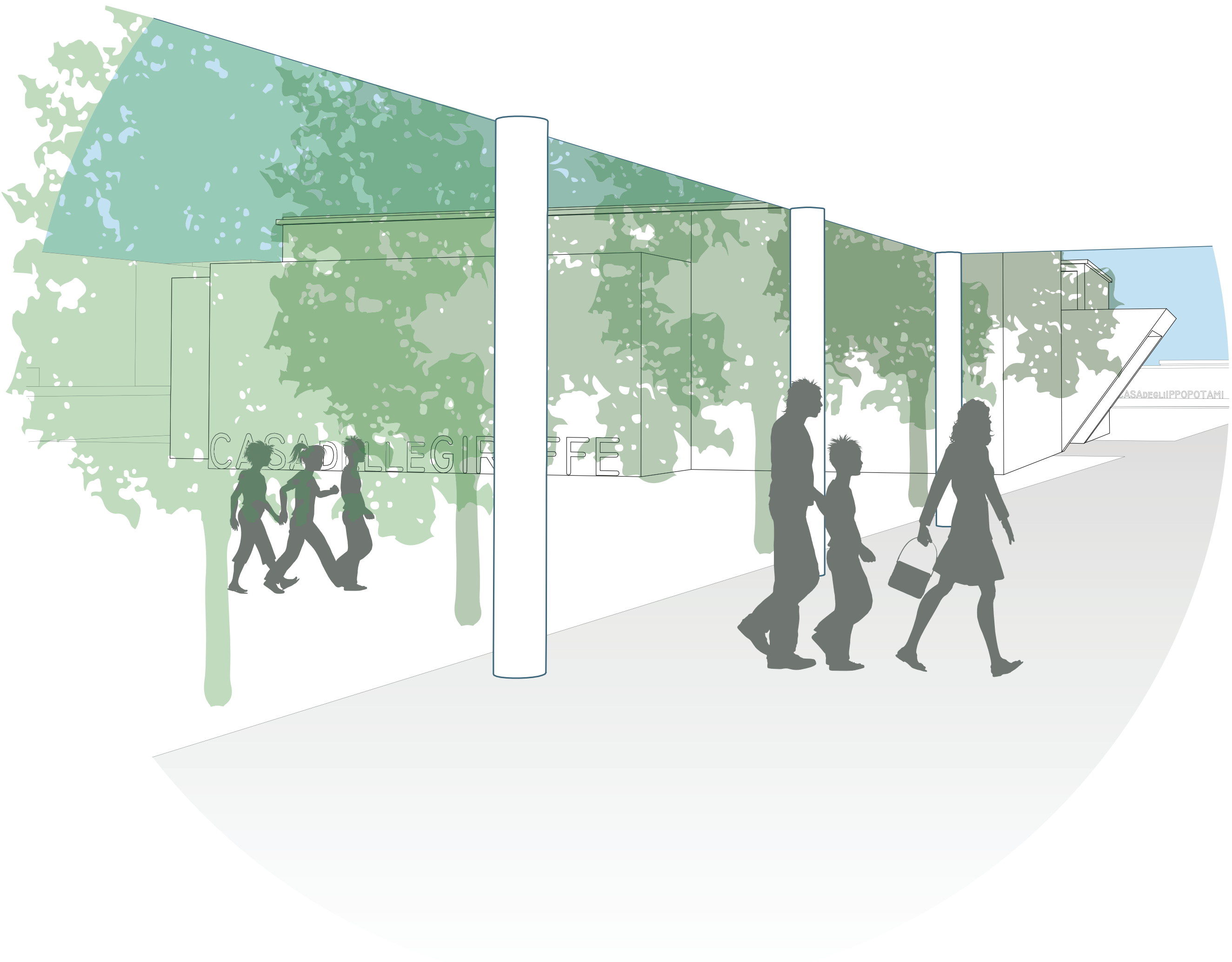
SERIES OF PROJECTS THE CENTRAL STOA alternatives

location
CENTRAL PART OF THE PARK, THE CONTRAST BETWEEN THE FULL STRUCTURE OF THE REPTILARY AND THE LINEARITY OF THE STOA IS VISIBLE

features
THE STOA GIVES THE POSSIBILITY TO BUILD, FOR EXAMPLE, A TERRACE, IT CAN START FROM THE FIRST FLOOR, RETTILARIO, AND USES THE SUPPORTING STRUCTURE OF THE STOA AS STRUCTURE OF THE TERRACE

THE STOA CAN BE INTEGRATED BY KEEPING THE COVERED ROUTE

SERIES OF PROJECTS THE CENTRAL STOA
alternatives



location

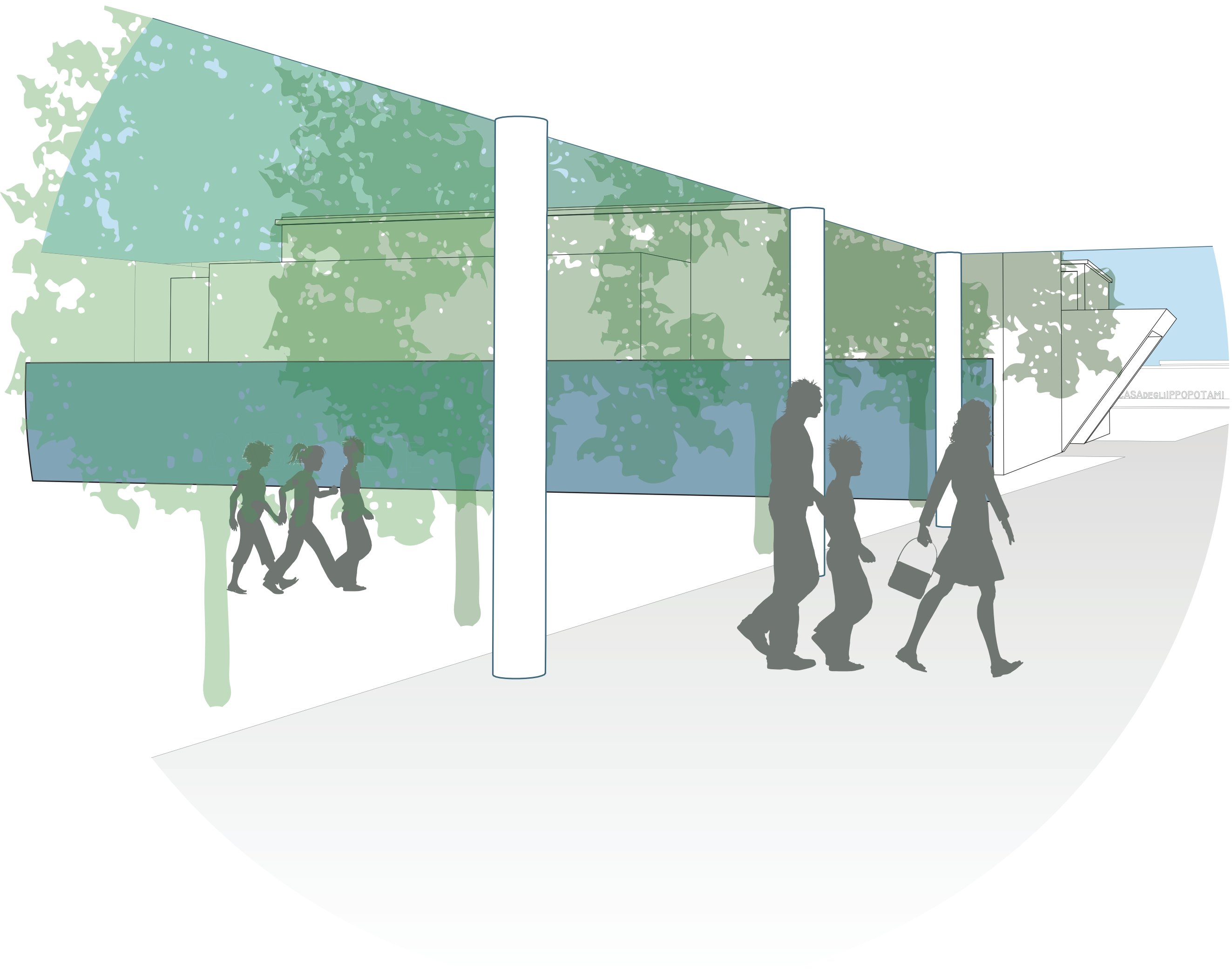
CENTRAL PART OF THE PARK, ALONG THE COVERED ROUTE OF THE STOA, ARRIVING FROM THE SOUTH NEAR THE HOUSE OF THE GIRAFFES

features

THE STOA DOESN'T TOUCH IN ANY WAY THE STRUCTURES PRESERVED INSIDE THE PARK, IT DEFINES A STYLE BUT LEAVES FREEDOM TO FUTURE DESIGNERS TO READY THE VARIOUS STRUCTURES TO NEW FUNCTIONS

THE STOA ALSO HAS ITS OWN AND INDEPENDENT FUNCTIONS

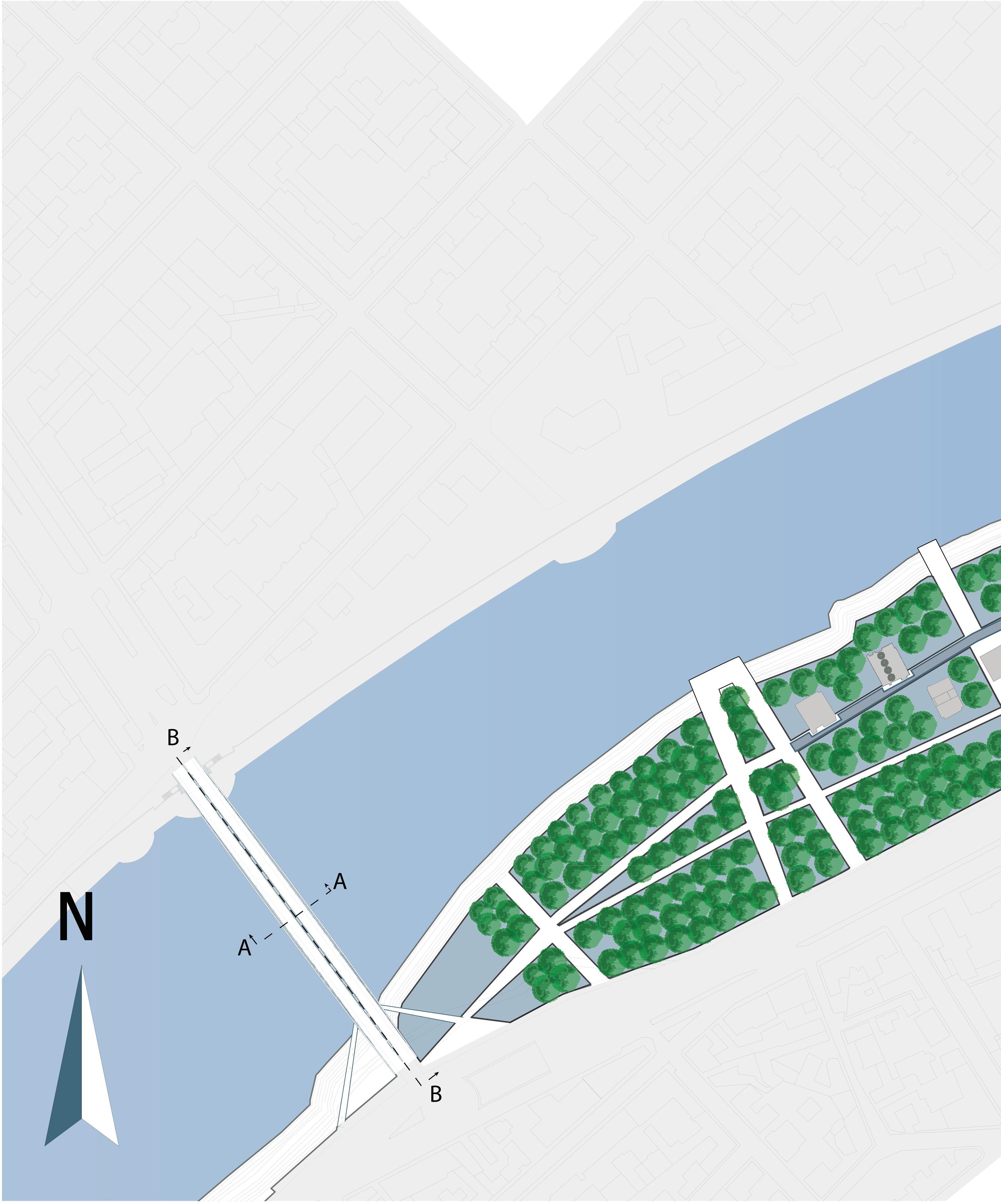
SERIES OF PROJECTS THE CENTRAL STOA
alternatives



location
CENTRAL PART OF THE PARK, ALONG THE COVERED ROUTE OF THE STOA IN A PORTION OF THE ROUTE IMMERSED IN THE GREEN

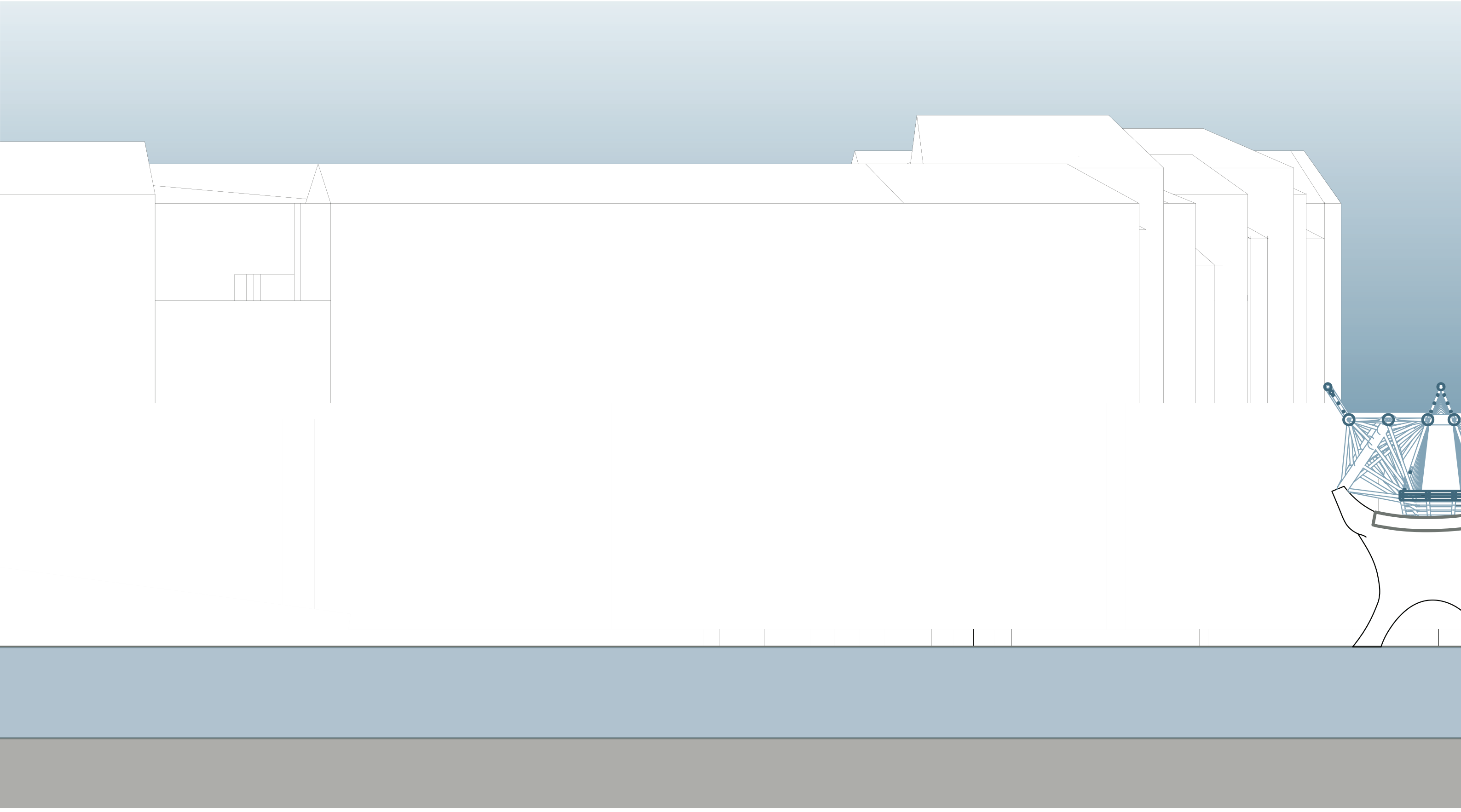
features
THE STOA ALLOWS THE TANSFORMATION OF THE STRUCTURES INTO PUBLIC OR PRIVATE, ITS FORM AND LOCATION LIMITS THE PRIVATIZATION OF LARGE PARK'S PORTIONS AND THE COMPLETE COVERAGE OF BUILDINGS

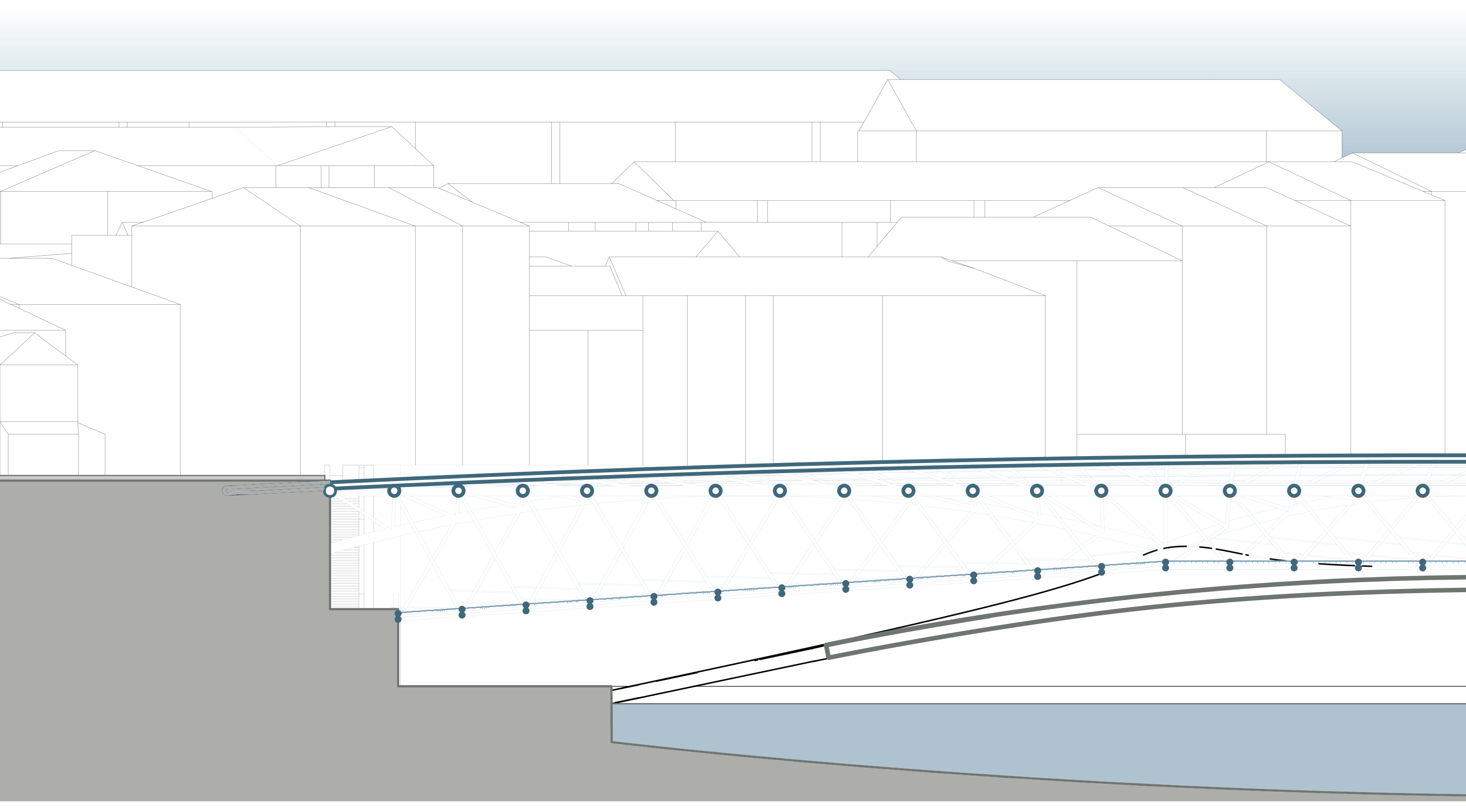
THE STOA IS PUBLIC, ALWAYS GUARANTEES PASSAGE TO ANYONE


B
A
A
B
N

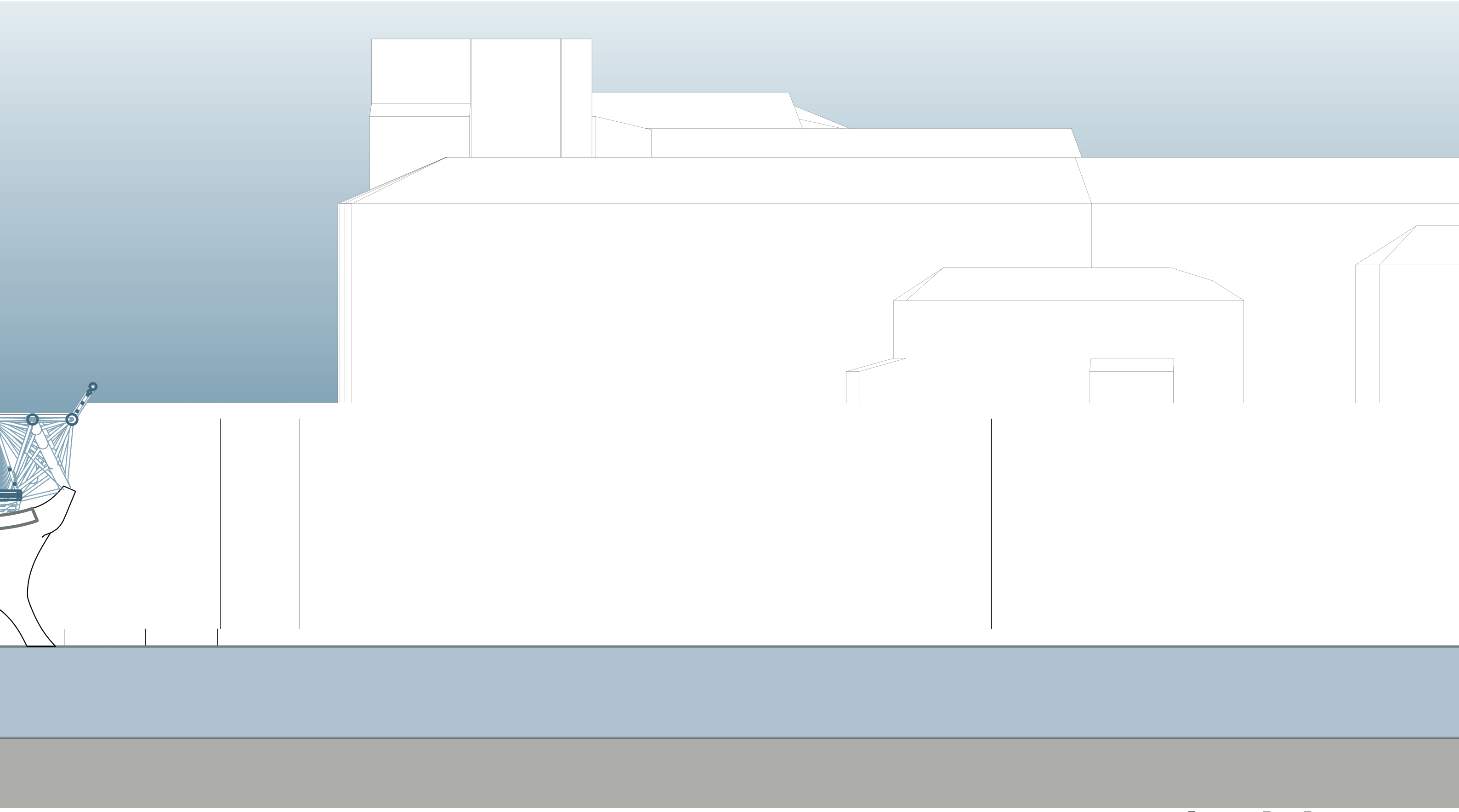
general plan

SERIES OF PROJECTS

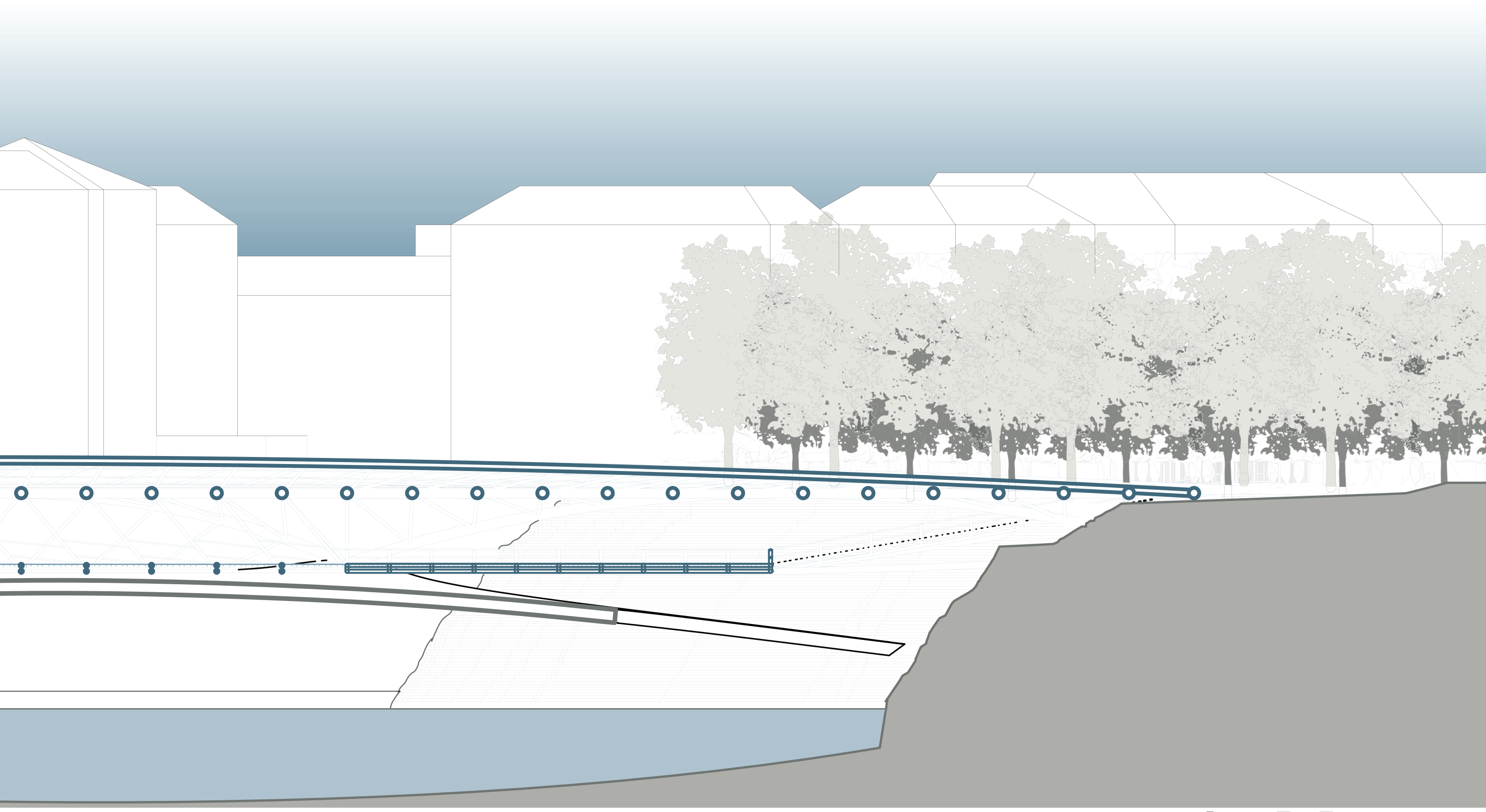




THE BRIDGE

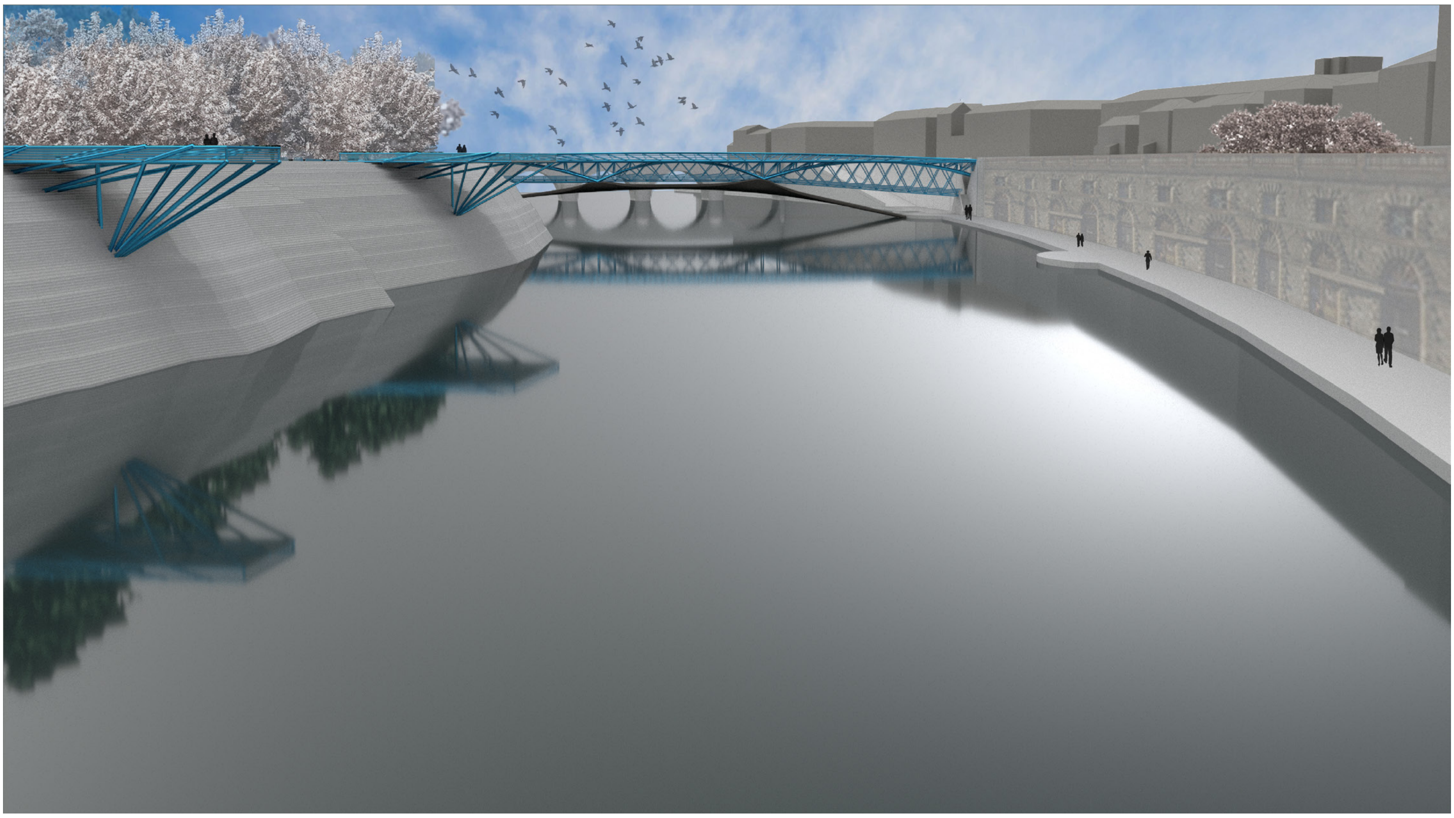


section A-A

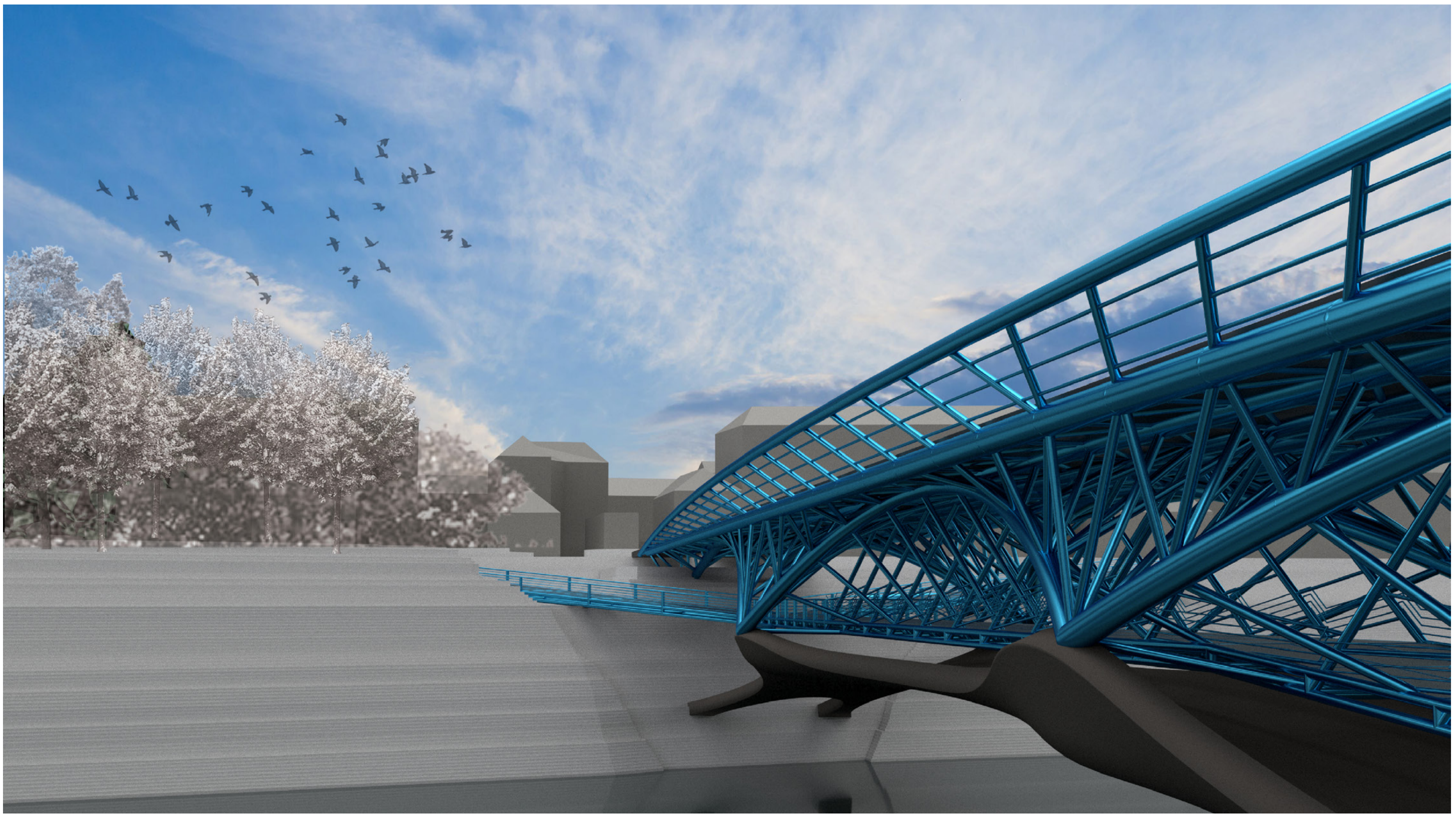


section B-B

SERIES OF PROJECTS



view from Ponte Regina



view from Murazzi sul Po

ACKNOWLEDGMENTS

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structure is
an organ in the
body, or part of an
organ, that does a
particular job