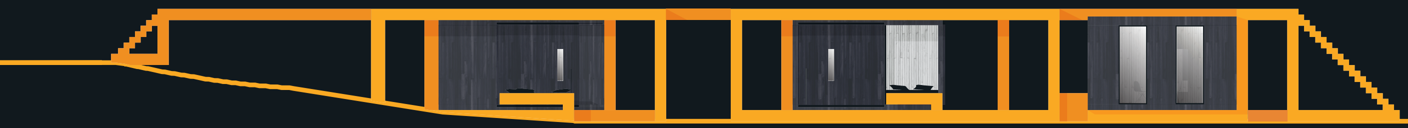

INHABIT THE OUTLOOK

a prefab leisure house on the edge of the cliff

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MA4 - ARK13

MA4 Architecture & Design

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CONTENT

PROJECT TITLE:	Inhabit the outlook - a prefab leisure house on the edge of the cliff
SEMESTER PERIOD:	10th semester, February-August 2012
GROUP NUMBER:	MA4 - ARK13
ADDITIONAL MATERIAL:	enclosed CD
MAIN SUPERVISOR:	Peter Lind-Bonderup
TECHNICAL SUPERVISOR:	Andreas Falk
AUTHOR:	Davide Bello
PAGE NUMBERS:	113

SUMMARY

This project report describe the design process for a compact and temporary leisure house which is intended to be located in one of the most unique areas of northern Italy, the Garda Lake.

The implicit approach to the architectural design of this project is referring to the Master education in Architecture & Design at Aalborg University, dealing with the topic of Tectonic and focusing on the specific aspect of Prefabrication.

The proposal reinterprets the historical context into a new house for the spare time that dips in the landscape blurring the boundaries between nature and artificial, private and public.
In order to establish an intimate relationship with the place, the leisure house is constituted by two main elements: a concrete structure firmly situated into the site, that allow to continue the public passage, and a series of three prefab living unities which once linked to the structure form a whole composition.

Located on the border between the forest and the lake, the house becomes a transition element from the dense wood and the open view of the lake.
Together these spaces create an experience that works over time emphasising the natural aspect of the dramatic landscape.

INTENTION

The scope of this thesis is to design a meaningful architectural project, a leisure house located by the Garda Lake, making use of prefabricated tools and techniques in order to conceptualize the positive experience of living, trying to obtain a greater balance between the quality belonging to a leisure architecture and the efficiency coming from a prefabrication system.

Prefabrication is not the aim, it is the tool.

The techniques (systems, processes, technologies) and the positive payoffs coming from the offsite fabrication, are going to be firstly analysed and further combined together with thoughts related to the understanding of architectural qualities.

Indeed, I am interested in both the difficulties and the potentials involved in the **prefabrication** and the design of an **ambitious architecture**.

This statement brings to a first dilemma due to the fact that the prefabrication is historically associated with standardization but, as it will be shown through the report this is just partly true.
Indeed the final result for this project is considered to be personal and unique, thereby going beyond the general notion of standardized production.

Therefore, one of the challenge for this essay is to understand how a prefabricated house can become specific in relation to site and user.

MOTIVATION

The thesis is the tool through which one finalizes his studies. It is the chance to shows the skills acquired and put them into practice through the realization of a project, which, in the case of our University, takes into account the architectural aspects, as well as the technical ones.
From my point of view, this is also a chance to learn and gain further knowledges throughout the exploration and the development of new topics.

Prefabrication is a field which has come and gone, particularly during the recent years.
Moreover it is a topic which architects have to face, willy or nilly, since that nowadays the process of building is more industrialized than ever before, especially in the house market.
The offsite construction is not a tool that directly promise lower costs and higher qualities, but is a process that if used in the right way can offer greater precision, shorter construction period, better value and greater predictability. [Ryan E. Smith]

Indeed, the expectation for this project is to make use of prefab systems in order to design a relevant house for the spare time, highly connected to users and site where is going to be settled.

It should be shortly underlined that the project is going to be developed as a real proposal for a Danish couple leaving in Copenhagen, who is planning to settle down this place in the future.

METHOD

PROGRAM --- SKETCHING --- SYNTESIS --- PRESENTATION

[ill.02]

The main method used to develop this project is the Integrated Design Process (IDP), where technical, functional and aesthetic considerations are made and reviewed throughout the whole process, generating a continuous interaction which lead to an integrated design.
[Knudstrup, 2005]

PROGRAM

This phase is mainly based on empirical investigations and studies, with the aim to understand the problem statement and gather useful informations which help into the clarification of a coherent solution.
At last, the program sets up a list of design criteria, demands, concept and ideas that work as a guiding line for the further vision establishment and sketching phase.

The topics that will be analysed are going to be:
prefabrication, quality of the dwelling, studies upon the site (context, weather conditions, topography, infrastructure), tectonic, analysis of case studies, analysis of the user profile, room program.

SKETCHING

The informations gathered in the analysis phase are here going to take shape in a series of physical design proposals and concepts. This phase is based on both a technological and architectural approach, this means that in an integrated way sketches about architectural considerations - functional and aesthetic results - and technological cognitions are combined and reviewed together.
In this phase the main concept emerges: through a critical analysis of problems and remarks coming from all the design proposals, some more detailed than others and dealing with different aspects. These are finally going to be integrated, evolved and redefined in order to end up with a project concept.

Therefore, this phase is not just involving sketches and technological considerations, but also physical models, use of 3D tools and technical tools.

SYNTHESIS

Here the concept coming from the previous phase is going to be deeply investigated and finally established, reaching its final form, expression and detailing.
Adjustments, verifications and developments in the functions, aesthetic and technic are made based on optimization of the involved constructional needs, environmental needs and technical parameters, all coming together to form the final design.

PRESENTATION

The presentation phase consists of visualizations explaining the final building.
The building is formal expressed, through its plans, sections, facades and detailing. In this phase physical and 3D models will be used in order to get a better understanding of the complex problems. Here the internal and external expression is concluded.

In particular this phase consists of these drawings:
context plan, floor plans, cross sections, elevations, technological details and perspectives.

In addiction to the presentation phase, a **reflection** upon the project will conclude on the fulfilment of the initial motivation and vision of the project.

ANALYSIS

meaning of PREFABRICATION --- lack of PROGRESS in construction industry --- HISTORY of prefabrication --- ARCHITECTURE & QUALITY --- QUALITY IN PREFABRICATION --- FORMULA of architectural PRODUCTION --- PROCESS of offsite construction --- TRANSPORTATION --- prefabricated construction SYSTEMS --- MATERIALS --- TECTONIC --- PLACE, TIME & BEING

[ill.03]

MEANING OF PREFABRICATION

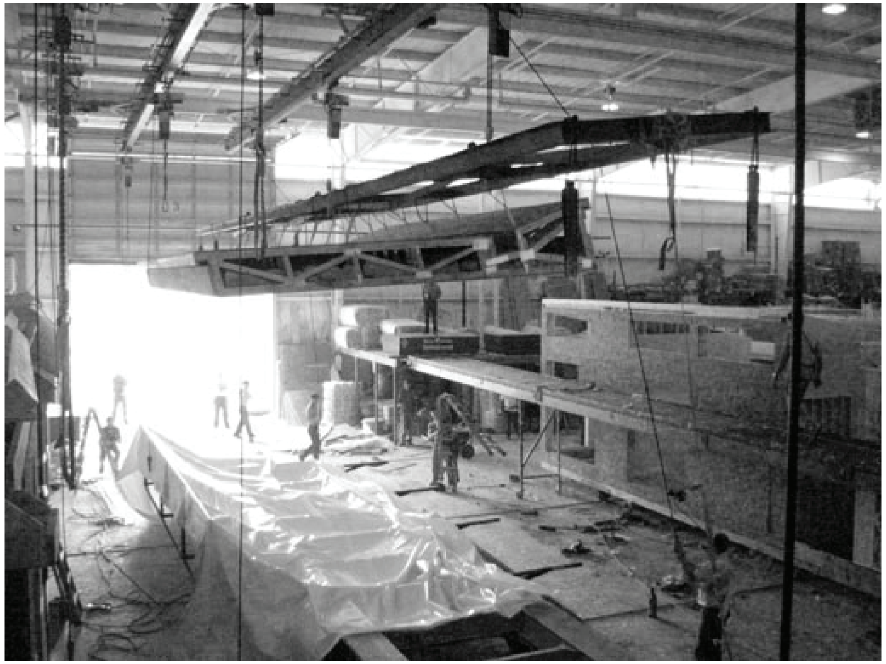
Thinking about the word "prefabrication" one might wonder why that "pre". The only explanation is that fabrication was at one time considered something that happened on site.

If we then have a look at the Merriam-Webster online dictionary, we see that

"prefabricate" means, ***"to fabricate the parts of at a factory so that construction consist mainly of assembling and uniting standardized parts."***

This definition has an entry date of 1932, seemingly not to have changed since. Meanwhile the technology of industrialization has progressed since that time, especially in the industrial-manufacturing process.

According to Ryan E. Smith the lack of progress in the word usage is an indication of lack of dialogue concerning construction methods and progress in the construction industry in general. [Ryan E. Smith]



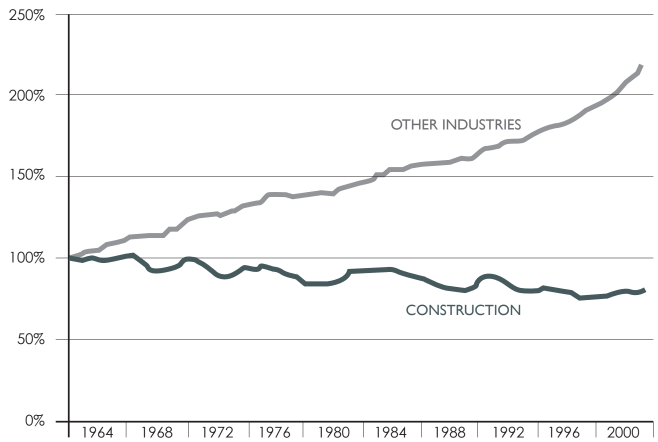
[ill.04] Res4, Dwell Home/Wieler Residence, fabrication

In order to not misunderstand the content of this thesis, the terms "**prefabrication**", "**offsite fabrication**" and "**offsite production**" will be used interchangeably to mean elements intended for building construction that are produced offsite and assembled onsite.

Moreover, for the sake of this project it is important to state since the beginning that, despite the conventional wisdom, **prefabrication is not necessarily a synonymous of standardisation**, as it will be shown through the report.

LACK OF PROGRESS IN CONSTRUCTION INDUSTRY

Since the industrial revolution, the process of modernization has deeply changed the way of provide products. But if this is true about automotive, shipbuilding and aerospace industry, it seams that the construction industry has been left behind.
When talking about prefab architecture the question is often one: if industrial-manufacturing processes can produce good and competitive products for society, then why is not possible to use the same processes in the architecture field in order to produce high quality and more affordable architecture?
The building industry has been one of the slowest industries in implementing proven, scientifically sound technological innovation and there are many reason for this lack.
According to Stephen Kieran and James Timberklake, one of the blame has been the separation of the designers from the makers, where architects have been detached from engineers. This means that one of the main gaps of the construction industry, compared to the other types of mentioned industries, is the integration of all acts of design and production, therefore the communication between the architectural and industrial spheres. [S. Kieran, J. Timberlake]



[ill.05] Percentage of US industrial productivity from 1964 to 2000.
In 40 years the idustrial productivity outside of construction doubled, while labor productivity within the construction industry is estimated to be 10% less than what it was in 1964.

The main barriers to industry adoption are:

- lack of knowledge between clients, industry professionals, architects, engineers and contractors.
- lack of information on proven precedents that show an added value for the cost.
- outmoded design and construction culture that promotes separation of disciplines.
- lack of availability of process and program.

Then why prefab architecture should be taken in consideration nowadays?

Nowadays, as an alternative to conventional building practices, there is an increasing interest in architecture, engineering and construction industry in developing approaches to building that follow **greater precision and efficiency**, that make a **better use of the workforce** and that provide **shorter construction cycle**.

Moreover architects' tools to integrate have changed. The architecture profession has embraced three-dimensional building information modelling and production tools. There are better communication tools enabling real time sharing of design, information and results.

Nevertheless, not just tools and architectural interests contributes to define the role of prefab architecture in our time. Indeed some general building principles of construction must respond to an efficient productivity: cost, labor, time, quality, risk.

In the following chapter it will be therefore clarified why prefab architecture can be a positive building methodology nowadays. [Ryan E. Smith]

COST

It is proved that the onsite construction has been estimated to waste up to 40% of all new products brought to site. On the opposite, prefabrication can save material waste, and therefore reduce costs implemented in a building project. This can be seen as the primary method adopted by offsite products to **reduce construction costs**.
Furthermore, offsite assembly offers the promise of **disassembly and reuse**. This is what J. Timberlake call "total sustainability", broadly defined as being 100% compliant throughout all building materials and systems in an economic and useful manner.
Another cost reducing factor is coming from the central potential of prefabrication and its being a repetitive design and prototyping process. This allow the possibility to easily **test the product**, or the single offsite element, refining them before the final production and assemblage, amortizing the production costs.
At last, some costs for transportation and craning are higher than the ones of onsite constructions, but sometimes some onsite constructions may be even more expensive.

LABOR

In addition, despite improvements in workplace safety, the construction site for onsite projects, remains a dangerous place. On the contrary, offsite projects contribute to a more stable and fairly remunerated construction industry with improved safety and working conditions.

TIME

The greatest benefit to productivity of offsite fabrication is a reduction in onsite construction duration. [A.Gibb, Off-site Fabrication, 1999]

QUALITY & SUSTAINABILITY

Offsite methods allow for a product which is not just higher in precision, but also well integrated in an environmental way.
Indeed, significant are the reductions in energy consumption due to decreased building time, controlled transportation, reduced material waste, use of a technical and technological innovation system.

About quality in prefab architecture it has been dedicated a further analysis in this thesis, showed in the following chapter.

RISK

On the other hand some risks can occur. The small and quick adaptation of an onsite construction, can often be made faster than with industrial-produced elements.
Others are the risks, more concerning the motivation of the lack of progression of the prefab industry (see the previous chapter).

CONCLUSIONS

As it is shown there are pro and cons in using prefabrication and the aim for this thesis is to understand which are the **benefits and lacks of using this method, compared to conventional on site construction, both from technical and qualitative perspective**.

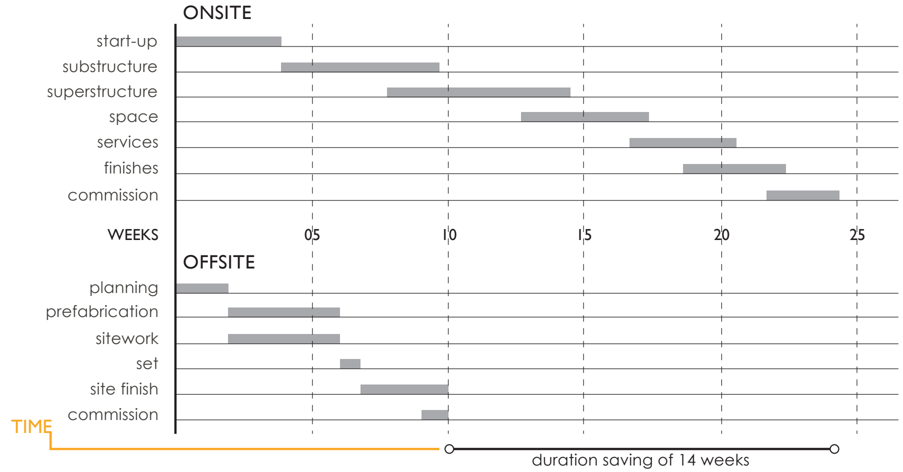
PRO

- Save material waste.
- Disassembly and reuse of materials and prefab elements.
- Testing before final assemblage.
- Lifecycle investment: costing more initially, but providing better value in long term.

COST

- Inside and safe workplace.
- The use of light material increase by 30% the productivity for the same product.
- The productivity is improved when materials are easy to install.
- Flexible installation in different weather conditions.

LABOR

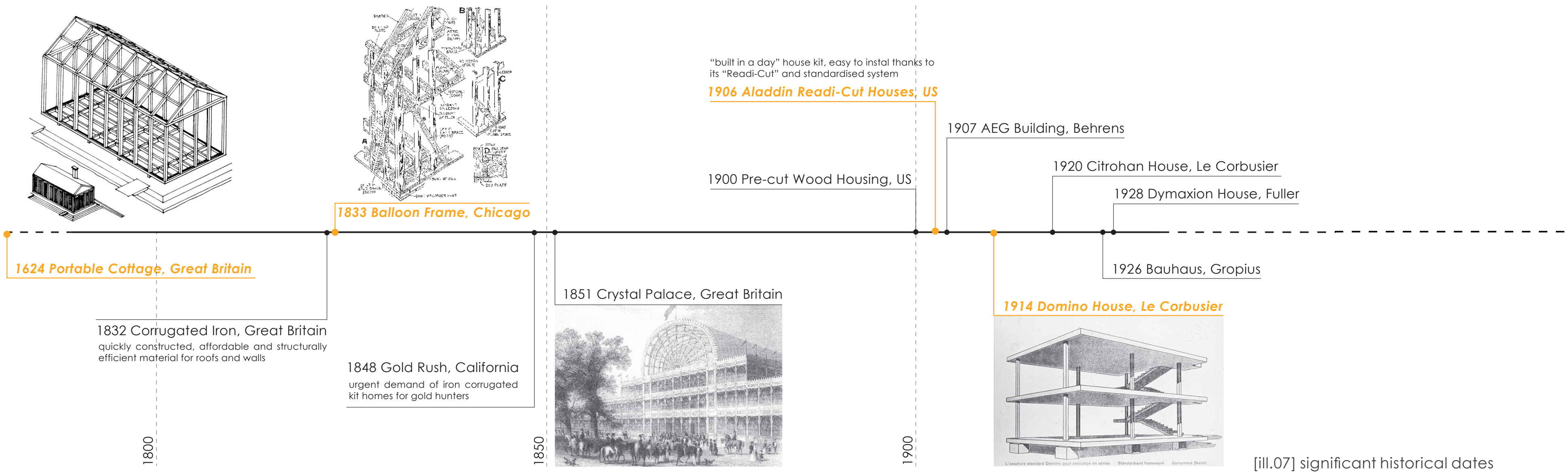


CONS

- The ergonomic needs to be improved to reduce fatigue and increase safety.
- Adaptation on site of prefab element can be difficult.
- Transportation is higher per unit volume.
- Craning a prefab element can require skilled laborers or dedicated crew.
- Reduced dimensions of different elements due to transportation.
- Use of light weight materials easy to carry.

[ill.06]

HISTORY OF PREFABRICATION



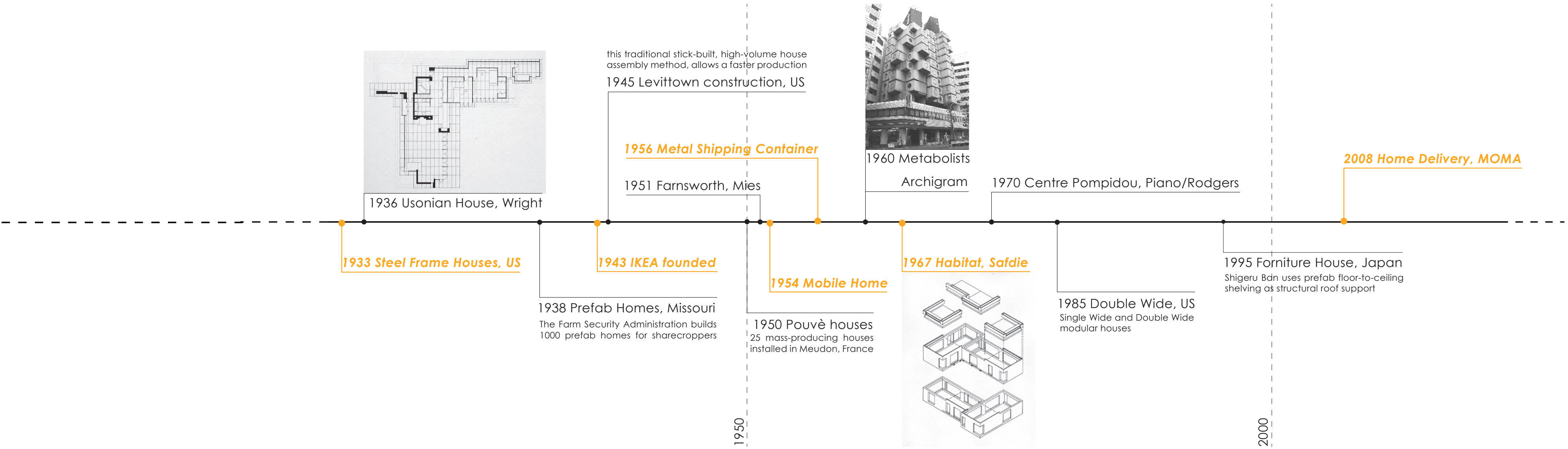
[ill.07] significant historical dates

"Prefab architecture is a tale of necessity and desires." [Ryan E. Smith]

Even if the history of prefab architecture, as we intend it today, took place in the modern age as a marriage between architecture and industry, the prefabrication can be tracked back to antiquity, to the construction of ancient temples and timber structures. [Ryan E. Smith]
The Crystal Palace by Joseph Paxton is cited as one of the first prefabricated building although one of the earliest example in the history took place during the seventeenth century when simple timber framed shelters were shipped by boat in many of the Britain colonies.

The prefabrication was then the first fast and easy solution to the increased demand of immediate houses, a solution therefore designed by craftsmen rather than architects. The whole idea was indeed to make it possible for unskilled workers to put a house together using a minimum of materials [Knudsen et al.2000].

Other prefabricated structures improved the previous systems throughout history, following the same principle of creating something movable and easy to ship. One of the most known is without doubts the "balloon frame", a system characterized by a light wooden frame that became really popular in the 1850s, so popular that Chicago was almost entirely constructed of balloon frame before the fire of 1871.
Another contribution coming from the Great Britain is the use of iron manufacturing for building construction. During the 1800s components like windows, columns, beams and trusses were produced in foundry, fabricated in a workshop and assembled on site. One of the first employments of cast iron construction (precursor of the contemporary structural steel structure) was in the bridge buildings, where pieces were standardized, cast repeatedly and shipped



to the site to be erected, saving time and cost.

In addiction to bridge and ships, the most extensive use of this material was in the standardized structure known as Crystal Palace. The palace was not the first one made of cast iron, but it was the first attempt to combine the earlier timber frame system, like the balloon frame, with this new material.

Thanks to the positive experience of a quality mass-production coming from the cars industry, a hope began to arise in the modern architectural environment, where the idea of accessibility and affordability was trying to be combined with good quality dwellings. Through the 20th century Le Corbusier was the main exponent of such thoughts, experimenting dwellings seen as machines for living in (es. Maison Citrohan, Dom-ino) [Arieff 2002].

Other major exponents of this period were: Buckminster Fuller, Walter Gropius and Hannes Meyer.
After the two World Wars, the industrialized building progressed. The massive destruction of the housing stock occurred to be rebuilt rapidly, cheaply and efficiently [Davies 2005, Arieff 2002]. This primary aim was indeed not concerning building aesthetic and enjoyable architecture, but mainly to restore and renew the dwelling stock.

To conclude, nowadays the majority of the building is at some degree prefabricated and the number of prefab building increase every year.

If at the beginning offsite construction was mainly seen as a quick way of producing large-scale housing, now, many promising architects aim to integrate aesthetic and perceptional values with affordable offsite constructions.

ARCHITECTURE AND QUALITY

The following chapters will seek to clarify the abstract concept of *quality* in architecture.

The purpose is not to give a clear definition but to understand how is possible to describe and take advantage of the values belonging to architecture.

Prefab houses are often seen as lower class of building and this could be attributed to the fact that historically the building that relay on pre-fabrication are only as good as the demands place on them. [Davies 2005] On the other hand architecture is seen as more than just a building. The question is, what is this more? [Ida Wraber]

What gives Quality to Architecture?

Architectural quality is commonly used in architectural speeches, however it does not seem to be a well-defined concept.

The will to create something of quality, which is pleasurable to look and to live in, is the result of the connection between function, technique and economy to the desire of beauty. [Bøggild-Andersen, Wolf 1950]
Furthermore, especially in this contemporary society, characterized by speed, mobility and flexibility, great is the request of a place where to rest and have a moment of peace and tranquillity [Mechlenborg 2005, Winther 2006], therefore the quality in the contemporary dwelling should not just be seen in its design, functionality, durability and personality, but also represented in its safety, calm and habit.

Quality is therefore a wide concept, which can be related to the properties or characteristics of an object, but many are the objective and subjective interpretations. [Jensen, Beim 2006] Interpretations which are different also from one historical period to another, which are related to intrinsic and connected aspects such as utilitas, firmitas and venustas, or that have their main focus on mathematical proportions, orders and harmonies.
Moreover not just physical and visual matters can identify the qualities of a dwelling, but also other sensorial experiences contribute to define the quality of it. Therefore "the architectural quality of a building is not only a result, or the sum, of the temperatures, proportions, textures, scents etc. of a room but it is also influenced by the specific person's earlier experiences and perceptions". [Dahlin 2000]

Therefore, there are several different approaches to handling the concept of architectural quality: from the classicist/structuralist theories, to perception/psychological theories and phenomenological ones. All of them have different perspective on where the architectural quality is to be found, and all of them belongs to the architecture itself.

QUALITY IN PREFAB ARCHITECTURE

According to Juhani Pallasmaa some processes of industrialization carried out during the 1960s, were a standardization without any appreciation of history or sense of beauty, whose the only consideration was the rationalization of production. "But the brutal standardization was also the outcome of a tragic amnesia in the 2500-year-old tradition of harmonic proportions, a tradition whose purpose was to link man to his built world, to creation, and the universe."
[Juhani Pallasmaa, Encounters, 2005]

Can the industrial process of prefabrication coexist with the concept of architectural quality?

Juhani Pallasmaa in this statement was describing the historical period concerning the second postwar, when many factors (such as property speculation and immediate needs of dwellings) brought to see industrialization as a process of pure "brutal standardisation".
The **prefabrication**, in its earliest form, **was more concerned about mass production** and **replication** than taking care about quality.
However, nowadays, **it is of course possible that the architectural quality can coexist with the process of prefabrication**, simply because this method needs to be seen as a **tool to create architecture** and not as a product of the latter.

The economical values and the technical values, belonging to prefab buildings, could be combined together with the architectural values as well.
Nevertheless, there are different ways to define quality in prefab architecture, like there are many to define the architectural quality, which similarly involve the same research strategies and ontology:

- **in the social science field**, the quality should be investigated in the effect of the prefab architecture on people's feelings and experiences
- **in the natural science field**, the quality could be discussed upon physical characteristics (space, environment, light quality...)
- **in the humanities field**, quality can be discussed on the meaning or history of architectural quality as an aspect which describes the totality of the building. [Mo 2003]

To sum up all these values Peter Zumthor talk about "***building with a soul***: [...] *buildings that provide me with natural spatial conditions appropriate to the place, to the daily routine, my activities and the way I'm feeling* ..." [P. Zumthor, Thinking Architecture]

In conclusion it should be again important to mention that the architectural quality, and therefore also the quality which concerns prefab architecture, involves multidisciplinary fields and that the inquiry and discussion upon quality in each of these fields have to produce a knowledge which can describe in an overall manner all these fragmentary cognitions.

THE FORMULA OF ARCHITECTURAL PRODUCTION

My study wants to go further the understanding of quality in a prefab architecture.
Indeed, dealing with prefabrication as a tool to create Architecture, means take into consideration all the factors belonging to the "process of offsite construction" (treated in the following chapter), which determines not only the Quality, but also Costs and lead Time.

According to James Timberklake, for the last 100 years, as the economy has become more sophisticated and global, one equation has governed production:

Q (quality) x T (time) = S (scope) x C (cost)

No matter which variable is defined as paramount to a project – quality, time, scope or cost – the other variables must stay in balance. [S. Kieran, J. Timberlake]
Want less time with a fast track schedule? Then give up quality, spend more money or reduce the scope.
Want higher quality? Increase the budget proportional to your scope and likely increase time. Project after project around the globe has been dominated by this equation.

Especially nowadays clients demand more for less, therefore architects have to adapt to the rule of economy increasing quality and scope while reducing cost and time of production.

Since Cost and Time, expressed in this equation, belong also to the concept of prefabrication, it is meaningful to verify how the Quality and the Scope can proportion the equation.
As stated in the "history of prefabrication" chapter, offsite production was initially developed with the Scope of an immediate house solution, reducing Time and Cost to the disadvantage of architectural Quality.
However, considering all the pros which a prefab system can guarantee (see pag.5), an encreased Quality for a higher Scope (leisure house) can be achieved.

It is finally necessary to mention how the "**process of offsite construction**" works, acting with coherence in order to reach this last aim: a high Quality prefab leisure house (Scope) at modest Cost and less Time.

PROCESS OF OFF-SITE CONSTRUCTION

The prefabrication process can be compared to the process of creating an industrial product, where the industrial production method is developed in parallel to the design, as an integrated process.
In this sense, the architect can be comparable to an industrial designer.
The cost of a project and the time it takes to manufacture it determines its viability in the marketplace. Therefore the process of off-site construction is a process which includes all the activities that take place from market interpretation to the final product. [Ryan E. Smith]

As it is shown in ill.08 **prefabrication process requires several steps, from design to construction, and a simultaneous collaboration of architects, professional engineers and constructors**.

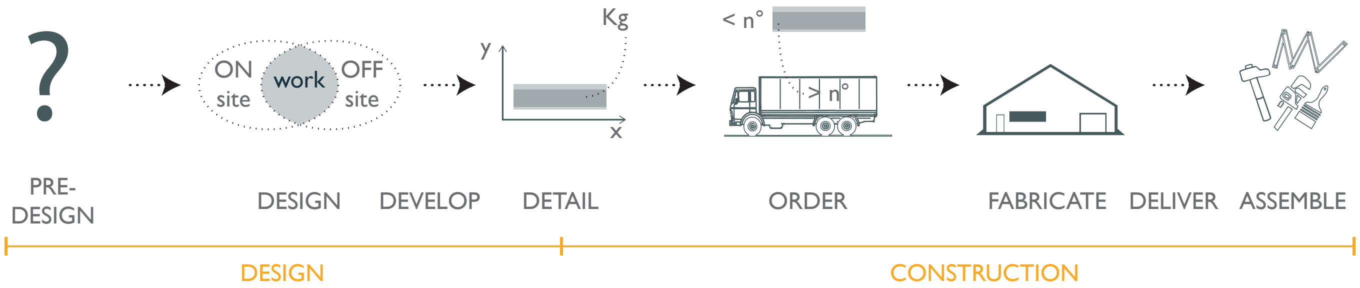
The first thing to understand is whether the prefabrication is the best solution for our project (Predesign).

Secondly we must structure the work so to divide what is produced on site from what is prefabricated, in order to reduce assembly time and cost and reduces mistakes.

In particular the following stages must be taken into account in order for the process to be really effective:

- Overall dimensions for transport (height, width, length and weight restriction).
- Reduce the number of element to transport. (In the following chapter It will be treated the importance of deciding the "degree of prefabrication", which is strictly related to transportation).
- When it is possible a simulation of construct sequence should be performed in order to anticipate potential conflicts.
- Place the components in the right order, which is the reverse sequence.
- Consider the crane capacity and location.
- Access on site.
- Road closure.
- Delivery time.
- On site: Setting - Hosting - Positioning - Adjusting - Connecting.

Moreover the assembly operations must be designed as a continuos flows to ensure safety, quality, time and cost parameters.



[ill.08] process of offsite construction

TRANSPORTATION

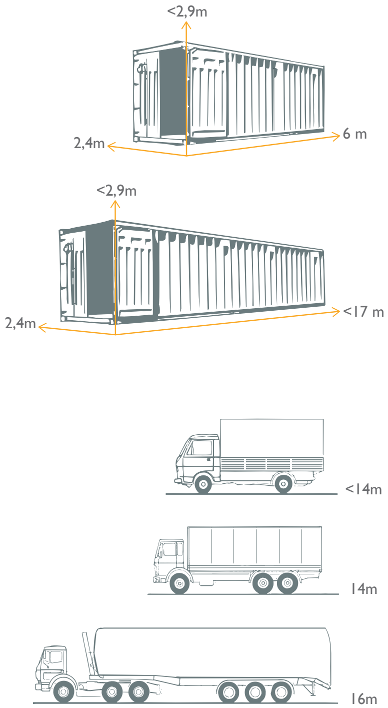
Particular attention should be given to the transport phase, because transportation limits size of individual panels, modules or components.
It 'easy to understand how the size limit is the most challenging factor of prefabrication, but it can also contribute to find interesting solutions during the design phase.

The two primary methods of transporting products, from factory to site, are containers shipping and cargo shipping.[Ryan E. Smith]

1. **Container shipping** have a fixed width of 2,4 m and a length that can varies from 2,4 m to 17 m. The height varies from 2,4 to 2,9 m. The typical container is 6 m long, 2,5 high and has a maximum payload of 28.200 kg.

2. **Cargo shipping** refers to "abnormal" shipping size and it includes all the methods of shipments including rail, truck, ship, air and on rare condition helicopter. This dimensional shipping is applicable for the components that are too big to fit in containers.

Nevertheless, truck is the most common means of transportation when shipping prefab system.
The dimension of trucks load varies from country to country, but generally the length goes from 14 m to 16 m with a fixed width and height of 2,4 m.



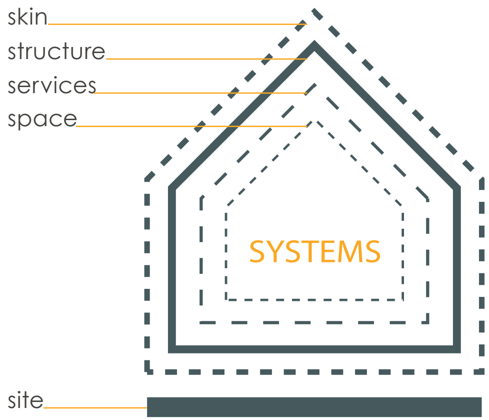
[ill.09]

[ill.10] cargo shipping

PREFABRICATED CONSTRUCTION SYSTEMS

After taking into account the means of transport as a crucial part of the design phase, it is important to clarify which are the construction principle related to prefab architecture, in order to choose the system that works best for this assignment.

A construction system is generally thought of 5 categories:
SITE, STRUCTURE, SKIN, SERVICES, SPACE and STUFF (furnishing and fixtures), where prefabrication can be used to deliver everything but the site. [Ryan E. Smith]



[ill.11]

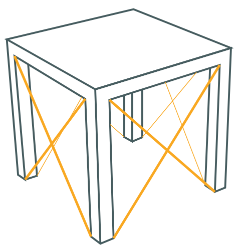
STRUCTURES

Structures are load-bearing and lateral resisting systems that transfer dead loads, live loads and dynamic loads to the ground.
They generally includes: foundations, frames, load-bearing walls, floors, roofs.
Can be divided in 2 categories:

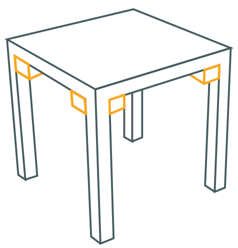
1. MASS STRUCTURES: which transfer loads through surfaces and solids, instead of distinct elements.

2. FRAME STRUCTURES: which acts as skeleton systems. They are the most common structures, easier to be erected, flexible for non-load-bearing infills. Generally composed of vertical and horizontal elements they needs some type of lateral load-resisting systems:

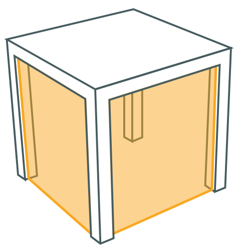
- BRACE FRAME: the junction of column and beam is done with diagonal members of steel (the most common are "X" bracing) welded or bolted to the main structure.
- SHEAR WALL: which infill bays between columns and beams. In prefabrication the panels are fabricated offsite and placed into structural bays.
- RIGID FRAME: enclosed in the frame structure (in order to guarantee external protection from thermal differences, and interior space separation).
- CORES: such as stairs and elevators, where steel frame structures can be attached.
- SPACE FRAMES: are 3D truss formation that consist of lightweight interlocking members.
- DIAGRID: diagonal grids which use triangulation and can act simultaneously as vertical gravity load-bearing structure and lateral load-resisting structure.



[ill.12] brace frame



rigid frame



shear wall

SKINS

Envelopes which generally constitutes exterior walls and roof systems. They must perform a variety of tasks: functional (comfort, shelter, view), constructional (assemblage to a main structure), formal (aesthetic, cultural and contextual response), environmental (lifecycle perform, protection from radiation, conduction, convection and daylight, guarantee ventilation, insulation).

The envelope relation with the structure can be: spatially placed in front, behind or in line, determining the aesthetic, the energy performance and the interior spacial arrangements.
In prefabrication they can be assembled to the structure both onsite or offsite (depending on the transportation and size limitations).
A classification can be made according to construction or assembly criteria:

1.LOAD TRANSFER: composed of wood, glass, metal, ceramic, stone cladding. Bearing and non-load-bearing. The skin can be distinguished as a separated element from the structure.

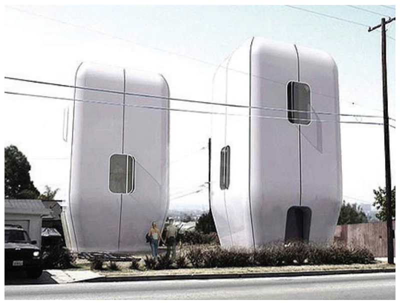
2.SHELL ARRANGEMENT: single skin or multilayered which perform both structure and enclosure.

3.TRANSMISSION: transparent, translucent or opaque skins attached to the main structure through different glass facade systems.

SERVICES

Include the heating, ventilation and air conditioning, plumbing, electrical, and any other equipment such as kitchen and bathroom prefabricated modules, which can be assembled onsite.

[ill.13] load transfer skin



[ill.14] shell arrangement single skin

[ill.15] transmitted opaque skin

MATERIALS

Prefabrication can make use of any kind of material, although most elements today are composite made from one or more materials.

Generally, materials for prefabricated structures are steel, wood and concrete, because they are more affordable and available.
Glass, polymer and aluminium are mostly used for non-load-bearing enclosures, furthermore some precious metals such as copper, bronze and durable alloys (stainless steel and titanium) can be adopted for facades. [Ryan E. Smith]

WOOD:

PROPERTIES: Natural material, eco-friendly, easy to manipulate manually or with machinery, low toxic, biodegradable, easy to recycle and reuse (e.g pressed wood panels).

USES: Columns, beams, quarter, half and edge-sawn members, laminated elements, walls and floors panels, entire modules, exterior walls (some with additional layers: waterproofing, vapour barrier, insulation, gypsum board)

CONSTRUCTION PROPERTIES:
Precision of the cutting and fitting in the factory. Usually assembled with nails or screws. Factory produced elements can be easily shipped on site and there assembled. Structurally resistant, even for hight spans when laminated. Easy to recycle/reuse, manipulate, renewed.

STEEL/ALUMINIUM

PROPERTIES: Ductile, hard, conductive, precise, strong and durable. Ferrous metals (mild steel, iron, stainless steel) can lead to corrosion or rusting when exposed or washed, while non-ferrous metals (aluminium, titanium, zinc, copper) are corrosion resistant but employed mainly for cladding, roofing and enclosures, because more difficult to extract and therefore more expensive. Aluminium is the non-ferrous metal easy to be recycled without loosing its original properties, it's light and durable. Some metal properties can be improved and increased combining metals in the process called: alloying.

USES: Structural applications of mild steel and aluminium, enclosure frames in aluminium, exterior cladding in copper or titanium.

CONSTRUCTION PROPERTIES:
Mild steel and aluminium are used as structural elements in prefabrication, they are more expensive than wood and concrete structures, but their strength-to-weight serviceability is superior. Able to be quickly erected. It's elastic and under same high stress can deform instead of breaking like concrete does. Can be assembled with bolts or welds. If bolted can be later disassembled and quickly erected on site.

[ill.16] Mount Whitney Trailhead, Anderson Architects

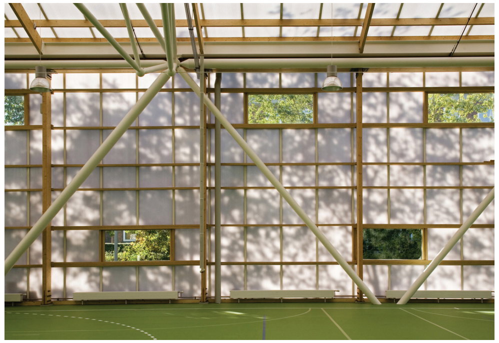
[ill.17] Watershed, Float Architectural research, Wren

[ill.18] Marrowstone Island House, Anderson Architects

[ill.19] Cantilever House, AndersonAnderson Arhitects

[ill.22] Precast Concrete, Hansons silo Co.

[ill.20] New Caixa Building, Herzon & de Meuron



[ill.23] Sports & Culture Centre, Dorte Mandrup, CPH

[ill.21] Ecumenical Art Chapel, Sanaksenaho, Turku

[ill.24] Sports & Culture Centre, Dorte Mandrup, CPH

CONCRETE

PROPERTIES:

Heterogeneous. Its properties vary according with the percentages of its components and additives . Durable and long lasting, but it needs more labor to produce architecture, and needs the supplement of other material to be casted.

USES:

Structural frames, panels and modules.

CONSTRUCTION PROPERTIES:

High resistant to compression. Admixtures and reinforcing are nowadays added in prefab concrete elements, increasing the cost, but there is still a long way to go in precast construction methods. It's the heaviest material in prefab systems and the most difficult to be transported.

POLYMERS

PROPERTIES:

Elastic, high degree of plasticity, some of them can be recycled or reused (polycarbonate, polyester, polyethylene, EFTE), toxic while produced.

USES:

Cladding panels and barriers (polycarbonate, polyester, polyethylene, EFTE), roofing, sealant and adhesive materials (elastomer: silicone, neoprene, EPDM).

CONSTRUCTION PROPERTIES:

Perform waterproofing, vapour barrier, sealant, flexibility.

TECTONIC

Structural systems and materials have been explored during the previous chapter. The following one wish to analyse and understand HOW to exploit these fundamental elements in order to achieve the aimed architecturla expression.

Vitruvius introduces three requirements, which have to be reached in order to produce architecture of high quality; firmitas, utilitas, and venustas.
[Kruft 1994, p.24]
He thereby proposes that "techne" both designates matters of construction and function as well as matters of aesthetics. Therefore Firmitas relates not only to the type of construction, but also to the relation between statics, construction and material. In the choosing of material Vitruvius underlines the importance of using each material according to its natural properties, and thereby construct durable buildings of high quality. [Andersson 2005, p.8]

However, many are the further views about the meaning of tectonic.

According to **Sempere:** the tectonic can be recognized in the assemblage of 4 basic elements: the earthwork, the heart, the framework/roof and the lightweight enclosing membrane or infill wall; explaining the way they are linked together, and therefore expressing as main tectonic element their junction, he claims that "the logic of technique gives identity to the form".
[Wraber, 2005, p12 and Frampton, 1995, p86]

According to **Frampton:** it is in the overall construction logic and articulated details, which reflects the transfer of loads through the joints, where the term tectonic should be reserved. [Kenneth Frampton web x]

Furthermore the "*Details express what the basic idea of the design requires at the relevant point in the object: belonging or separation, tension or lightness, friction, solidity and fragility*". [Zumthor, 2010, p15]

[ill.25] Chiesa di Padre Pio, Renzo Piano, S. Giovanni Rotondo, 1991-2004

In regards to this thoughts, the aim of my project is that the whole construction principle or logic wants to be evident, and that the logic used in the construction does not has to be hidden, on the contrary, it should determines the form.

The wish is to design an architecture where the material has to be used for its properties and the poetic qualities that it can assumes.

Since the aim is to use off-site construction systems, then this has to be expressed through the choice of "light structures", easy to assemble, focusing on details and joints.

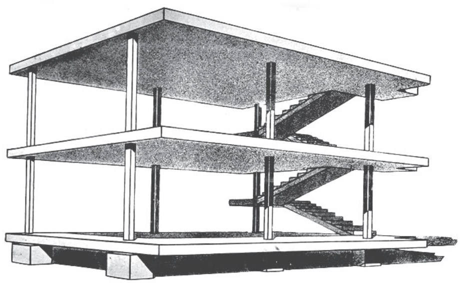
FURTHER FOCUS POINT FOR THIS PROJECT:

The above mentioned points are important both in achieving an understanding of the concept of tectonics and to design a project in its whole, where aesthetic, functional and constructional aspects are integrated together.
Furthermore, especially in the delineation of my design concept it has been of great inspiration the explanation of tectonic given by Suo Fujimoto in the book "Primitive Future".
He points out two different ways of designing or defining tectonic:

- one is more concerning the physical understanding and visualization of the structure of a building, made of distinguishable elements like pillars, floor and stairs, just like Le Corbusier exemplified with the Domino House.
- the other is more concerning the experience of tectonic, where pillars, floors and stairs do not exist or do not determine the tectonic of a dwelling, it is instead a graduation of field and experiences that generates the spaces.

Differently from a primitive nest, designed for people, he try to enhance the figure of the cave, a space not designed for humans, but which can be used as a dwelling: finding unconventional relation between the people's needs and the configuration of the cave, where they can organize their function in an unpredictable way and where the reaction to this space generates interactive situations.

[ill.26] Final Wooden House, Suo Fujimoto, Kumamoto Japan, 2008



[ill.27] Dom-ino, Le Corbusier, 1914-15

This aspect has been examined to point out that some provocative architectural solutions affect the users behaviour towards the dwelling.
Similarly, a leisure house, or house for the free time and therefore far away from the everyday routine life, has the potential to be developed with unconventional solutions.

1. VISIBLE CONSTRUCTION SYSTEM
2. USE OF MATERIAL FOR ITS PROPERTIES
3. UNCONVENTIONAL SOLUTIONS

CONCLUSIONS

In conclusion, the previously examined subjects, underline the key issues that will be concretely analysed in the following case studies and will be helpful both in the statement of the vision and in the design process.

In particular, the following statements can be considered as main focus points to take into consideration:

- PREFABRICATION IS NOT NECESSARELY A SYNONYMUS OF STANDARDISATION.
  The following case studies will show how it is possible to realize unique projects through off-site construction, where the standardisation relies just in the production process. The possibility to create something unique, using off-site production, is going to be the main vision of this thesis.

- THERE ARE PRO AND CONS IN USING THIS METHOD from a technical point of view.

- IT IS POSSIBLE TO OBTAIN AN ARCHITECTURE OF QUALITY USING PREFABRICATION as a construction tool. In the case studies and during the design process, further combinations of construction system (i.e. conventional + prefab) will be questioned to find out the more suitable solution for site and vision.

- THE CONSTRUCTION PROCESS HAS TO BE CONSIDERED IN ITS WHOLE.
  However, not all the passages of this construction process will be concluded in this thesis, since some other professional figures would be needed.

- TRANSPORTATION IS ONE OF THE MAIN ASPECT OF THE CONSTRUCTION PROCESS which can influence the design of the elements.

- MATERIAL AND STRUCTURE NEED TO BE CONSIDERED AS WELL, both in relation to prefab requirements and poetic and tectonic expression.

CASE STUDIES

DEGREE of prefabrication --- Jørn Utzon: ESPANSIVA --- RES4 ARCHITECTURE --- Anderson Anderson Architecture: FOX ISLAND RESIDENCE --- Anderson Anderson Architecture: MARROWSTON ISLAND HOUSE --- Zaha Hadid: THE HEYDAR ALIYEV CULTURAL CENTRE

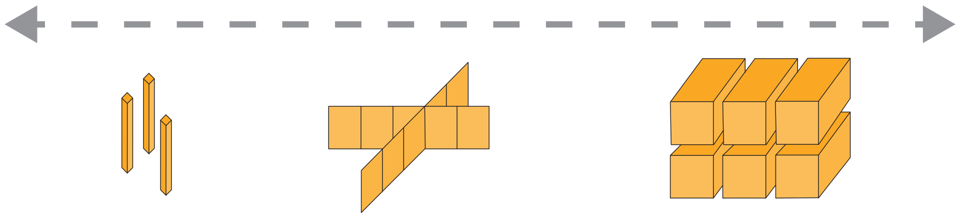
[ill.28]

IN THIS CHAPTER THE AIM IS TO INVESTIGATE THE MAIN DEVELOPMENT OF PREFAB HOUSE ARCHITECTURE, FOCUSING ON SIGNIFICANT REFERENCES WITH PARTICULAR ATTENTION TO MODERN AND CONTEMPORARY EXAMPLES.

DEGREE OF PREFABRICATION

Prefabrication can be understood as many different types of building systems and methods of production. All of these systems have been designed to be pre-fabricated and transported from the factory to the site, therefore their dimensions and materials are mainly connected to transportation, lifting and assemblage in situ. [Ryan E. Smith]
Indeed, there are different degree of prefabrication categorized as **components, panels and modules** and each of them will generate benefit and disadvantages in the construction process.
It is extremely useful for this thesis to analyse and understand these categories, in order to choose the better system coherent with the design of the main concept, further developed in the sketching and design process phase.

In order to do not get confuse, it is useful to clarify that this categorization refers to the **delivery method** and not at the type of construction.



FLEXIBILITY	HIGH	MEDIUM	LOW
TRANSPORTATION	EASY	MEDIUM	HARD
ASSEMBLY TIME ON SITE	HIGH	MEDIUM	LOW

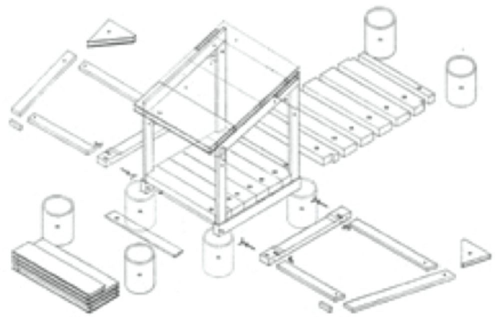
[ill.29]

Several others case studies have been taken into consideration during the analytical phase, but the following that will be shown are the ones that better exemplify the different degrees of prefabrication.

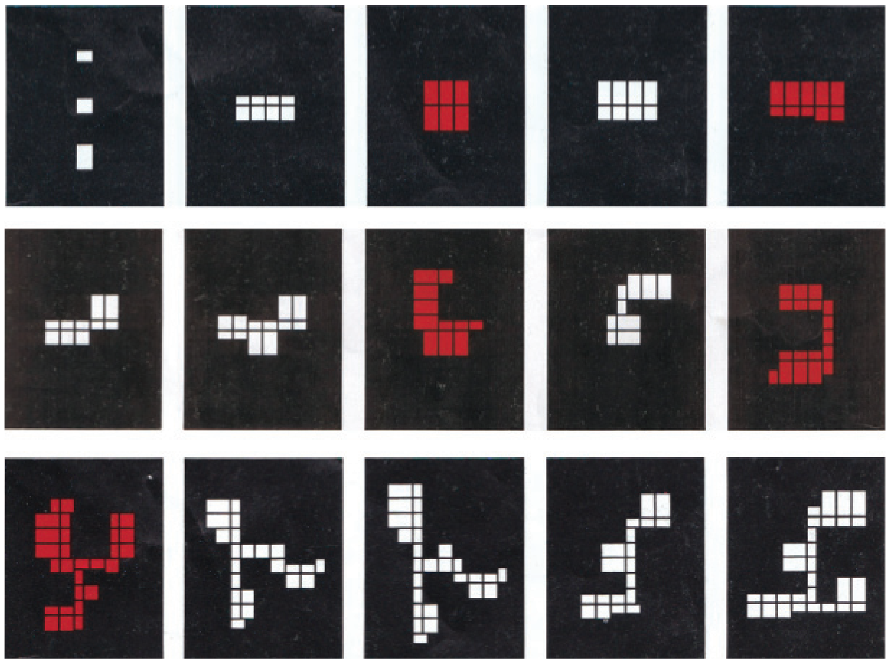
JØRN UTZON

The espansiva by Jørn Utzon is a modular, standardised, additive system for low cost and low-density rural housing designed in 1970.
The system is based on modules of three standard sizes where each volume can coincides with a different function.
These modules can be considered as small pavilions made of structural wooden frame with a standardised roof pitch at 17,5 degrees. The coating is made of wood panels that can be highly customized by users, which have the possibility to choose the size of openings. [Ida Wraber]
The potential of this system is the great possibility to create variation with a large amount of single building elements. As it is visible from the plan drawing diagram, the user is free to combine the different pavilions together in order to create the composition he prefers.

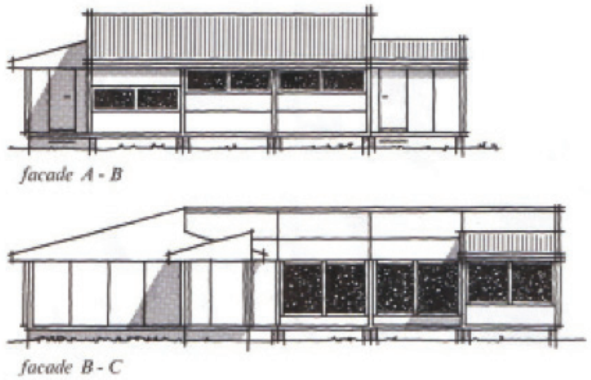
Although, the main purpose of this system is to create quite complex design by using simple spaces and materials, this great possibility can also generate a quite chaotic expression, especially for non-architects users. [Ida Wraber]
We can consider this project as a great attempt to make the single-family house typology affordable, reducing costs and allowing a great degree of flexibility.

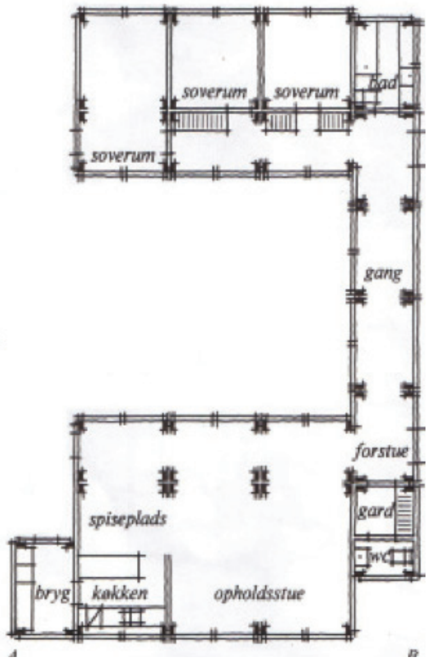


[ill.32] Espansiva, exploded axonometric



[ill.30] Espansiva's systems composition, Jørn Utzon





[ill.31] Espansiva, elevations and floor plans

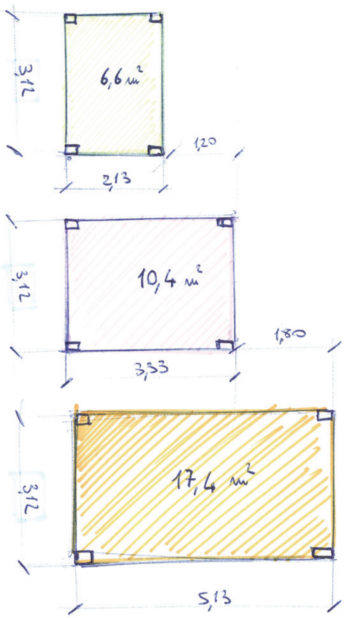
There are two main interesting solution in this system.

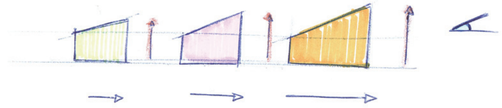
The first one is that all the plans that can be generated are based on three modules that have just one fixed dimension in common [ill.35]. Each module is not designed for a specific function and can be used for several purpose. [ill.34]

The second one is that the roof angle slope is always the same for each of the three modules and since that every unity has different length, this will generate different heights [ill.33].
In substance by changing just one element (length) it is possible to generate a great amount of variations.

From the structural point of view, It is possible to consider this prefab system as a **mix between components** ,that are the wooden posts and beams which form the frame structure, **and panels**, that can be highly customized depending on the plans necessity.
Once the plan has been decided the site must be prepared for the foundations, and afterwards it is necessary to transport the elements in the right order and assemble them on site.

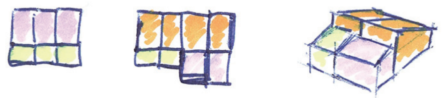
One of the weaknesses of this system is that the great amount of elements by which is composed every unity requires high precision and time during the assemble phase on site.





[ill.33] This 3 modules have the same angle but different length, this means different heights.

[ill.34] Whithin these 3 modules there is the possibility to create many different plans.



[ill.35] The 3 modules have a fixed dimension of 3,12m

RESOLUTION: 4 ARCHITECTURE

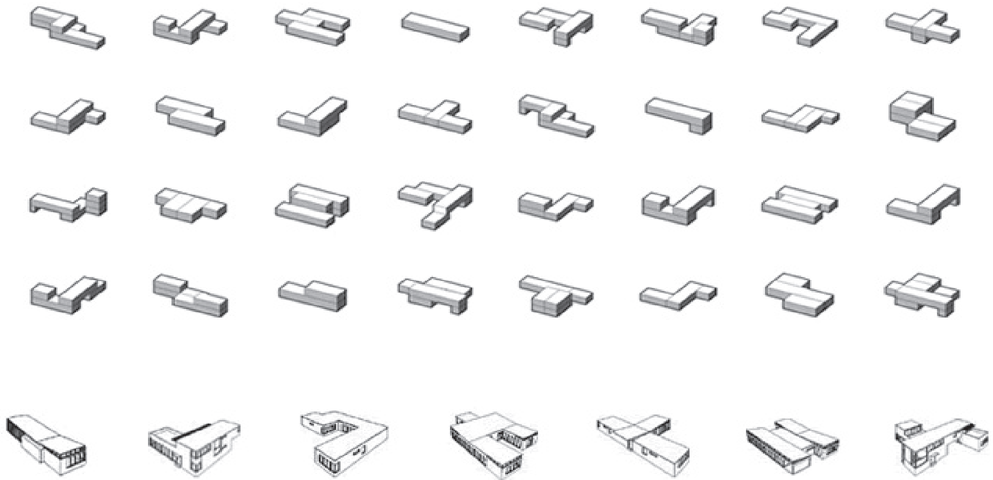
"Resolution: 4 Architecture" is a firm founded in 1990 by Joe Tanney, which has developed a solid knowledge of modular industry by working with a myriad of providers trying to find ways to design and deliver more productive architecture without sacrificing quality.

Res4 has developed mass customized architecture by what they call the "modern modular series", that is a design process by which **modular typologies are developed in different combination by using the same designed system**. As like as the espansiva, the concept is a modular system made of predetermined blocks that can be customized and assembled in many different configuration of housing. The illustration 37 shows 35 out of many other options that the architectural firm propose.

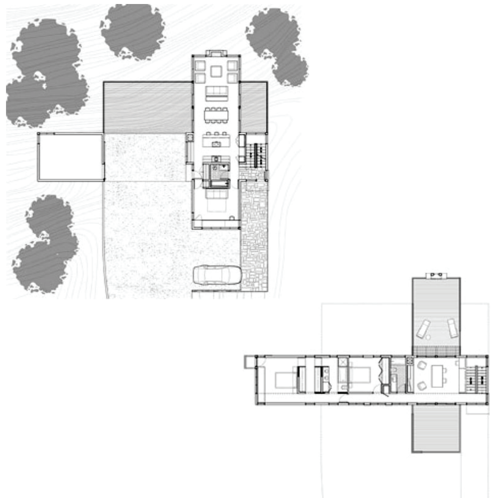
In addition to the modular system Res4 developed with manufactures a standard method for detailing, lighting, mechanical systems, finishes and so on.

The strength and success of this project lies in the firm's **ability to foresee and take control of every phase of the construction process, from design to delivery of the house**.

[ill.36] Res4, Dwell Home construction



[ill.37] modern modular series



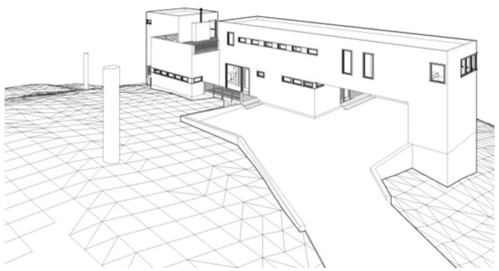
[ill.38] Res4, Dwell Home, ground a first floor plans

When looking at the categories of prefabrication we can consider the modern modular series as a 3D method where almost 85% of the dwelling is produced offsite.

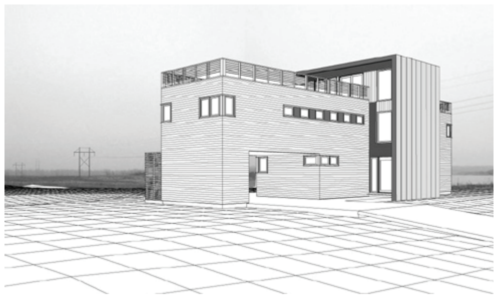
This system guarantee low costs and an high speed of realization, but what even J. Tanney is worried about, is that the costumer is always pushing to lowering down costs and time giving up with quality.
[Ryan E. Smith]

This method allows a high degree of variation based on the same structural principle, which is a post and beam wooden frame that can approximately cover a span that goes from three to five meters.
The wooden frame allow to create different modules that have the characteristic to be narrow and long.
Each module can be designed for a specific function, builded on factory and then delivered to the site where it will be assembled.

The final result it is a house based on several long "bars" whose system reminds to the Lego brick constructions and that present its main limitation in building in height, since it can not exceed two floors.



[ill.39] Krikawa Residence, Res4, San Diego, California



[ill.40] Gordman Residence, Res4, Ashland, Nebraska

[ill.41] The White Box, Res4, Columbia County, New York

ANDERSON ANDERSON ARCHITECTURE

Mark Anderson and Peter Anderson are two architects and builders who researched, developed, designed and produced industrialized building for over two decades mainly around the United States and Japan. Unlike other architects who have experienced the same field, their work has led them to investigate various systems of prefabrication such as CNC (computer numerical control) timber manufacturing, panelised systems of factory-framed, structural insulate panels, metal building system investigations, precast concrete, shipping containers and portable modular construction.

The success of their works is due to the ability to establish a strong collaboration between designers and builders.
They use prefabrication as a system from which takes advantages in terms of production, modularity and portability and not only as a fast and cheap solution.
[Ryan E. Smith]

In the following pages there will be analysed two examples of their works chosen for the diversity of systems and methods involved.

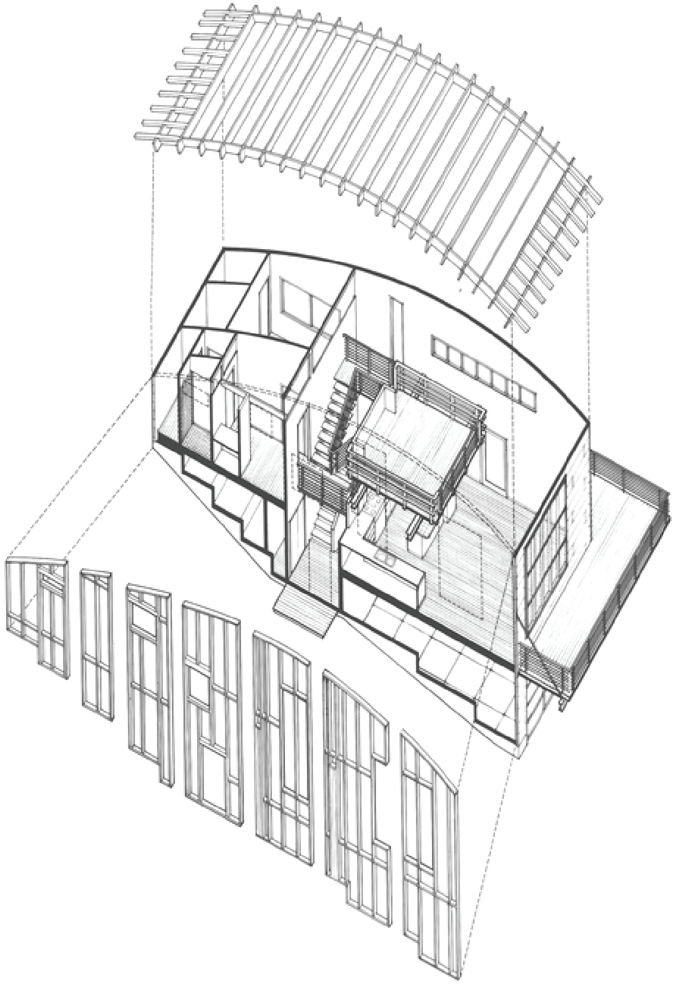
Fox Island Residence: (panelized)
This homes uses prefabricated 2,4 m wide vertical panels, which remain standardized from the main floor and above, but are lengthened or shortened at their lower ends to adapt to varying slopes and lower floor configurations. [M. Anderson, P. Anderson]

This project is designed to take advantage of the cost saving efficiencies of factory building, but at the same time it is able to adapt to specific building sites and to users need without giving up with quality.

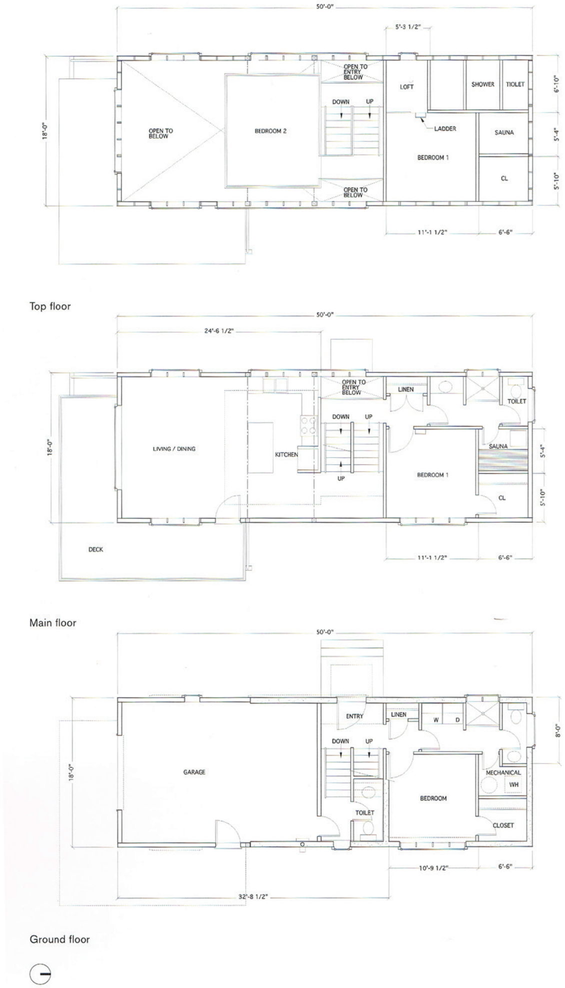
[ill.42] Fox Island Residence, Anderson Anderson Architecture, Gig Harbor - Washington, 1992

The balloon-framed studs run continuously from foundation to roof and the interior space result as an open space divided just by the structural wooden panels.
[M. Anderson, P. Anderson]
[Ryan E. Smith]

[ill.43] general view of Fox Island Residence, Anderson Anderson Architecture, Gig Harbor - Washington, 1992



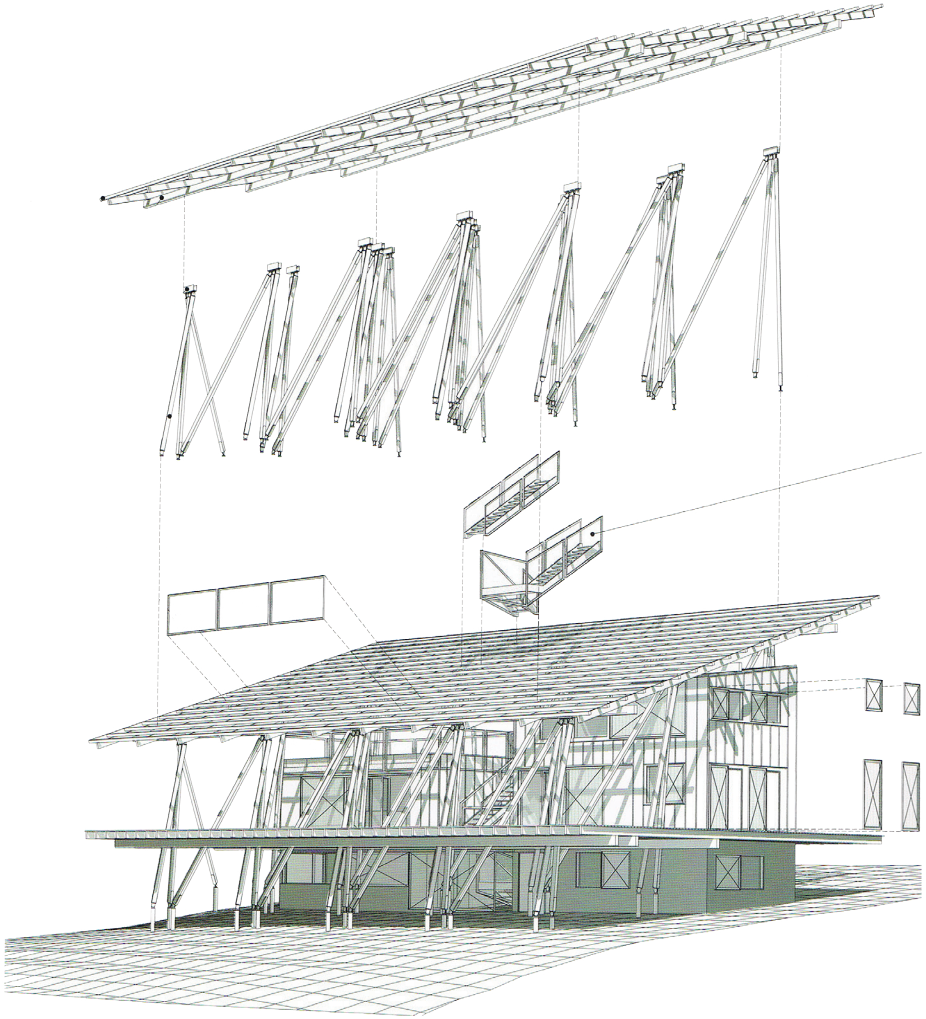
[ill.44] axonometric drawing with exploded wall panelsand curved roof



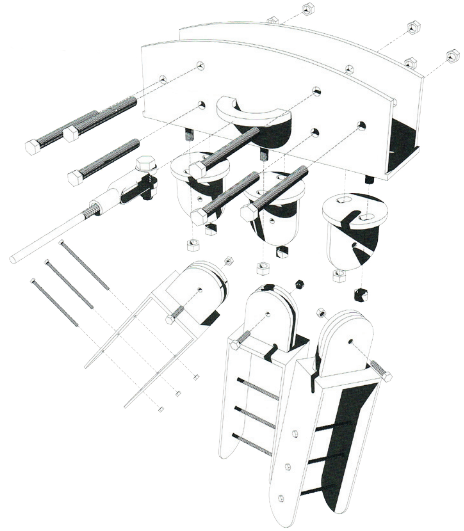
[ill.45] top, main, ground floor plans of Fox Island Residence

Marrowstone Island House: (CNC Timber Framing)

The house, located on an island in Puget Sound, has been developed in collaboration with a fabricator using new-generation CAD/CAM timber-milling machines.
The main concept is to utilize the timber frame structure to support a roof which is detached from the house and that works as a big umbrella.
The scope is to create a free space for interchangeable living spaces, resulting in a variety of options for modular approaches to the building enclosures.
The umbrella roof is framed with tripods of glue-laminated timbers, which has splayed legs providing shear resistance in all direction and eliminating the need for cross bracing.
The architects' thought about this system is that the **large number of small, modular components has proven to be a cost-effective and efficiently transportable prefabricated structural system when applied to particularly inaccessible locations**, but on the other hand they think this is not a complete solution since the structure require other system of enclosure. [M. Anderson, P. Anderson]



[ill.46] exploded axonometric of Marrowstone Island House, Marrowston Island, Washington, 2003



[ill.47] detail of a fabricated structural steel connector

To conclude, Anderson and Anderson see the great advantage of prefabrication in its predictability in relation to time, cost and expectation.
Moreover, they believe that the future of industrialized building will be the use of standardized systems rather than single components. [Ryan E. Smith]

Beyond these considerations, what is visible from their works is the constant research in experimenting new solutions always taking in great consideration user needs and the site where they are settled.

ZAHA HADID

This case study cannot be compared to the previous ones in terms of scale and typology, but it has been take into consideration to show how **off-site construction can be used to realize unique projects**, which move away from the concept of standardization and mass production.

The Heydar Aliyev Cultural Centre is a cultural complex designed by Zaha Hadid and located in Baku Azerbaijian. It is a massive complex that will provide space for a conference hall, three auditorium a library and a museum.

The primary role of this project is the research for a sinuous and organic architecture.
The final effect is a curvilinear form that looks made of one single continuous surface that rise softly from the ground, wrapping the various spaces before folding into the interior to become ground. [web 03]

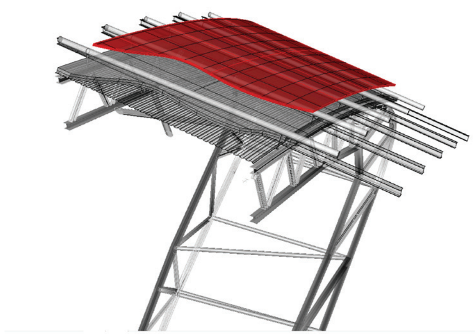
As for other projects from Z. Hadid the feeling is that the design started from one of her famous free hand drawings and that just afterwards the stuff began to think about how to act with the structure without compromising the architectural expression.

As it is shown in the illustrations, the roof structure is made of a truss system specially designed to follow the fluid forms.
Part of the structure has been erected on site while the concrete panels that compose the cladding has been produced off-site.
Thanks to parametric design systems in combination with off-site construction it was possible to divide the roof in hundreds of panels that correspond to an ideal curved surface. **Each of the panels produced in factory, has to be considered unique even if the process of production used is standardized**.

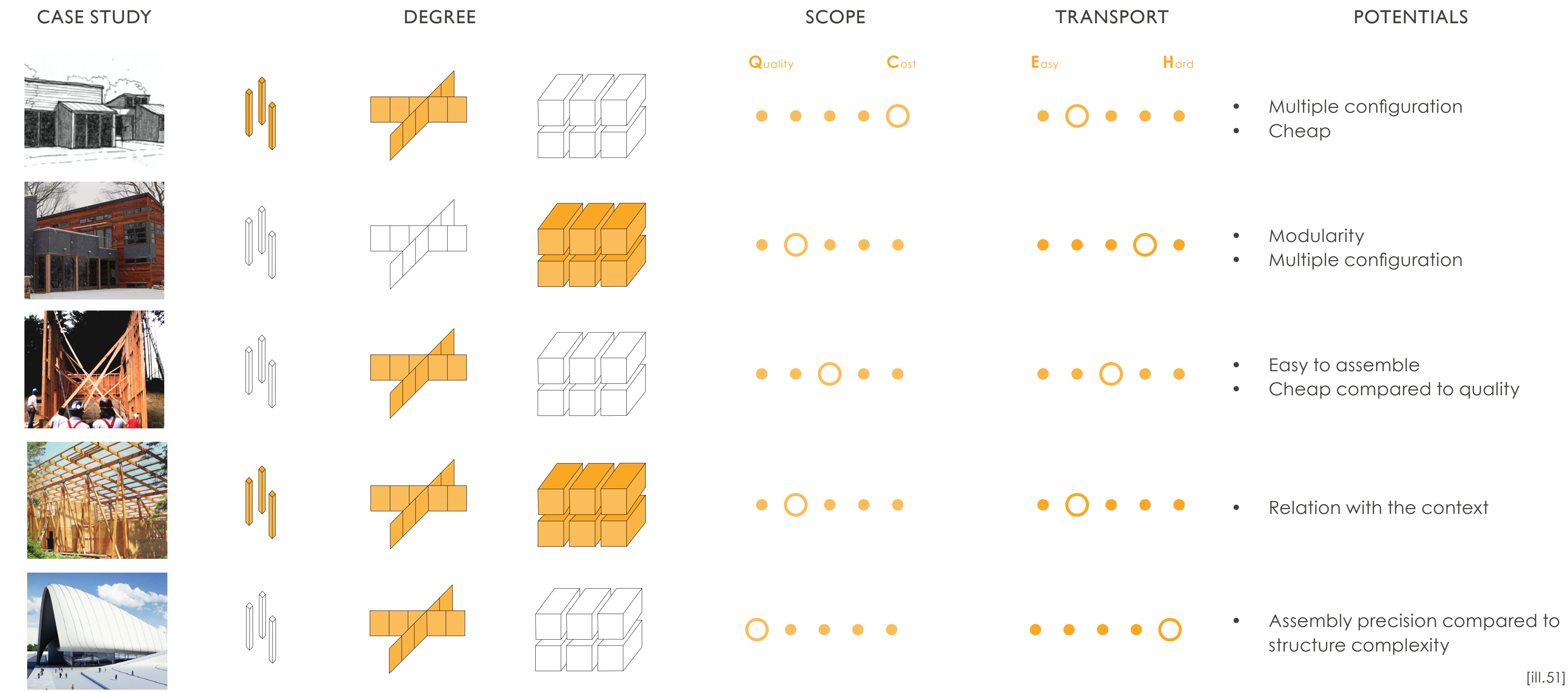
Unlike the other case studies this example shows how prefabrication, in this case, is not the primary scope but it is just a tool to solve a problem that would have been difficult to solve with conventional on site systems.
The architectural Firm took advantage of the possibility of creating and controlling many different elements in a protected indoor environment. A process that guarantee safety and short time construction, where the final target is all about quality.

[ill.48] The Heydar Aliyev Cultural Centre

[ill.49] Construction phase



[ill.50] structure detail



[ill.51]

What is deductible from these studies is that the **balance between the scope**, which is the design intent, and the **production method**, must be taken into account since the beginning of the project.
Indeed the degree of prefabrication will influence drastically the flexibility of the project but not necessarily the quality.

Transportation and **site conditions** are two other factors that influence the design as well.
On one hand the "modules system" is the most complete of the three, where almost 85% of it is finished off-site and this will of course reduce time and mistakes on the construction site. On the other hand this system has less flexibility due to the size limitation imposed by the transport.
The potential of this method has been successfully explored by Res4 Architects with the modern modular system which has the ability to create an incredible number of different designs, that anyway take advantage of the same standardised but highly customizable elements.

The "components system" has the great potential to be easily transported and this characteristic works well especially when applied to particularly inaccessible locations.
This method prove an high level of flexibility, which basically allow any kind of design but on the other hand is the system that require most money and time.

CONCLUSIONS

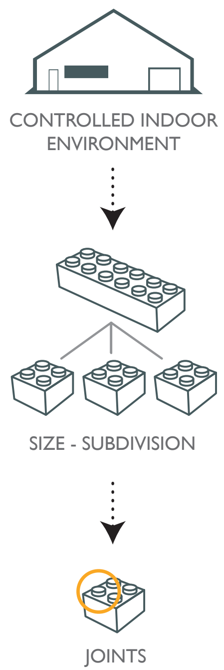
As just shown, there is not one way of using prefabrication, as the way **to use this method depends on the scope one wants to achieve**.

Anyway, it is of course true that there are some common factors in using this system.

First of all, in every case, the process starts in a **controlled indoor environment**.

Secondly, the elements that combine the final product must be designed based on the means of transport, which means that the final product have to be necessarily divided in **several pieces** with certain **size**.

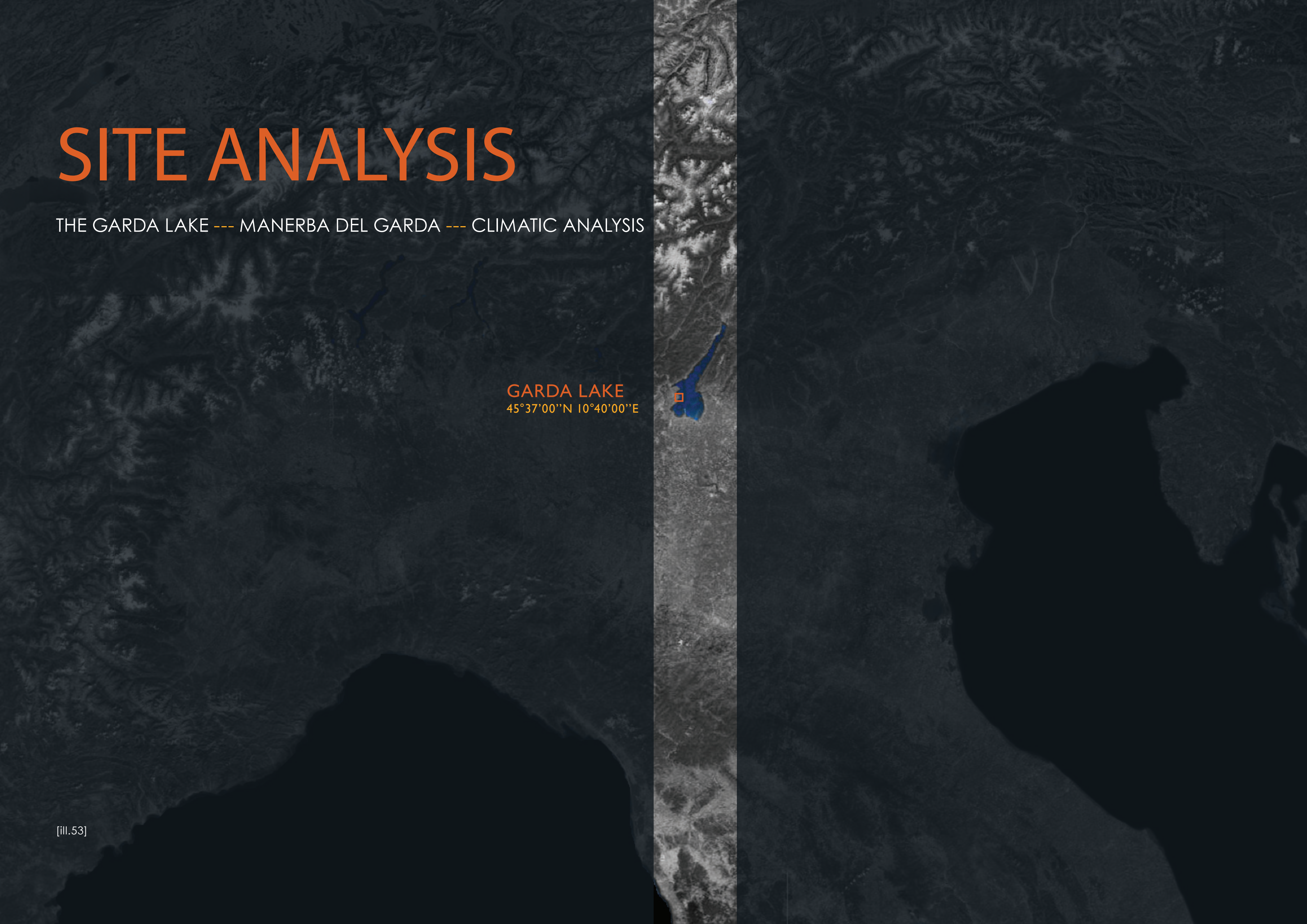
Finally, the elements created must be assembled on site, and this require to think in advance about the **connection systems** between the different elements and the foundations.



[ill.52]

SITE ANALYSIS

THE GARDA LAKE --- MANERBA DEL GARDA --- CLIMATIC ANALYSIS



[ill.53]

PLACE, TIME AND BEING

Finally, after having focused the attention on issues that mainly concern architecture itself, it is important to understand how architecture relates to the landscape.
This issue will be reconsidered during the design phase as it represent a crucial aspect, since the chosen site for this project is extremely unique.

The relationship between architecture and place is been a central issue in the 20th century.

In general Architecture is specific in relation to User, Time and Location, while prefabrication is considered to be the opposite of unique architecture. [M.Anderson, P.Anderson]
In its earliest form, prefabrication was not taking care of this relations since it was though to be in a large scale for a great amount of users in different locations and at an affordable price and time construction.
The result is that architects has been designing buildings for unknown customers and to some extent also for unknown locations.

Can Prefab Architecture be specific in relation to user and location?

Some architects have been quite skeptical about designing for unknown sites and users but during the last decade others started to cooperate with housing producers with the main focus of creating qualitative prefab houses, and at the moment many architectural firms have at least one prefab house in their portfolio.
[Arieff, Allison – Prefab - 2002]

Therefore, industrialization brings up a question: **to what extent is important that Architecture relates with the surrounding and its inhabitants?**

In this thesis is not important to define the most correct theory to follow, or to discuss whether proportion, order, multi-sensorial experience and cultural/personal experiences are more important than relation to the context, user and time.
Indeed the main important goal is to understand all the passages that can contribute to design a prefab architecture of quality.
Understanding therefore how architectural-technical-sensorial qualities are combined in some remarkable case studies of prefab architecture and understanding till which extend is important the relation of these architectures to the site, the user and the history of the place. Indeed it can result, from the following phases, that some qualities are more important than others.

[ill.54] Tubac House, Rick Joy, Arizona, 2000

THE GARDA LAKE

The Garda Lake represents one of the most unique areas of the Northern part of Italy.
Its beauty lies in the **variety of the landscape**. Indeed the orography of the area change drastically along its path: while the northern part is characterized by imposing mountains that overhang the water, the southern part is made of gentle hills and flat fields where the humans being began to settle since the prehistoric age.
The main cities of the area are located by the lake's shore to testify the crucial **relationship between men and water**.
The medieval structure of these centres, made up of stone houses, narrow streets and thick protective walls, is still visible today despite the urban expansion that characterized more or less every Italian city from the beginning of the XIX century. Expansion that raised drastically during the past 70 years causing the increasing of single family houses, building complex and summer houses scattered all over the landscape.
Despite this phenomenon has been deleterious for many Italian historical cities, the identity of the lake is still alive and strong, but it is also true that the harmony between "artificial and natural" get completely lost. The peculiarity and beauty of the historical centres and old houses scattered through the area, lies in them relation with the land, the geography, the natural flow of time and the scale. [Il Garda]

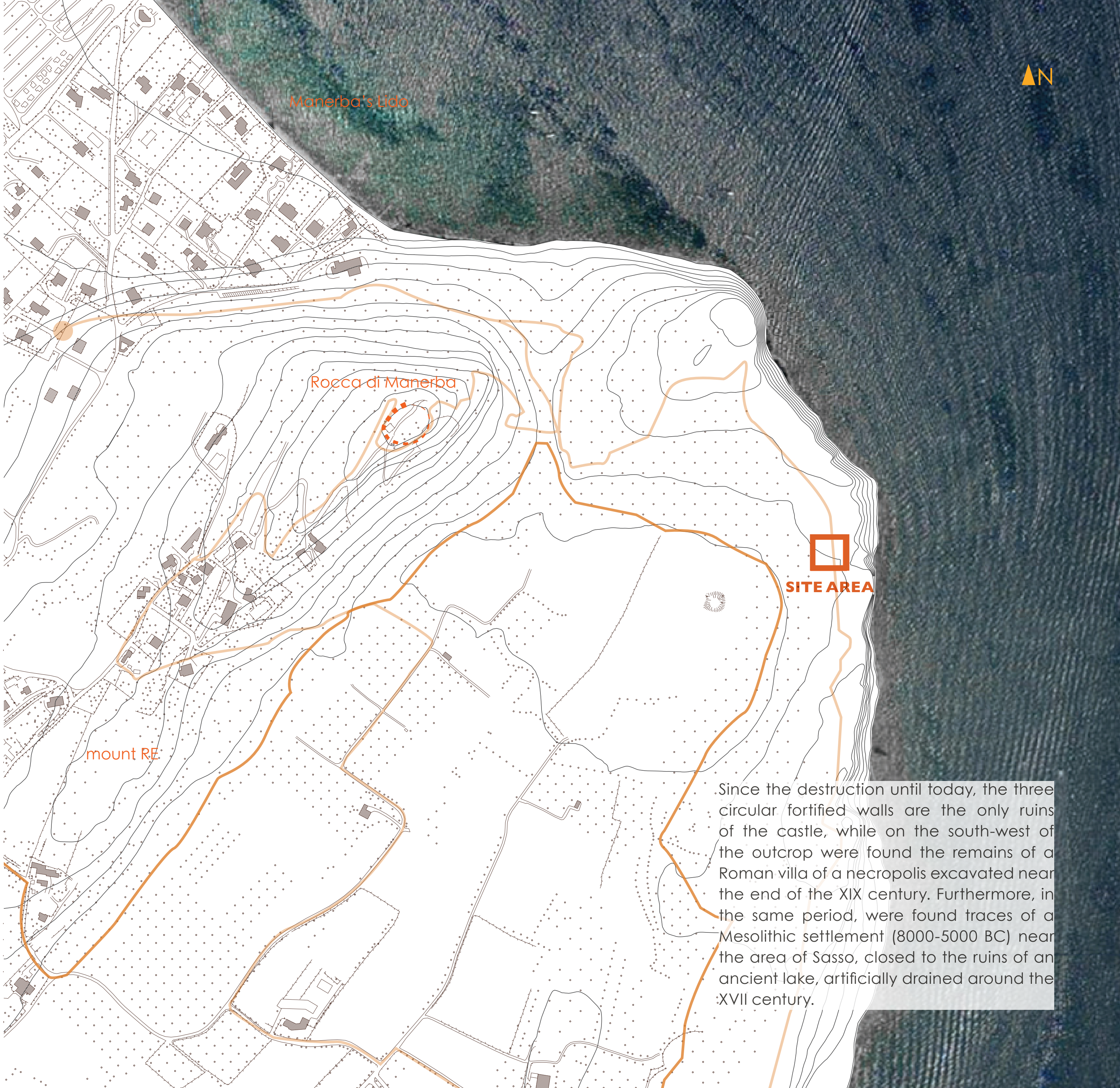
[ill.55] The Garda Lake

MANERBA DEL GARDA

Manerba was erected, according to some historians, in devotion to the goddess Minerva. Manerba is at the center of a particular territory (Valtenesi) and thanks to its shape, the rocky outcrop dominating the southwestern shore of Garda Lake, has attracted man from prehistoric times until the XVI century.

The populations that succeeded one another over the centuries were many, all united by a common conviction about the area: seen as a favourable position in time of peace thanks to its connection with the land routes and river-lake region, but very dangerous in a war scenario. This explains the presence of well-preserved castles in the Valtenesi territory dating from the XIII century AD, some of which are erected on the ruins of Roman forts. [La Rocca di Manerba]

“Rocca di Manerba” is the oldest and most important castle of the Valtenesi region, built in the XII/XIII century on the ruins of a medieval fortress and a settlement dating to the Iron Age, firmly anchored to the rocky outcrop of Manerba. After having been a formidable Lombard bulwark during the conquest of the Franks, and during the long conflict between the Guelphs and Ghibellines, since the sixteenth century, it became impregnable refuge of bandits and outlaws, forcing at that time the Serenissima Republic of Venice to the complete destruction of the walls in 1787. [web Manerba]



[ill.56] Site map

Since the destruction until today, the three circular fortified walls are the only ruins of the castle, while on the south-west of the outcrop were found the remains of a Roman villa of a necropolis excavated near the end of the XIX century. Furthermore, in the same period, were found traces of a Mesolithic settlement (8000-5000 BC) near the area of Sasso, closed to the ruins of an ancient lake, artificially drained around the XVII century.

[ill.57] bird eye view of the site area, the rock cliff, "Rocca di Manerba" and "Lido di Manerba" [ill.58] view of the site area from "Rocca di Manerba" (left corner).

[ill.59] pathway to the site area (behind the hill) from "Manerva del Garda"

[ill.60] view from the site area of "Rocca di Manerba" (left side) and the pathway.

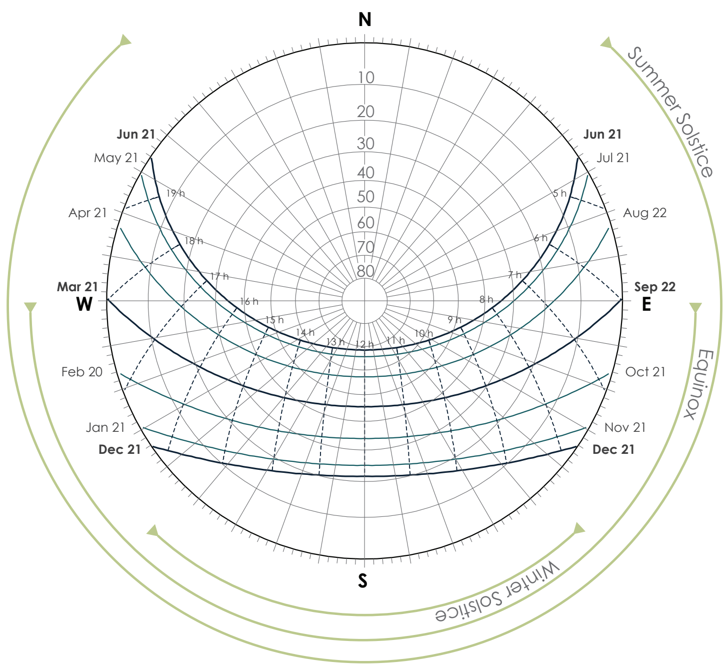
[ill.61] view of the site area from the path, visible on the right: Rocca di Manerba and the hightest point of the rock cliff.

CLIMATIC ANALYSIS

The presence of such a great amount of water, mainly in the northern side of the lake, where it reach a max. depth of 383 m, contributes to mitigate locally the climate, although without affecting the overall alpine weather, throughout the year.
In the southern side of the lake the climate is more damp and foggy, influenced by the Po Valley's weather. However, the flora is still the same of the one present along all the lake shore: hills covered by olive trees, vineyards and cypresses, indexes of a mild location.
Therefore, to sum up, the general climate condition which characterize the lake is defined by the combined presence of both an alpine and continental chilly weather and the one coming from a more subtropical mediterranean weather.
[Il Garda, E.Turri]

SUN

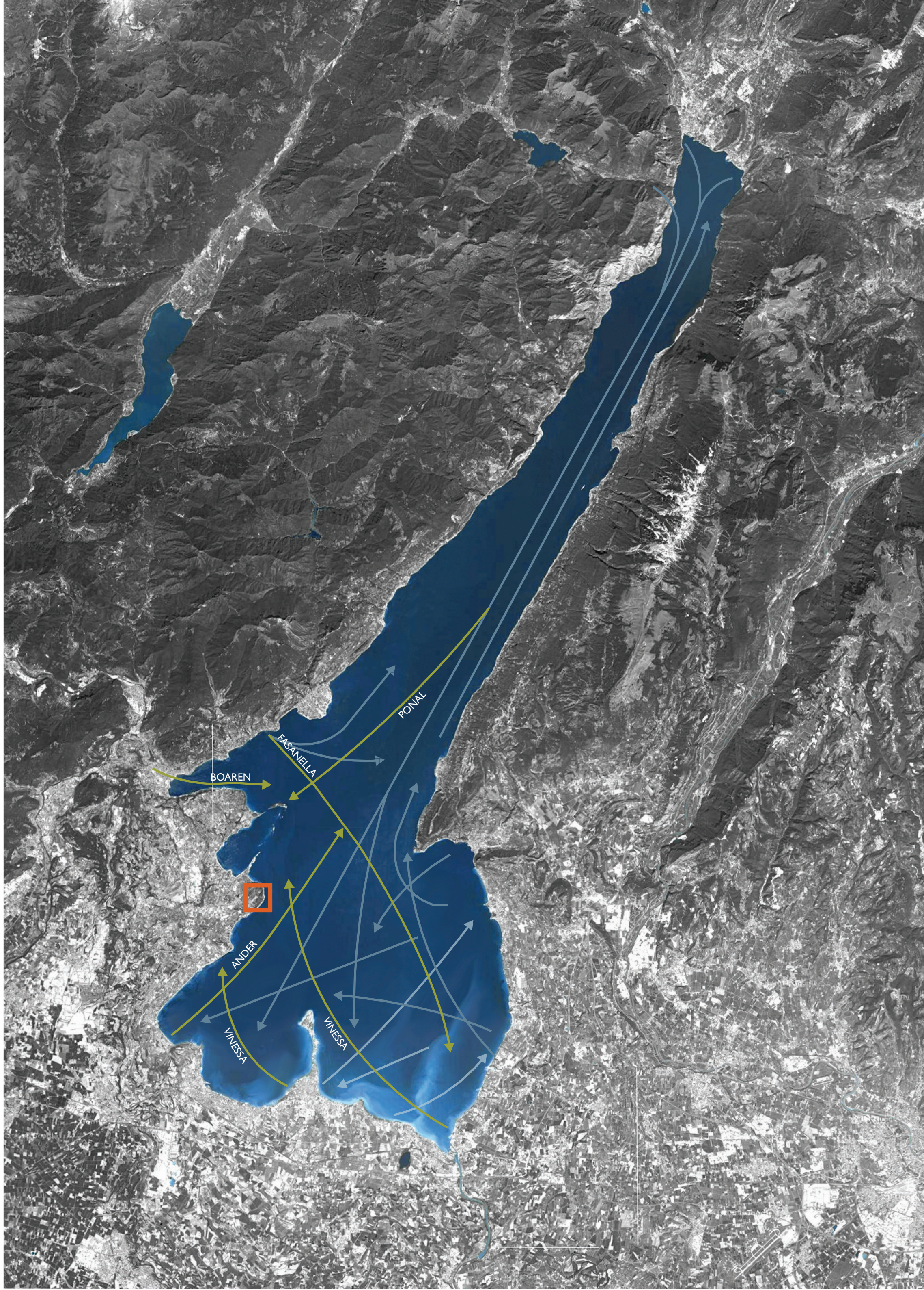
The main reason to explore the solar conditions in the site is to achieve the **best light qualities and orientation of the building**, fundamental to reach the best performance of it.
Therefore the sun diagram is an important instrument to understand how the sun-path and consequently the shadows could affect the site and the inside well being of the dwelling.
The sun diagram shows the position of the sun in the sky during one year, according to the site latitude of 45°. At this latitude, in the Northern Hemisphere, there is a difference in daylight hours between the wintertime, where days are short and the sun is discretely low at horizon, and the summertime, where the sun reaches almost 90° on the zenith axis.
Beyond numbers and diagrams, what it is helpful to understand is the quality of this light, which gives character to the site.
The great amount of sun hours, makes each thing becomes discrete, with its own form and distinct character, defining sharply the objects. [Christian Norberg-Shultz]



[ill.62] Sun path, Manerba del Garda

WIND

The Garda Lake is oriented longitudinally from north to south in the Po Valley, therefore many typical winds of this site are the result of a difference in weather between Northern and Southern side. This disposition and different weathers generate winds that descend from the mountains to the valley during the morning and go back to the mountains in the afternoon. The narrow passage formed by **the lake basin affects the winds direction, many of which are periodical, while others are only daily**.
The most known and regular wind is the one called Ponal. It is a descending wind from the alpine mountains which affects almost the entire lake, losing its intensity after "Torri del Benaco", where the lake widens, causing loss of the wind force. It is blowing in the early hours of the night, but is reinforced by the rising of the sun (till 12-15 m/s) [see appendix 03], due to increased temperature, and blow until noon. Other mountain breezes are the Montis, which blows from Monte Baldo and Bardolino to Peschiera, and the breeze Boaren, which instead descends from the foothills of Brescia to Desenzano and Manerba. [web Garda]



[ill.63] Wind orientations, Garda Lake.

SITE

Since the project I'm going to develop is a leisure house, the choice of the place must to be considered as important as the quality of the dwelling.

I decided to settle my project in Italy because, as it will be better explained in the following chapter, there is the **tangible possibility to realize the project in that specific area**.

Despite this reasons, one could argue: why that location, why that specific spot?
My answer is that there are different ways to read and express the concept of "place". According to Christian Norberg-Schulz *"a place is a space which has a distinct character"*, which has its own identity that goes beyond the concept of beauty. [Christian Norberg-Schulz]
The place where a man decides to dwell is the place where he identifies himself with the environment, *"when he experiences the environment as meaningful."*
[Christian Norberg-Schulz]

The spot I choose is not only beautiful itself but it also represents the perfect settlement for the project I am going to develop.

Therefore, the site is located on a rocky cliff situated 60 meter above the lake.
Thick high vegetation surrounds the spot, which is characterized by low arid grass fields and outcropping rocks.

Considering that the south part of the Garda Lake is characterized by its orographical flatness, we can agree that this is a **unique and extreme site**, an isolated place that assume its own identity, from which is possible to admire the lake and the surrounded landscape while being deep into the nature.

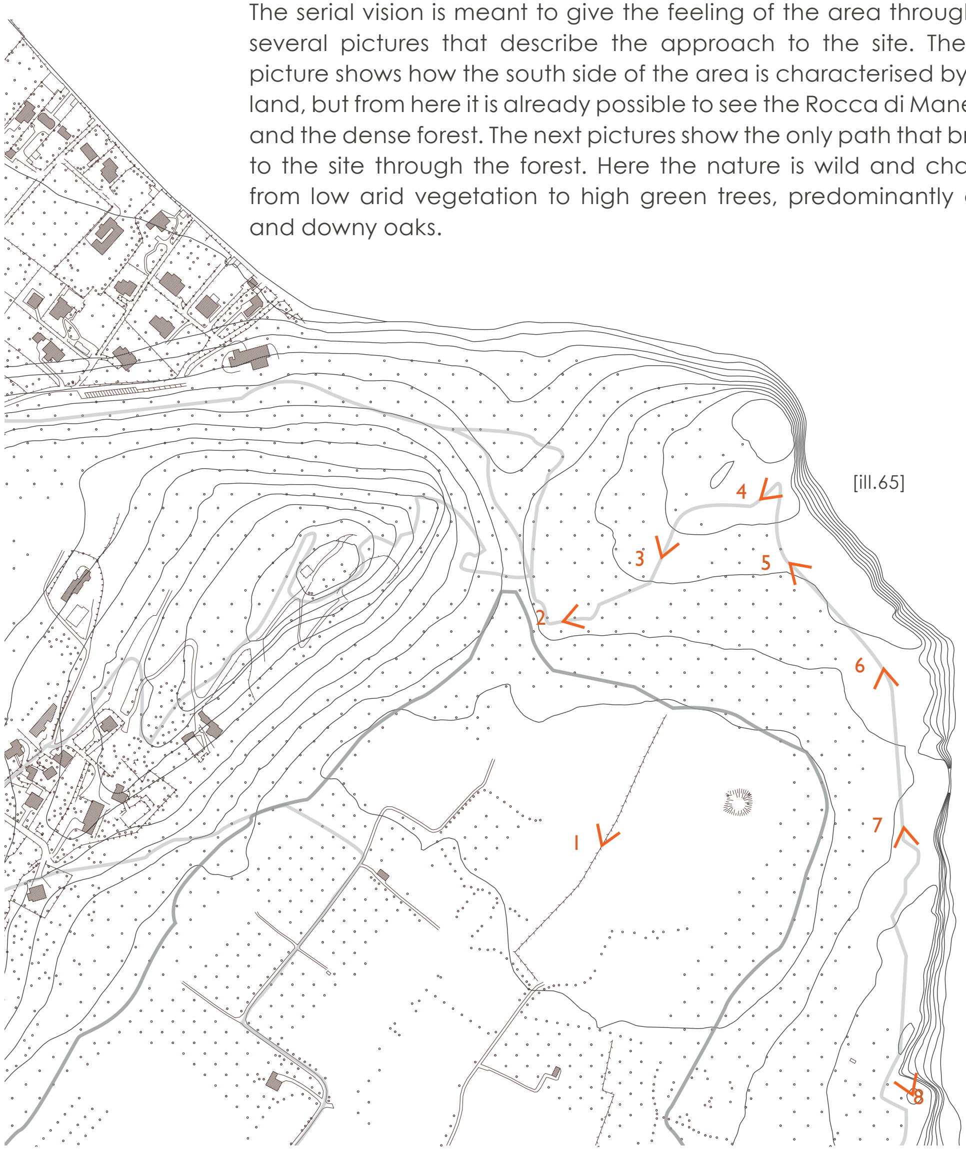
CONCLUSIONS:

As already explained, the site is completely surrounded by nature. The only architectural presence is the "Rocca di Manerba", that stands imposing on top of the nearby mount. The project area is surrounded by trees that reach the maximum height of 8m.
Therefore, the design of the dwelling has to take in account the landscape configuration: **the height of the trees, the wind that mainly blows form North and the climate that reaches 30 °C on summer and rarely fall below freezing on winter**.
Moreover, the spacial inside organisation have to face the **orientation**, not just to achieve good comfort condition, but also to frame specific **views** towards the lake and inland.
Finally, the **access road** to the site has to be revised in order to allow the means of transport to reach the area.

[ill.64]

SERIAL VISION

The serial vision is meant to give the feeling of the area throughout several pictures that describe the approach to the site. The first picture shows how the south side of the area is characterised by flat land, but from here it is already possible to see the Rocca di Manerba and the dense forest. The next pictures show the only path that brings to the site through the forest. Here the nature is wild and change from low arid vegetation to high green trees, predominantly elms and downy oaks.



[ill.65]

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LEISURE HOUSE TYPOLOGY

Leisure, or free time is the time spent away from business, work and domestic amenities. Therefore, the location, the scope and the distribution of functions, in instance, in a leisure house have a distinguished character, which differs from a single family house.
In a house of pleasure and vacation, the unconventionality and the relaxing feeling are a must, to divert the user's mind and behaviour from the everyday life.

Introducing prefabrication as a tool to create a house where to rest and enjoy the surrounding, can be seen as an alternative solution to reach this scope.
Indeed, a prefab architecture can try to reproduce in dimensions and organization an onsite-built leisure house, but has instead the possibility to use the prefab system as a solution to create a house which makes use of modular dimensions to challenge the spaces and their organization in a more interactive way.

Leisure house indeed does not necessary means large dimensions of the spaces. Le Cabanon, by Le Corbusier is an example. In 16 m^2 the organization of the spaces is done without having surplus, the restriction to the necessity is seen as a luxury.

The creation of a minimal house, as well, can be seen as a playground, where to reorganize the functions in a way which differs from the everyday routine.
Like in the experience of the house (ex.tree house) created in childhood, the essential functions and their active relationship refers to an house of leisure.

The importance has indeed to release on sensual experiences and intuitive approaches to the space, which are not a synonymous of conventional aspects.

[ill.66] Tree Hotel, Tham & Videgård Arkitekter, Harads, Sweden 2010

USERS

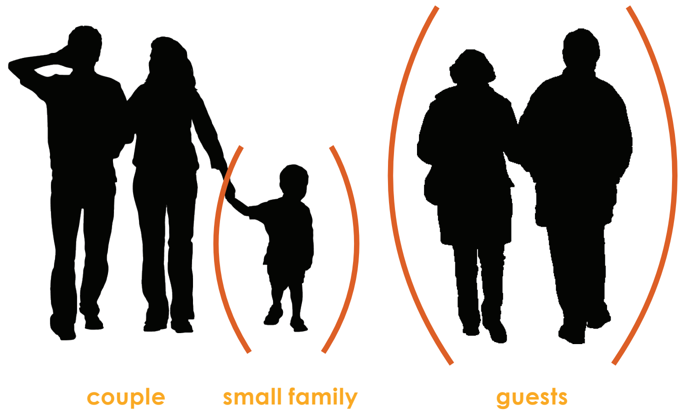
The Danish couple for which I am making this proposal already knew the location since they use to spend their vacations in a town nearby.
Their wish is to create a **small but comfortable dwelling**, **easy to assemble** and disassemble, even in a remote site like this one, where they can spend their spare time away from the everyday life.

In terms of dimension the dwelling must be **primary designed for the owner and his partner** but it also have to provide enough space for guests.
As the wish is to create a compact house it will be necessary to use smart solutions in order to do not waste space.

The dwelling will be used for short periods during summer as well as wintertime and therefore it must provide a comfortable environment for both seasons.

There are no particular requests from the client, apart from the obvious fact that the dwelling has to create a relation with the surrounding environment: the thick vegetation on one side that gives the feeling of protection and then the steep cliff that open the view to the lake on the other side.

The area is isolated and this will of course influence the users behaviour but it also give the chance to create an **intimate relation with the surrounding**.



[ill.67]

WHY PREFAB ?

After briefly explored and analysed prefabrication from an historical and technical perspective, It become clear how nowadays **prefabrication is a system through which is possible to obtain a qualitative architecture the same way as other construction methods**. It is then important to understand which are the reasons for using this construction method in place of a conventional one since both lead to the same purpose.

The first reason why I decided to approach this theme is that the client for which I am making this proposal has the wish to invest in prefabricated systems and as a first prototype he wants to realize a leisure house for him and his partner.

Apart from this personal reason it is then essential to understand which are the off-site construction **architectural values**?

I do not think that there are some universal architectural values that can be directly attributed to prefabrication because as it was shown in the case studies, there are different way of using this method.

Nevertheless the potential of using off-site construction, from an architectural point of view, could lies in its limits: **size** and **transportation**.

As already demonstrated, these two factors implies the use of lightweight material easy to carry. Moreover, transportation requires that the different elements that compose the final product have to be divided in several pieces (depending on the degree of prefabrication) that have to be afterwards joined on site.
These factors will generate an architectural expression that is representative of this working method, made of lightweight components where joints and structure become the detail that make the difference from a conventional on site construction system.
Therefore **lightness**, **structure** and **joints** can be considered as architectural values.

Both the potentials and the lacks of this system will be taken into consideration when approaching the design phase.

PREFABRICATION ARCHITECTURAL VALUES:

LIGHTWEIGTH MATERIAL
CLEAR STRUCTURE SYSTEM
CLEAR JOINTS SYSTEM

VISION

The vision for this project is to design a compact leisure house on a cliff by the lake that creates a strong relation with the context where it will be settled, making use of prefabricated tools and techniques.

[ill.68] concept: prefabrication as a tool to create an interactive leisure architecture

CONTEXT:
The location is really specific and one of the first steps is to understand how to relate the dwelling to the landscape.
The arrival to the project area is from Southwest through the wood. The dwelling will be then protected or hided from trees on one side, but still visible from the lake.
Once inside the views will be framed in order to show just some specific portion of the landscape to create a sort of sense of discovery and not to get bored all day from the same view.
The design will have to take care about the wind and the climate changing conditions typical of lake areas providing smart solutions like bigger openings on the South side wile the North side should be more protected.

EXPPRESSION:
Since the dwelling will be the only artificial element it will have a strong impact on the landscape. It is then necessary to understand whether to emphasize this aspect creating a landmark, or if it makes more sense to hide it in the environment.
The roughness of the place should be then reflected and emphasized through the use of a combination of few good materials.
Materials used for their properties and for the feeling they can express.

LEISURE:
The leisure house typology has to be expressed through the organization of the interior spaces and the connection between them, giving more importance to common areas and all the zones that allow to fully enjoy not just the house but also the surrounding landscape.
It will be therefore considerate how to integrate external spaces like a garden or a patio or even the use of the roof.

TECHNICAL:
In prefabrication, structure and architecture are strictly connected, so it will be extremely important to explore and evaluate the best solution to choose in order to fill the requirements of my vision.
Therefore in the following phase, potentials and lacks of prefabrication will be explored.
Prefabrication is a good solution to choose in remote site like this one as it is not an invasive construction method. Anyway, It will be necessary to choose a system easy to transport, made of small components and easy to assemble on site.
However this could be seen as a drawback in terms of architectural expression, it will be therefore necessary to avoid this problem exploring other possible solutions to integrate with the off-site construction.

ROOM PROGRAM

The dimensions expressed in the diagram are approximate and related to minimal room dimensions based on the activities they must accommodate.

Therefore, dimensions and number of rooms, will be evaluated during the design phase, as it could result that some activities or rooms require more space than others.

room program prefab leisure house

functions	areas	> private	> public	main possible orientations	views & perception
Entrance	2 m^2		+	N, ...	
Living room	6 to 15 m^2		+	E, S, W	+
Dining room	6 to 10 m^2		+	E, S, W	
Kitchen	6 to 10 m^2		+	N	
Master bedroom	9 to 12 m^2	+		E, NE	+
Studio	6 m^2	+		...	+
Bathroom	3 to 6 m^2	+	+	N, ...	+
Winter garden	...		+	...	+
Storage/Wardrobe	2 to 8 m^2		+	...	
Technical equipments	...			...	

[ill.69]

DESIGN PROCESS

--- PHASE 1 and focus points for the final design --- PHASE 2 analysis of 3 possible directions and personal interpretations and solutions
--- PHASE 3 final design

[ill.70]

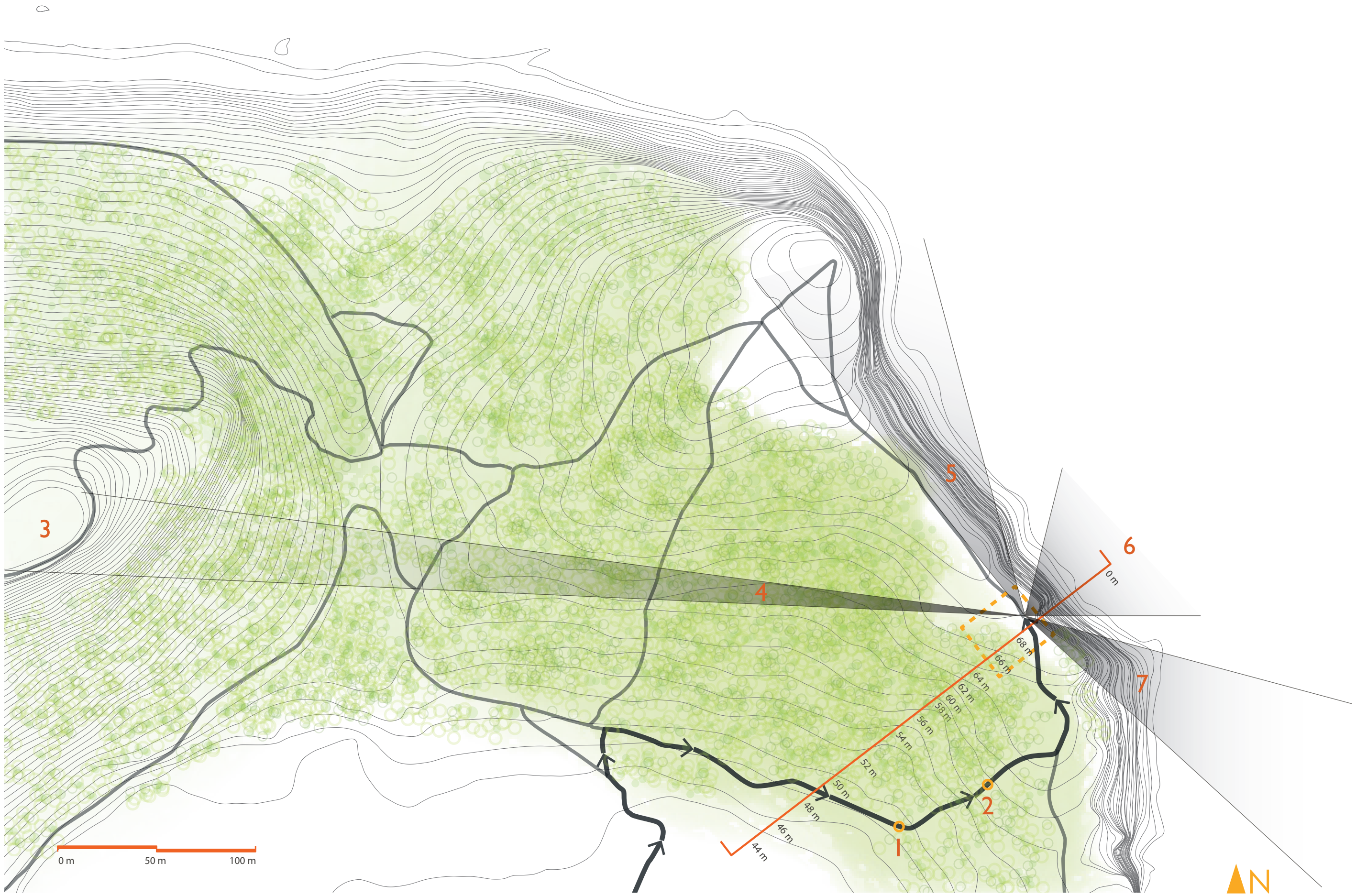
PHASE I

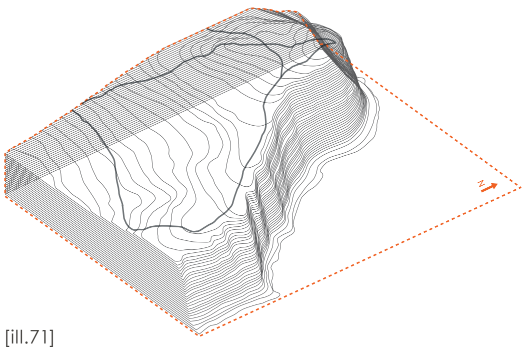
The first phase of the design process involved the interpretation of the site.

In a place where there is no connection with another construction or artificial element it becomes crucial to understand the natural environment.

In this regard, the first diagrams and thoughts have been made taking in considerations three fundamental aspects of this landscape: the slopes, the vegetation height, and the path that brings to the project site.

[ill.72]





[ill.71]

A second step of this phase was the understanding of the particular views from the chosen site, from the path in the wood and from the Rocca di Manerba to the site.

THE PATH IN THE WOOD

These two pictures visualize the path in the wood, which is completely natural and accessible from the public. This images suggested a possibility to supply the natural path with resting areas and facilities to the public and at the same time guarantee a private access to the dwelling.

1

2

FROM AND TO ROCCA DI MANERBA

From the Rocca di Manerba arise a question for the design of the project: how can it be visualized from that high point? The possibilities of being hided in the wood or exposed to a public view will be then considered.

from Rocca di Manerba 3

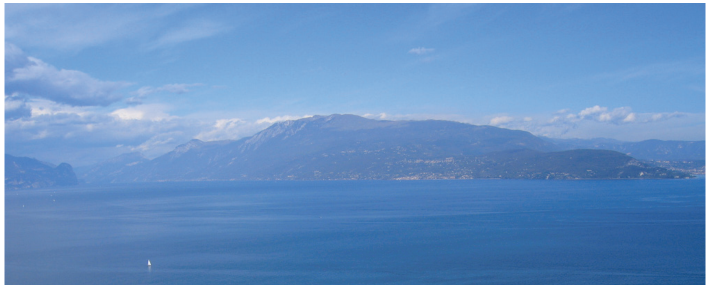
from the site to Rocca di Manerba 4

From the site resulted relevant the open exposure, without obstacles towards east. And in particular: the highest point of the cliff at NE, the open view to the lake at E and SE.

FROM THE SITE TOWARD NE, E, SE

[ill.73]

view to NE - cliff and lake 5



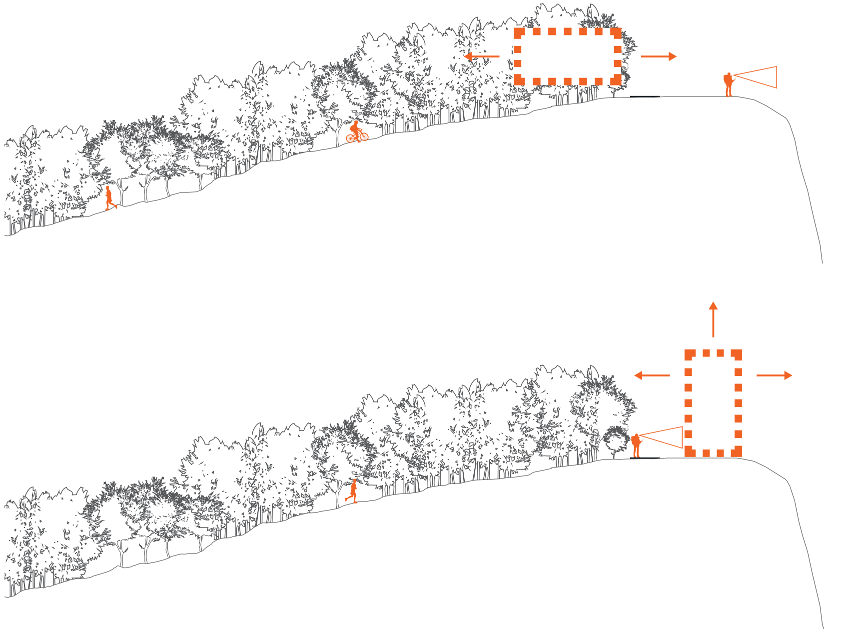
view to E - open view to the lake 6

view to SE - view to lake and path 7

As can be seen from these diagrams, three cases were taken into analysis.
In the first, the building creates a **discreet** relationship with the landscape: the height does not exceed that of the trees, the house is far from the cliff and try to minimize the visual impact (which can be mainly seen from the Rocca di Manerba and the lake).
The second is a structure that **impose** itself on the landscape. In this case it is important to well evaluate the visual impact of this exposure in a way that is coherent to the surrounding.
A further diagram show **how the exposure and the inclosure in the wood can be combined** and categorized in two distinguished functions: a more public area, exposed to the sight of the visitors from both lake and Rocca, and a more private area, hidden in the wood. In this case, the dwelling need to be organized and oriented in a way that guarantee the previously defined views.

[ill.75] Loblolly House, KieranTimberlake, Taylor's Island MD

[ill.76] Tower Studio, Saunders Architecture, Ile Fogo, Canada, 2011



[ill.74]

From the analysis conclusions which precede the design phase and the design phase itself, some focus points arose, and are hereby listed to clarify the steps which lead to the final design.

FOCUS POINTS FOR THE FINAL DESIGN

VIEWS

the views in this context are extremely important

therefore the dwelling has to consider them in its design, both if it is hidden or exposed

EXPOSURE

the exposure has to consider the consequences

therefore the design has to be contextualized with the surrounding

INTERACTION PUBLIC-PRIVATE

since the site area can be accessed by the public, a good interaction between public and private needs to be taken into consideration.

Public and private, being part of the same project and area needs to have a similar expression and also be distinguished as different

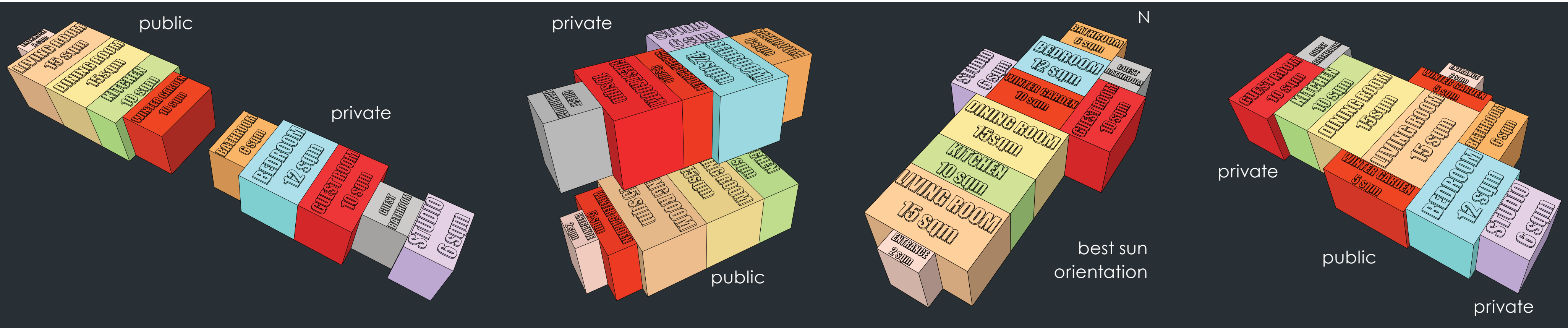
PREFAB + ONSITE

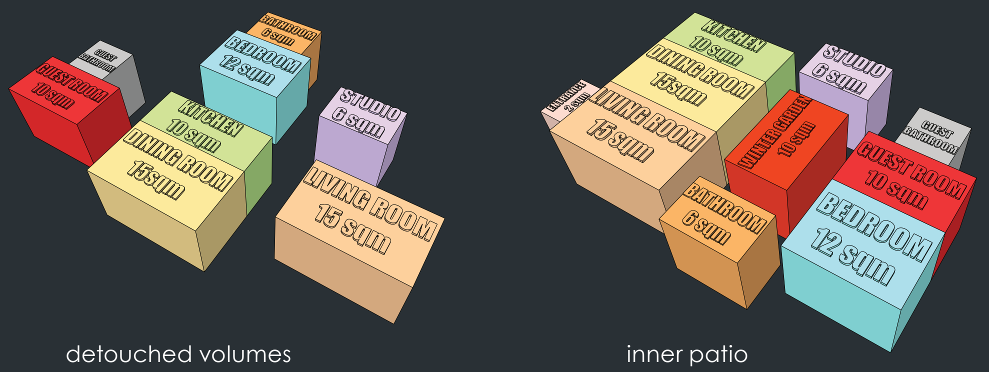
as expressed in the previous analysis phase, not all the parts of the project can be prefabricated

therefore the choice of prefab and onsite needs to be explained and distinguished

PHASE 2

The first phase of the design process was involving the analysis of possible **spaces organization**, mainly according with a western conventional division of public and private spaces.





[ill.77] these diagrams show the most conventional distributions of spaces: starting from the division from private (bedrooms, bathroom, studio) to public spaces (entrance, living room, dining room, kitchen, winter garden), to their organization according with the best sun orientation; from a central disposition of public spaces, to a detachment of all the spaces, which creates an interactive an more open relation with the surrounding.

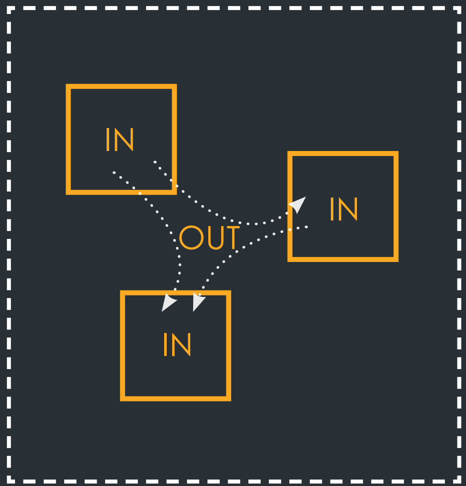
SPACES ORGANIZATION
RELATION INSIDE-OUTSIDE

In the next pages there will be analysed 3 different spaces organizations of existing prefab architectures, with some personal proposals for each organization type.
Here it is shown how they are grouped.

Some focus points for each analysis will give an idea of the design development, with pro and cons.

INSIDE ORGANIZATION

OUTSIDE INSIDE



INSIDE OUTSIDE

Due to the uniqueness of the site, the relation between the inside of the dwelling and the outside landscape had to be considered simultaneously.

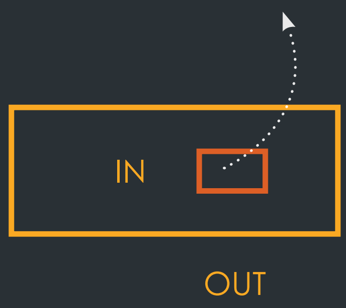
Therefore some analysis and form finding studies were done in order to understand the limits and the possibilities of each category of organization.

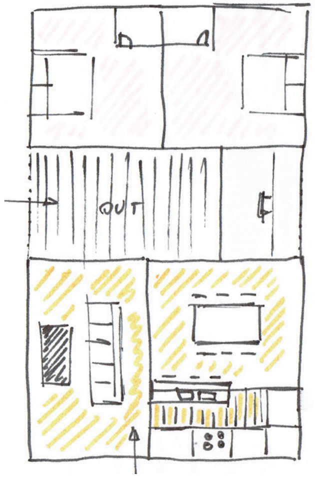
The last typology of organization is the chosen one for the final design.

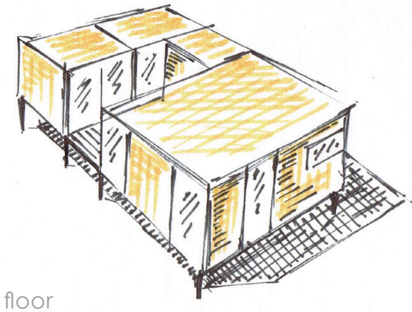
PHASE 2.1

1. INSIDE ORGANIZATION

- All the functions are organized within one space
- One big room
- Functional - simple - modular - compact
- Central core: technical equipments (kitchen, bathrooms)





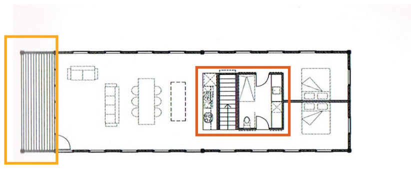


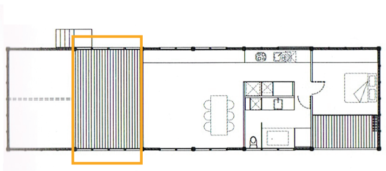
- 1 floor
- within one regular perimeter
- not specific in relation to wind and views
- outside connection between 2 unities

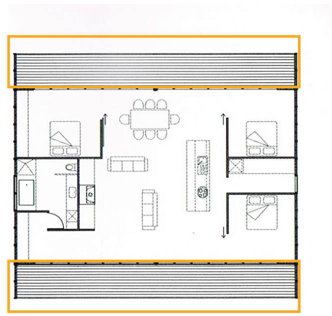
FOCUS POINTS OF THIS ORGANIZATION

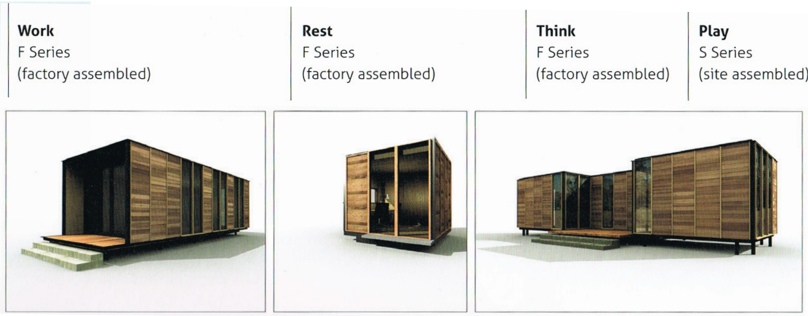
- To create more "play & leisure" it would be interesting to increase some heights or volumes, without being restricted in one regular perimeter or form.

- It would be interesting trying to dissolve the regularity of the modularity, to make it less evident like in some of Suo Fujimoto works.

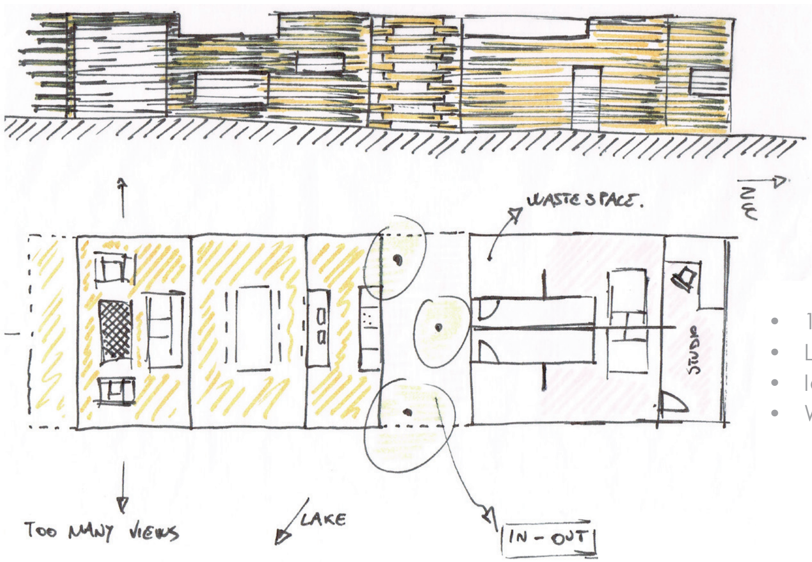


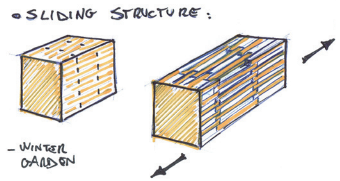






[ill.78] ARKit, Craig Chatman, photos, plans and 3D



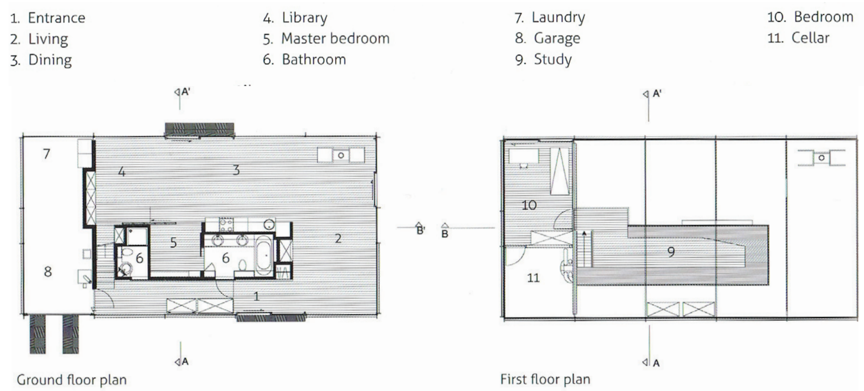


- 1 floor
- Linear
- lot so many interactions in the plan
- Within one unique shape

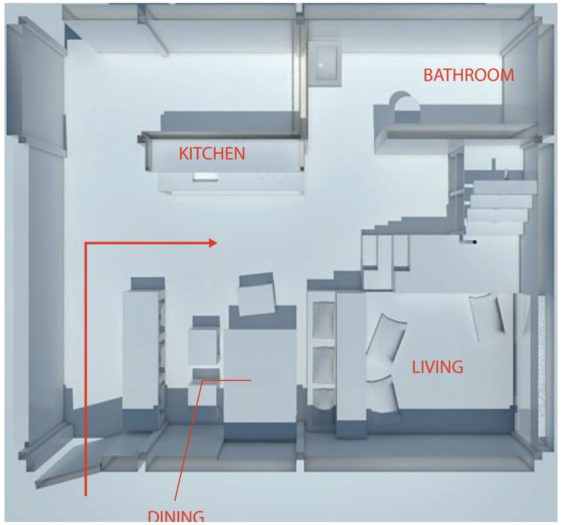
- The Denis House organization is composed of a central core, which is used as the most private space of the house. Thanks to a transparencies alternation the inner private space is more protected than the other spaces of the house. Furthermore the double high allow a great view on the top of the most private area: the studio.

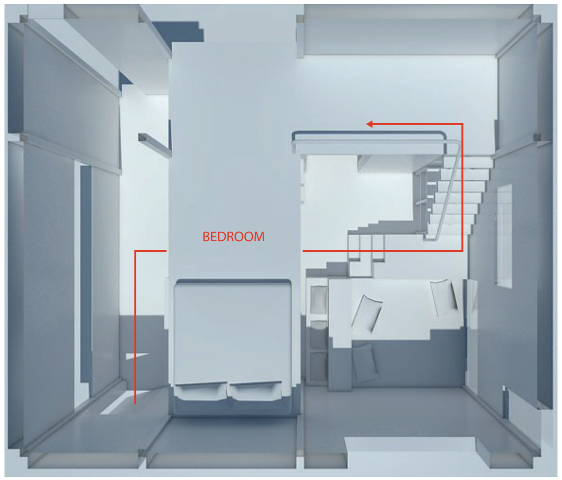
FOCUS POINTS OF THIS ORGANIZATION

- The possibility to create interactivity between inside and outside through the use of different transparencies or "sliding skins" will be then considered.



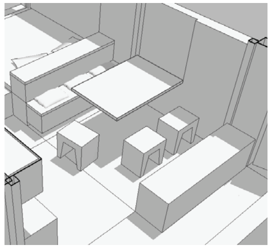
[ill.79] Denis House, Dethier & Assicies, photos and plans

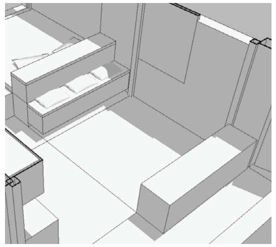


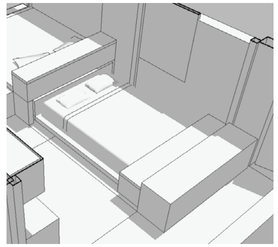


FOCUS POINTS OF THIS ORGANIZATION

- Those sketches take into consideration the modularity of the space: as well as for the Espansiva, the idea is to create a maximum of three different modular dimensions that can be combined in different ways.
- The result is a very compact house that in this case develop in height.

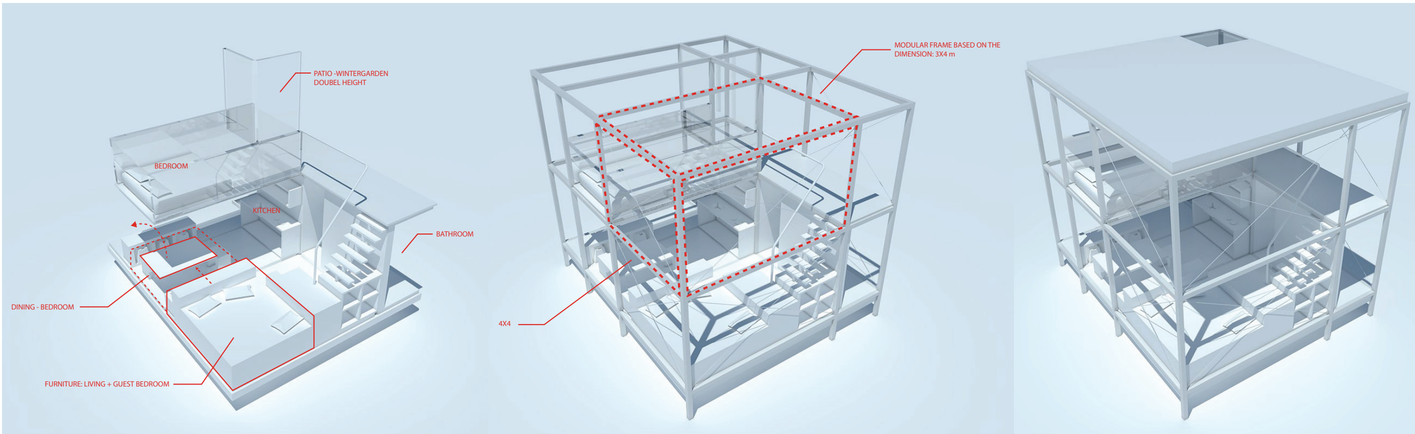


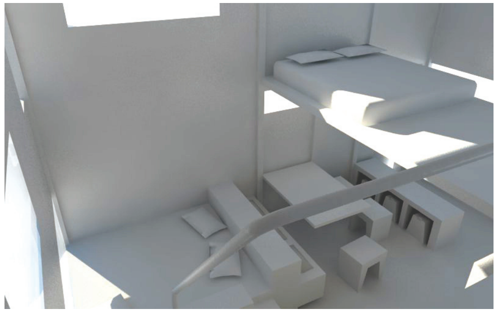


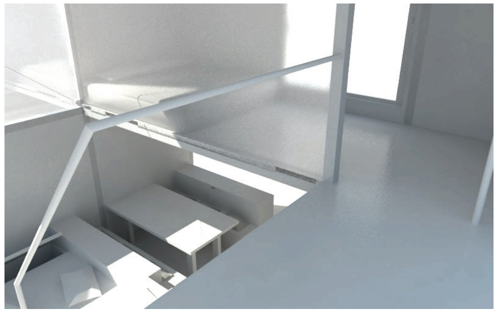


- Due to the small dimension of the living unity, the furniture become the element that must be smartly designed to increase the multi-functionality of every living space.

- The dwelling is clearly composed by the furniture, that divide the different spaces, and the structure, which is visible and clear in its function.
- The concept of the furniture dividing the space will be take into consideration trough all the process of the thesis.
- One of the main lack of this design is the total separation from the surrounding context.

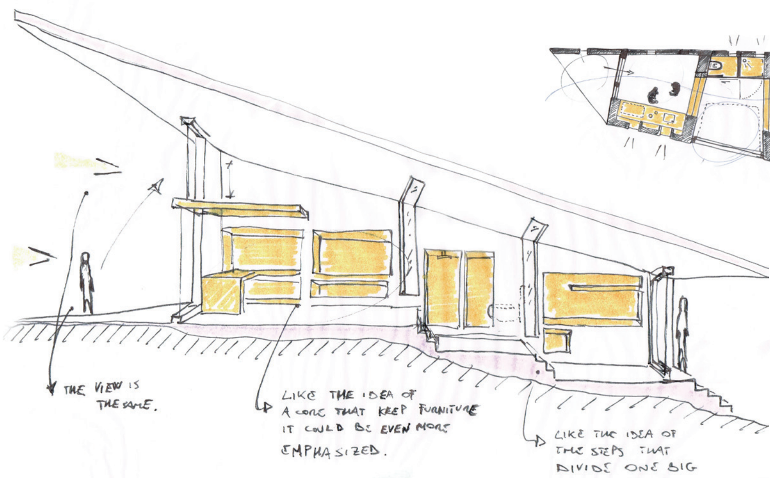


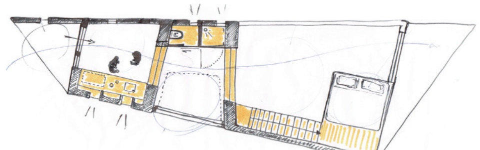


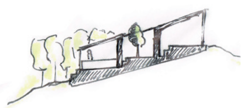


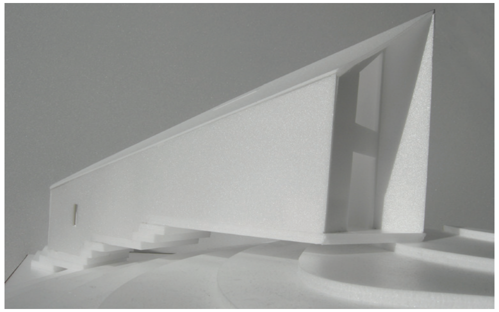
FOCUS POINTS OF THIS ORGANIZATION

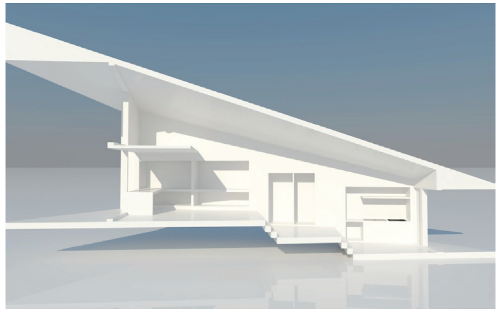
- The sketches on the right show the development of the previous design, where the furniture become an integrated part of the dwelling structure.
- Unlike the previous sketches this concept aim to work with the landscape, creating a path within the dwelling that starts from the wood and ends right next to the cliff.
- The steps inside the house become the only elements that divide the different spaces and that, at the same time, emphasise the ground slope.
- The idea of the "journey" within the dwelling will be explored and developed in the final design along with one of the main lack of this design: the views.







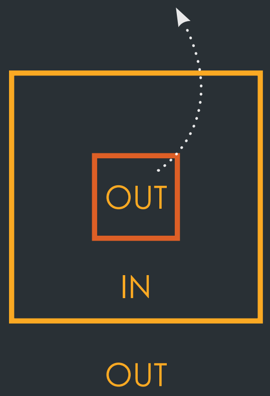




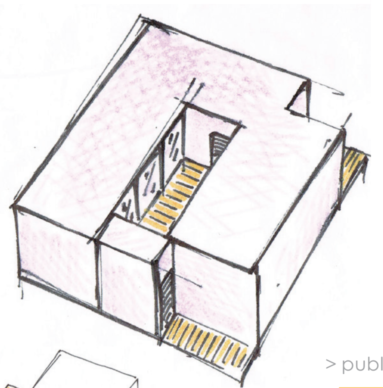
PHASE 2.2

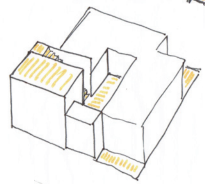
2. OUTSIDE INSIDE

- Integration of the outside space inside
- Central core: winter garden



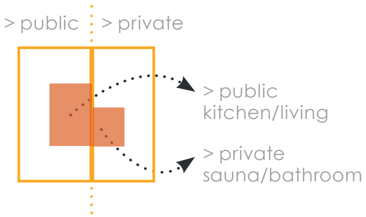
- compact
- patio = distribution
- more dynamic organization





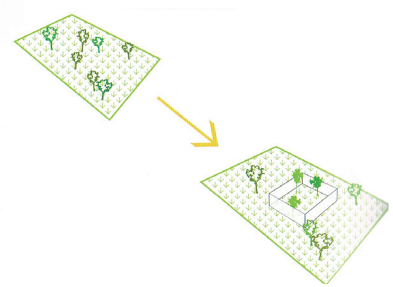
FOCUS POINTS OF THIS ORGANIZATION

- In the spacial organization showed in these sketches the relation with the nature is mainly inward, but in my case it would be more interesting to create outdoor spaces that allow different horizontal views.

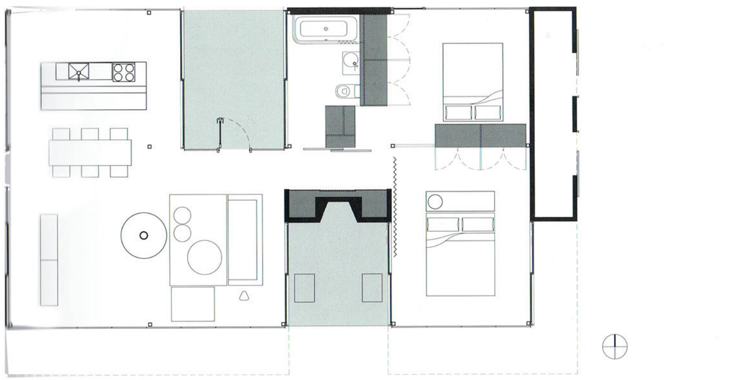


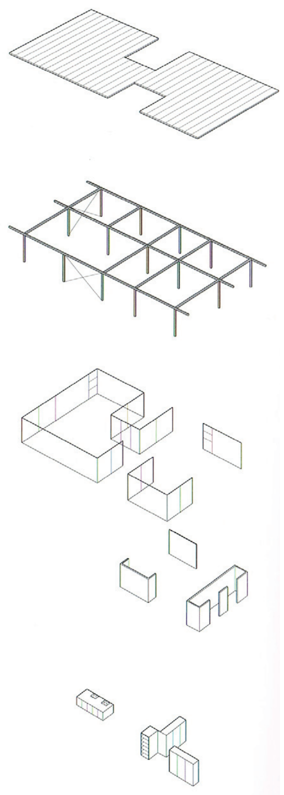
- The outdoor space in the Jørlunde Summerhouse become a distributions for the different rooms.

[ill.80] Jørlunde Summerhouse, Dorte Mandrup Architects, Jørlunde

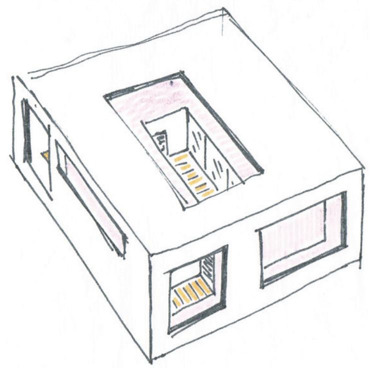


In the IT House, the organization of the inner space is divided by the distribution of 2D elements (panels) linked to the steel frame structure which is visible and clear, and that at the same time create outdoor rooms within the house.





[ill.81] IT House, Taalman Koch Architecture, photo, plan and exploded diagram



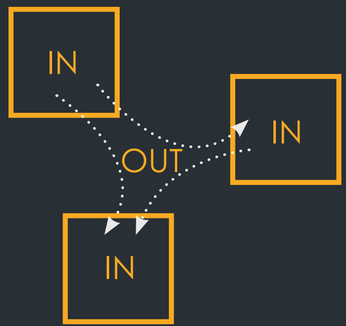
FOCUS POINTS OF THIS ORGANIZATION

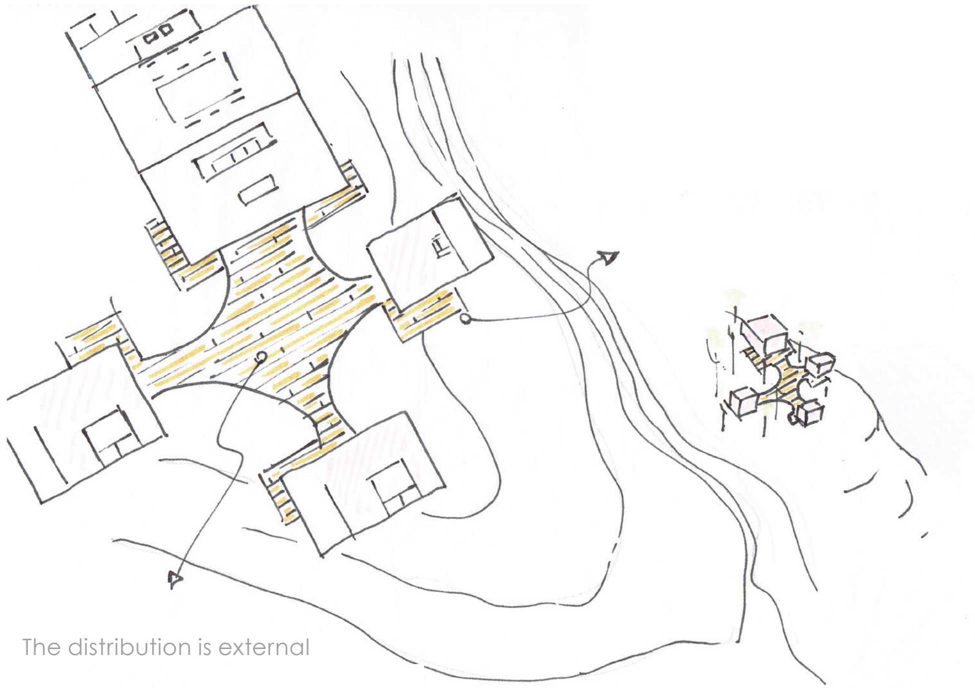
- The sketches showed in these two pages take into consideration the possibility to create an outdoor space within the dwelling. This possibility will be then considered and developed during the final design phase.

PHASE 2.3

INSIDE OUTSIDE

- Several unities for different functions.
- The connection between the unities can become the "central core" of my project.





- The distribution is external

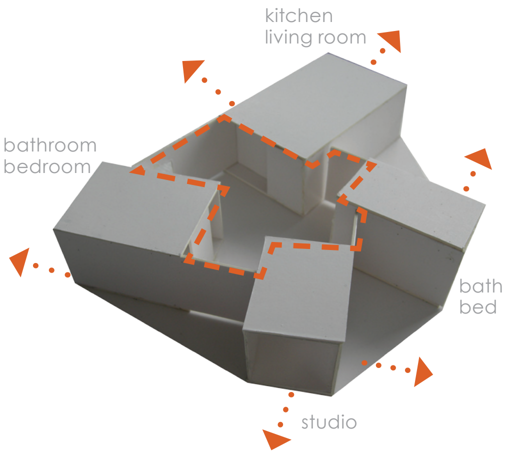
FOCUS POINTS OF THIS ORGANIZATION

- The outside platform could become the main structure, for the anchorage and stability of the detached volumes, and at the same time it could connect the different spaces.

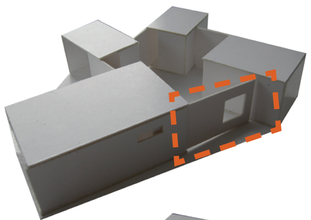
[ill.82] Casa Jax, Rick Joy, Tucson Arizona

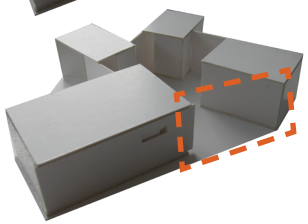
[ill.83] House O, Suo Fujimoto, Chiba, 2007

[ill.84] C/Z House, Sami Arquitectos, São Roque do Pico



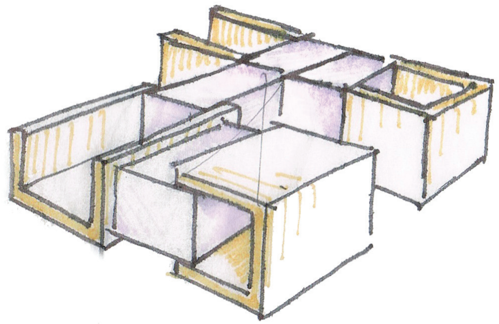
- Multiple orientation and views.
- Inner courtyard.
- The sliding walls of each volume are enclosing or opening the inner space.
- Each volume has a separate function.

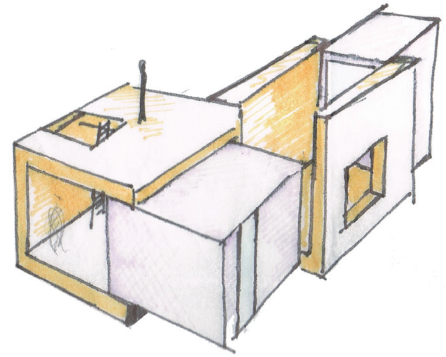


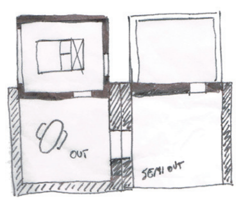


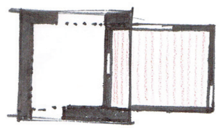
FOCUS POINTS OF THIS ORGANIZATION

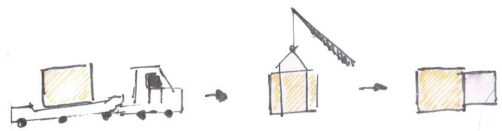
- The rough sketches and models displayed in this page show the possibility to design separate volumes that creates several views of the surrounding landscape.
- Every volume has a different function and it is connected by an outdoor space that can be used as part of the dwelling.
- The idea is also to create different spaces by using sliding walls or volumes.

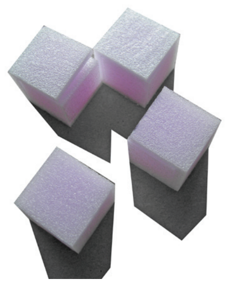


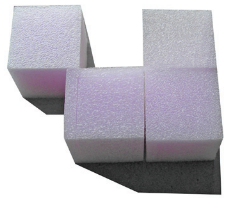






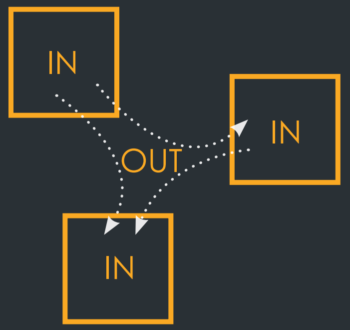






FINAL DESIGN

In these pages the final design is going to be processed and presented. The chosen thypology of organization is brought forward, as well as all the previous considerations upon: VIEWS, EXPOSURE, the interaction PUBLIC-PRIVATE and the connection PREFAB + ONSITE



All the sketches and concepts showed in the previous pages brought me to my final design.

What is clear from this first phase is that my dwelling has to deal with the landscape, creating a strong connection with it without being imposing.
Moreover the orientation and the views will be one of my main focus points as well as the creation of outdoor spaces.

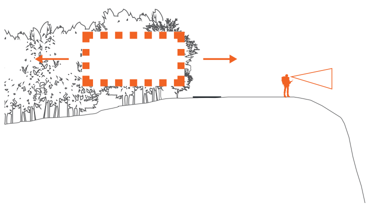
Some of these concepts will be then considered more important than others and therefore further developed.

PUBLIC + PRIVATE

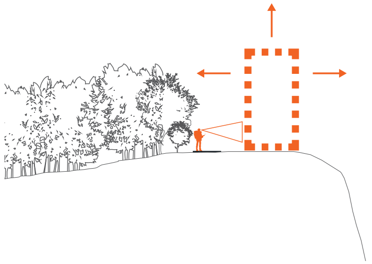
As shown in the first pages of the design process, one of the main dilemmas of this project is to understand which is the level of exposition of this project and the impact that it can generate in the landscape.

Since the building rise near a public nature trail, it is clear how this become one of the main issues to be solved.
Indeed If the building is located too far into the wood, as to hide it, the risk is to loose the view of the lake due to the slope, but on the contrary, if the building rise to the edge of the cliff, its presence will blocks the view from the public natural path.

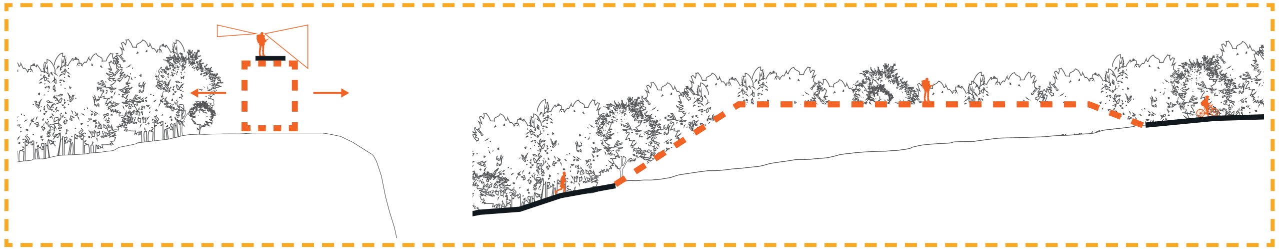
It is clear that In this location whatever you place on the ground will have an impact, therefore I started to develop the idea that what I "take" from the area for a **private** use it must to be "returned", and one way of returning the occupied space is to create **public areas**.



public path in front of dwelling

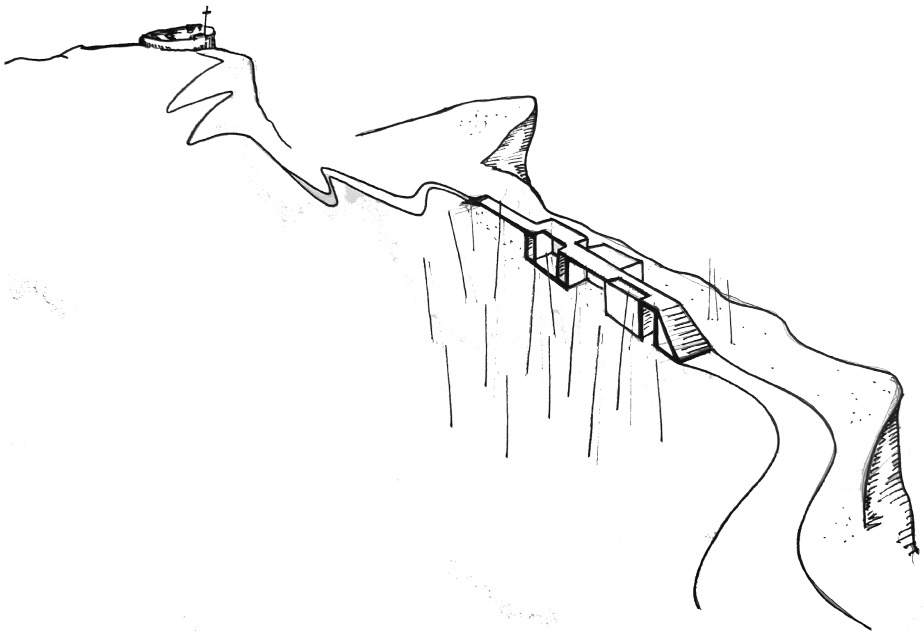


dwelling in front of the path



public path on top of dwelling

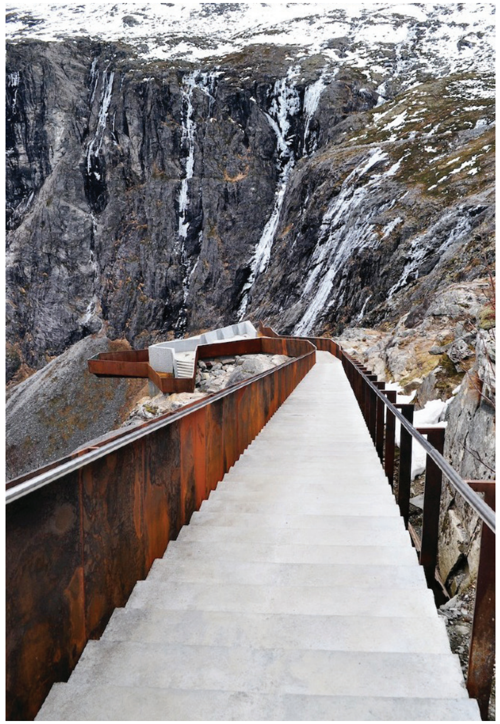
longitudinal section, the dwelling continue the public path



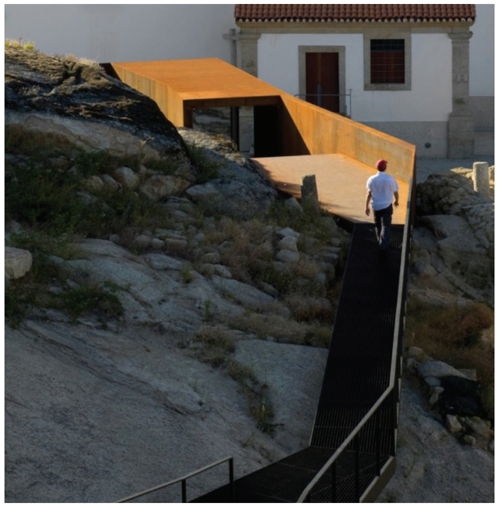
As well as for the Trollstigen National Tourist Route [ill.85] the idea is to design an integrated path to the existing one, which continues the visitors' route of the natural park from the intimacy of the forest to the stunning overlook of the lake and up to the highest point of the cliff.

The dwelling will become part of the journey that starts from the wood, following and emphasising the existing paths, rising above the thick vegetation and the slopes that characterize the area.

Acting in this way it is possible to allow the public to experience the place with a different approach, giving the opportunity to enjoy the area from other point of views without braking the natural trail.



[ill.85] Trollstigen National Tourist Route,



[ill.86] Castel Novo castle, COMOCO

[ill.87] Tolo House, Alvaro Siza

FIXED STRUCTURE VS PARASITE

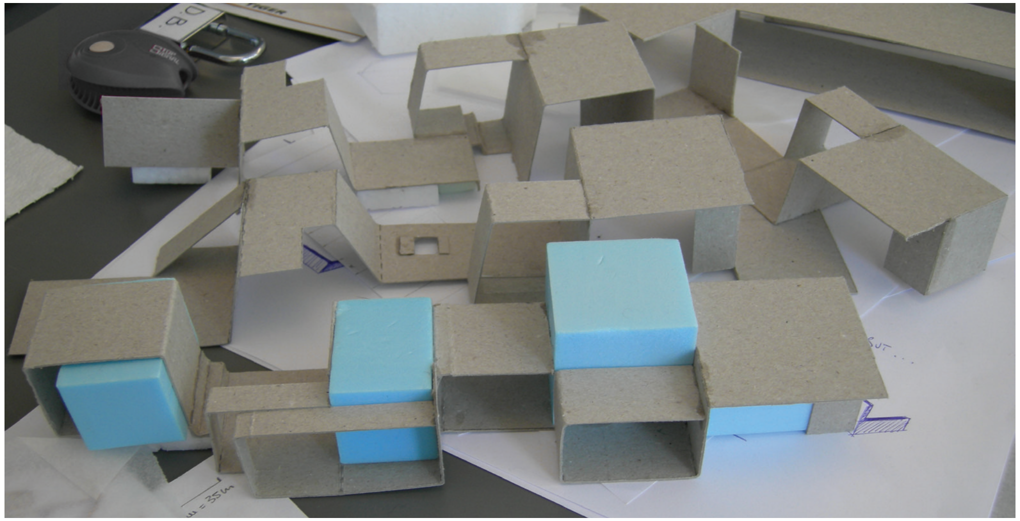
The idea is to establish a relationship between the landscape and the artificial element that will be settled on place emphasising the temporariness of the prefab architecture.

The project is then divided in **two main elements**: an on site fixed structure that has the function of continuing the public path, and the prefabricated wooden dwelling that can be temporary removed.

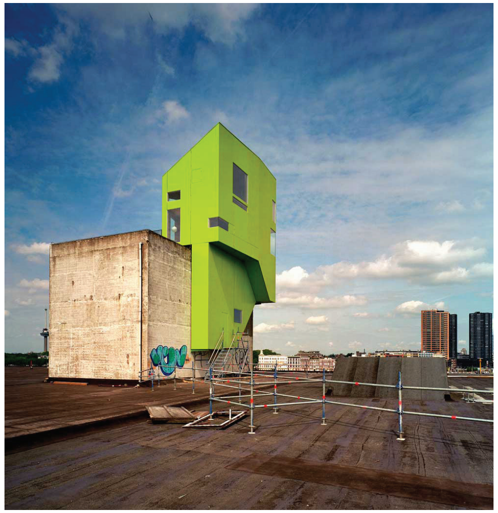
In a landscape consisting primarily of natural elements, the choice is then to create a linear structure, simple, almost rough, as opposed to organic forms of the nature. A structure that brings back to the size of the human scale.

Like a folding paper made of concrete, the structure emerges from the ground developing in length becoming roof, floor and wall, framing the views toward the lake and the wood behind it, creating outdoor rooms underneath and a walking path on top of it.

The private part will be then composed of simple, compact and light living unities, easy to carry, that like a parasite use the structure as anchorage, occupying the spaces in between the walls as forming a single entity.



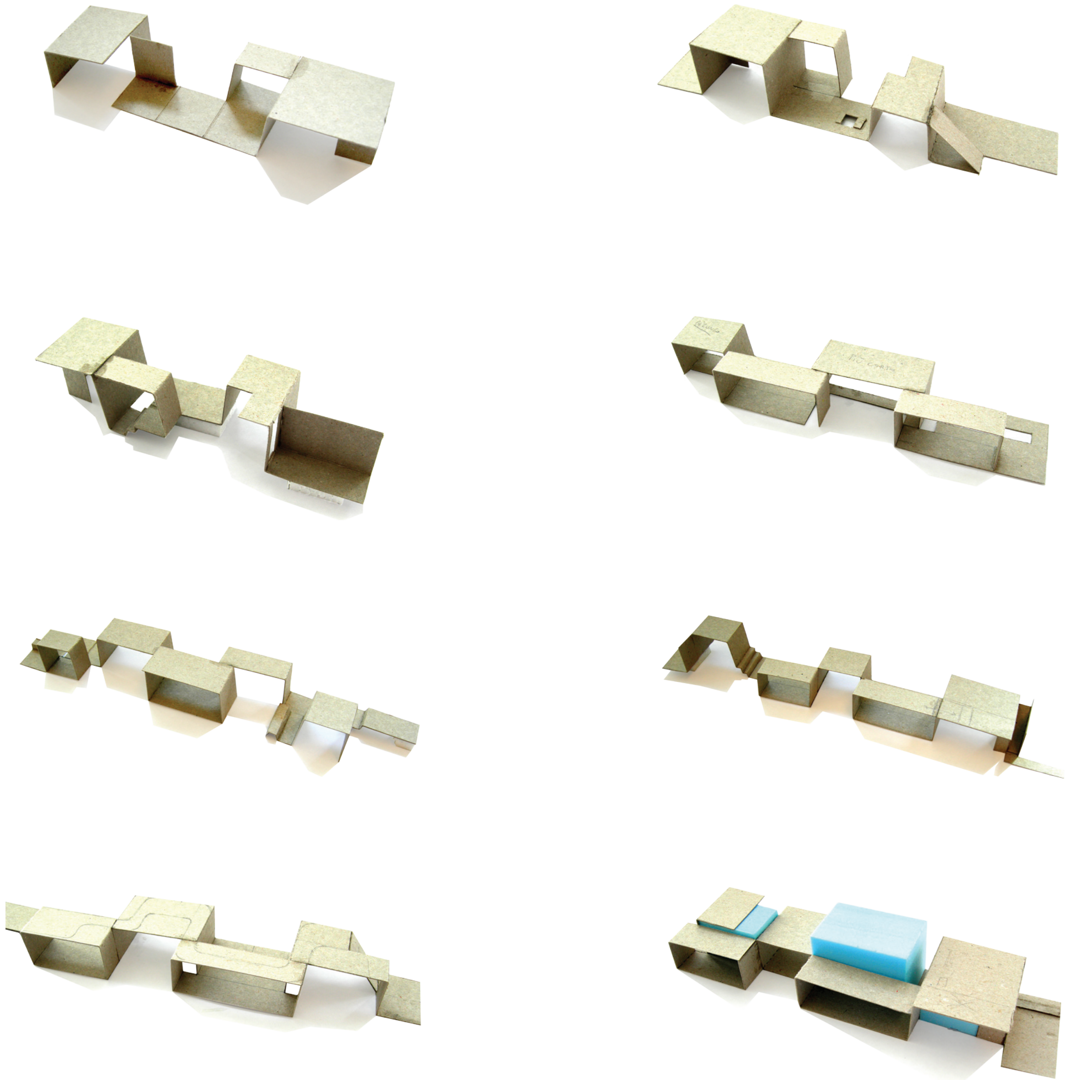
[ill.88] phisical models of fix structure and parasite dwelling combination



[ill.89] Las Palmas Parasite, Korteknie Stuhlmacher

[ill.90] Maryhill Overlook, Allied Work Architecture

[ill.91] Maryhill Overlook, phisical model



[ill.92] The folding paper experimentation

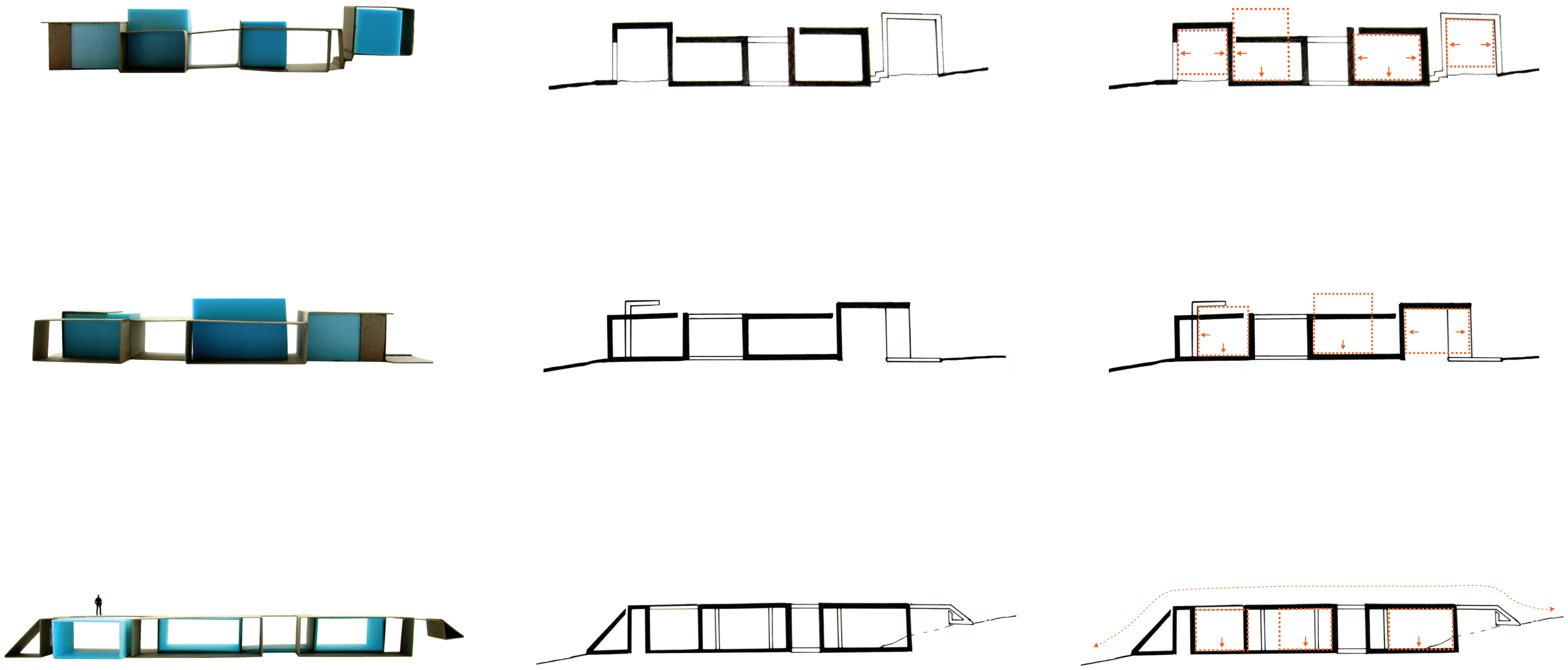
These series of models represents the evolution of the folding paper studies made for the concrete structure. All the studies (in 1:100 scale) were made using cardboard stripes, adapting their dimensions according to the necessities, but never exceeding 6m in width.

The first experimentations were mainly dealing with the concept of designing an anchorage for the dwelling as well as creating outdoor public spaces.

In the further studies I started to "de-materialize" the structure reducing the width by cutting the strip along the longitudinal side. Some other experimentations were made taking into account the slight slope that evolves from SE to NW.

Finally, the last investigations concern both the possibility to walk on top of the structure and the integration with the private living unities underneath.

These studies brought me to understand the potentials and lacks of using the principle of the folding paper.
What is interesting and dangerous at the same time, is that as the form starts to develop the design becomes unpredictable. This principle allowed me to create apparently random spaces that, however, are dictated by a rule.

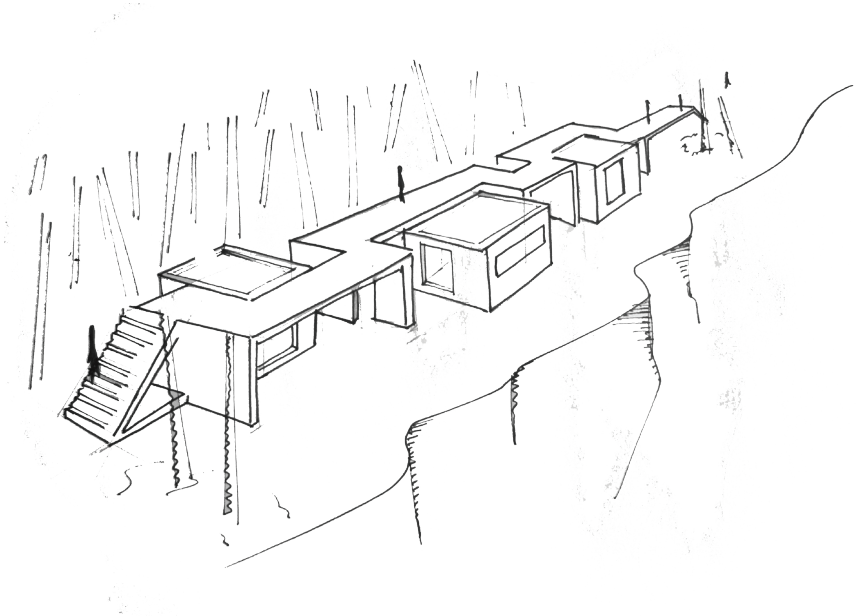


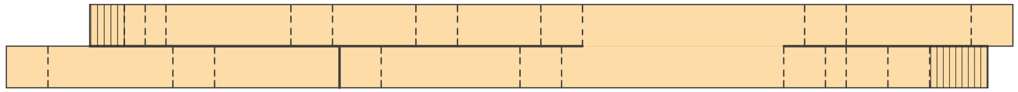
[ill.93] Folding paper + Living unities studies

This illustration shows how the first experimental forms were more articulated compared to the final choice.
Indeed, in the early studies it could happen that one of the living unity was completely surrounded by the concrete, while the others were just hanging on the wall. These experimentations evidence the living unities different heights that create an explicit distinction from the structure.

Nevertheless these early studies did not take into consideration the idea of walking path. Indeed this concept brought me to simplify the structure making the passage reachable while still using the folding paper principle.

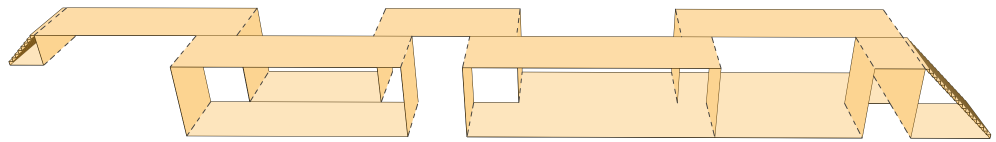
The result is a series of frames that overlap each others creating a sinuous flow both from the top side and underneath.



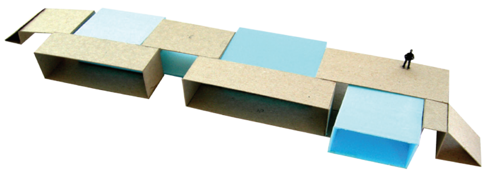


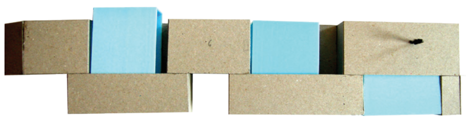
stairs
cuts
foldings

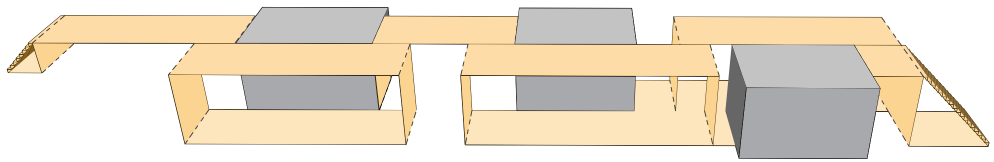
the unfolded structure



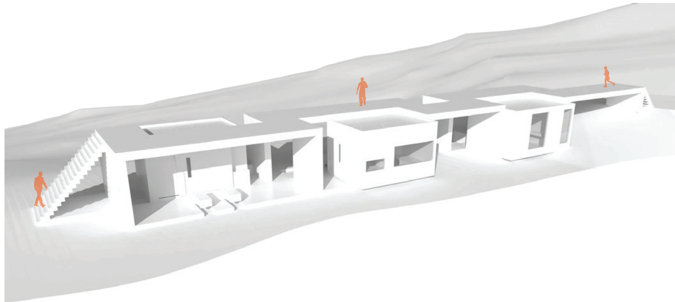
the folded structure

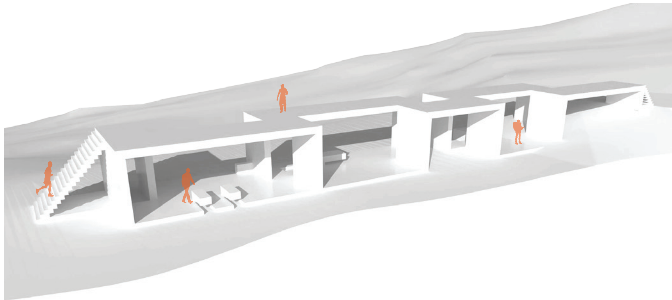


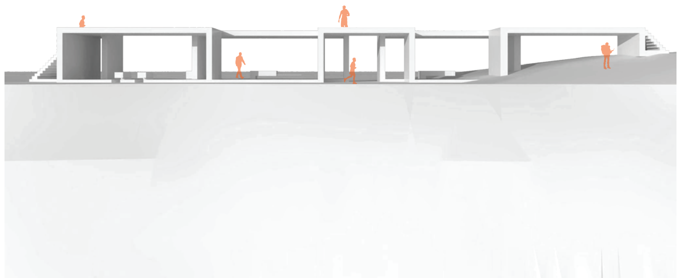




interaction public-private







As well as the "Rocca di Manerba" that nowadays is a ruin made of thick stone walls, the concrete structure of my dwelling is thought to lies on the ground, ageing in the nature.

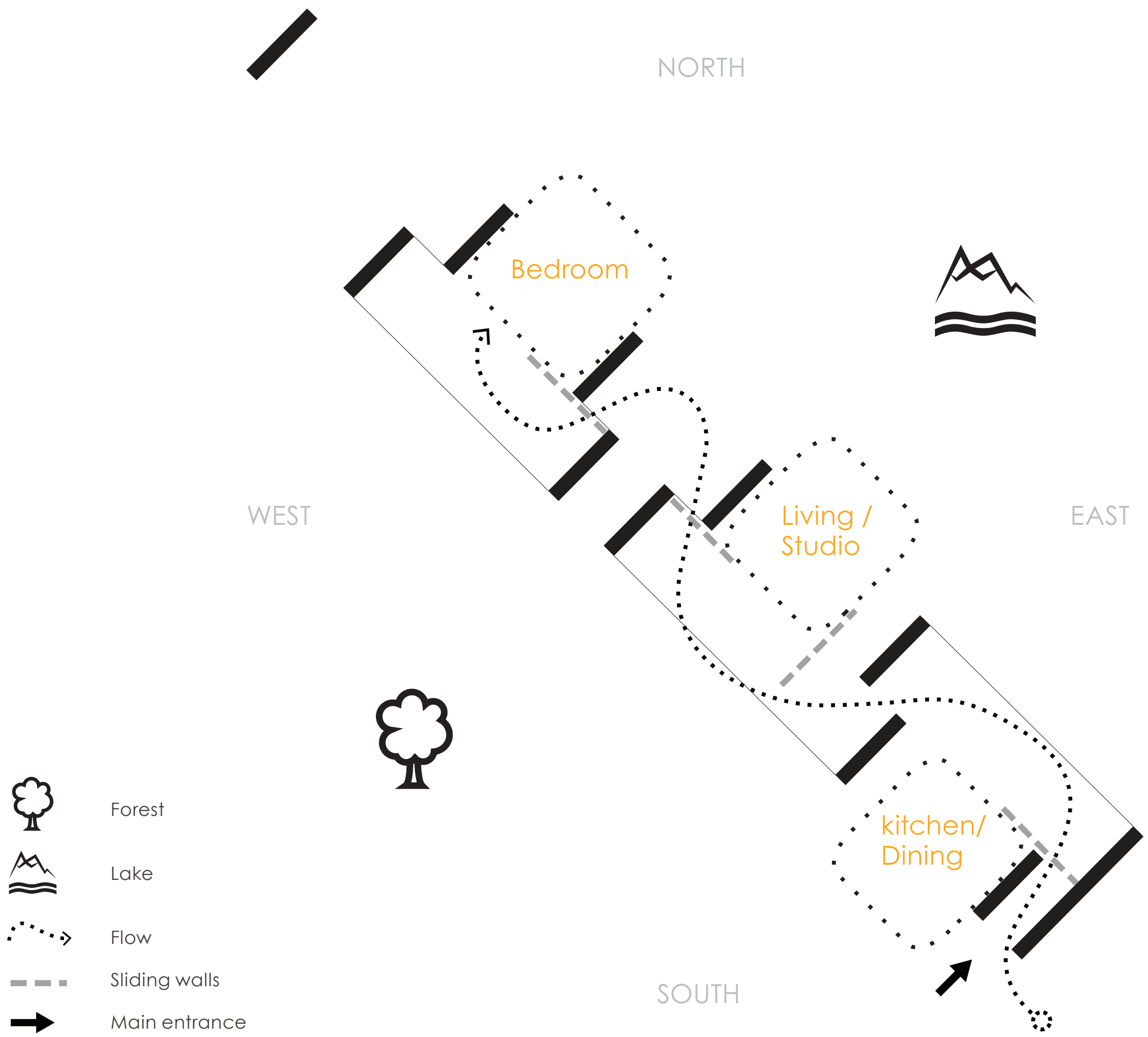
The concept is that once the prefab house will be removed, the structure can be still part of the landscape and being used entirely by the public as an overlook, the same way as the Castle ruins are used in these days.
The project is then thought over time to emphasise the temporality of the prefab architecture.

People like to go on top and on the edge of things, it's natural, especially in a context like this one. The purpose of this structure is then to give the possibilities to use the space in an unpredictable way both from public and private users.

PLAN DEVELOPMENT

Since the beginning of the process there was the will to integrate the outdoor space in the dwelling, but the problem was: how to incorporate the outside nature inside a compact prefab house?
The development of the fixed structure has given the possibility of expanding the space without increasing the size of the prefabricated house.
The room program was then divided into three main unities detached one from the other but still connected by the structure.
Acting this way, the transition between one room and the other forces to experience the exterior space, feeling the nature with all the senses and blurring the boundaries between forest and house.
The passage through the living unities becomes a journey that emphasise the position of the dwelling in the landscape and the alternation of the exterior walls frames specific views towards the lake and the forest but at the same time protects the private space from the public path.

As shown in the diagram [ill.94] the access of the house is through a narrow passage that leads into the dining room.Continuing North it is possible to approach the living room which is the central element of the building. Finally, the bedroom appear almost detached from the rest of the house strengthening the sense of privacy.

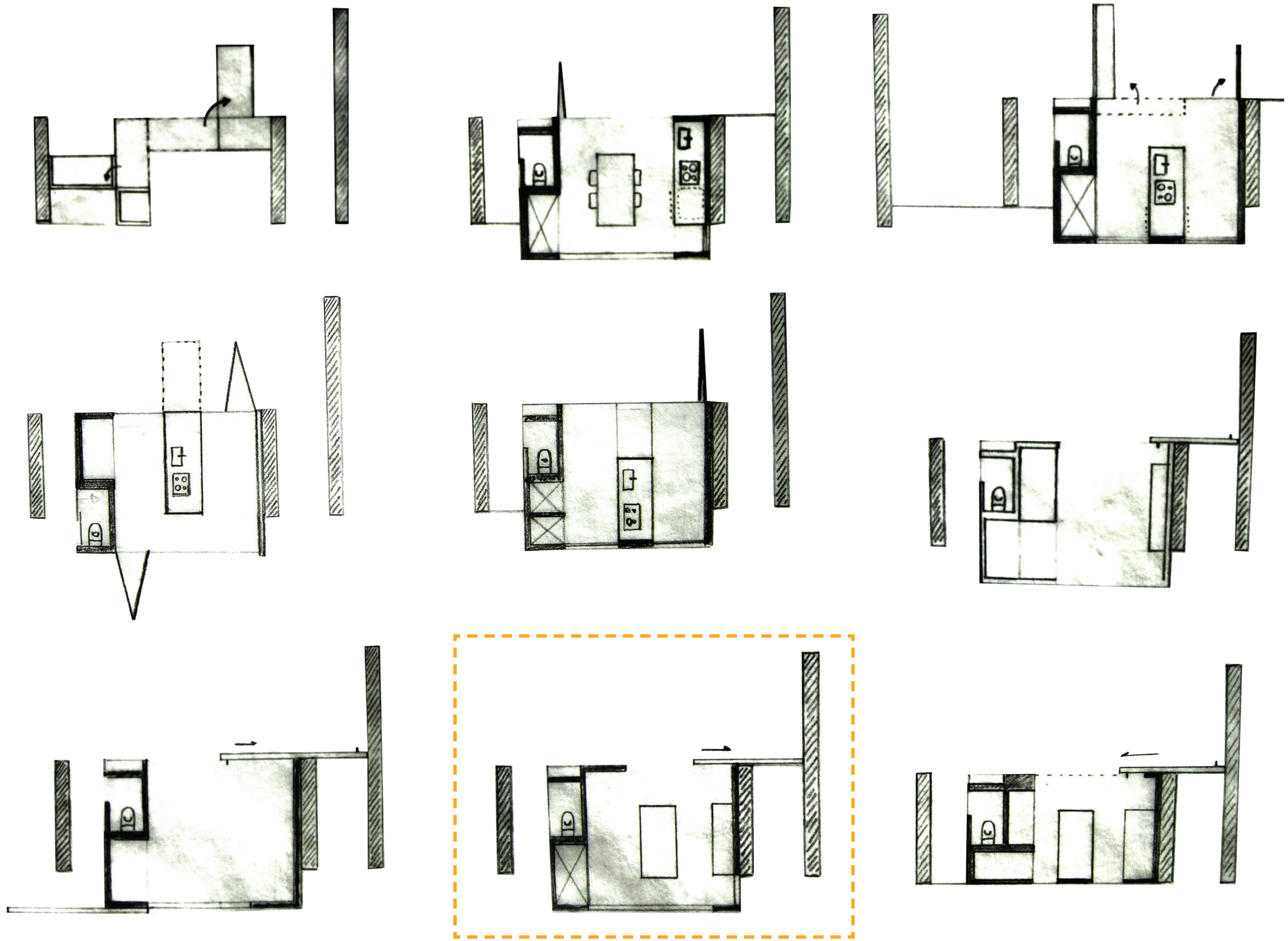


[ill.94] plan development diagram

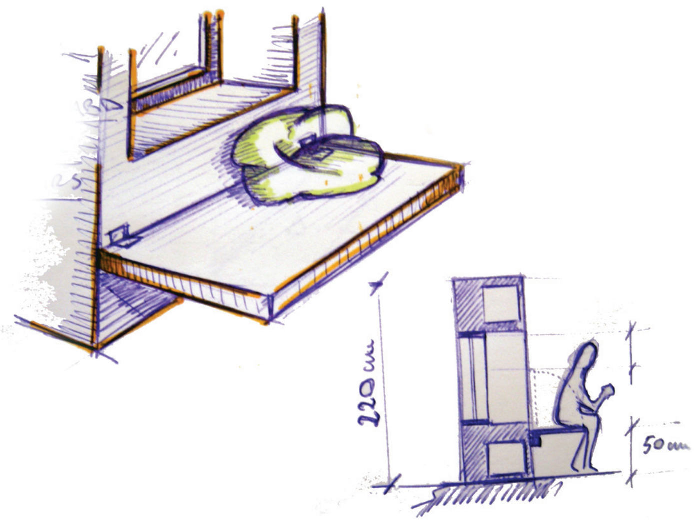
PLAN LAYOUT

Based on the function diagram, the house starts to take form.

The main scope in this phase is to make sure that the prefab unities and the structure merge as part of a whole.
Indeed the living unities are thought to be compact and easy to carry but at the same time they can expand through sliding walls, creating interactions between outside and inside.
When all the unities are closed they are easy to distinguish as separate elements but each time one room is opened the expression of the entire dwelling changes, dissolving the edge between the prefabricated and the structure.



[ill.95] First attempt of integrated furniture



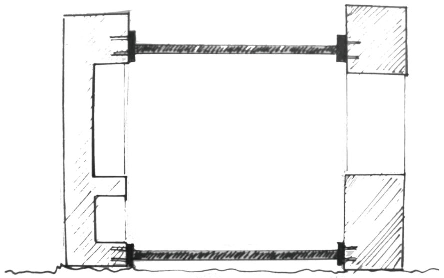
[ill.96] Bridge studio, Saunders Architects, Fogo Island

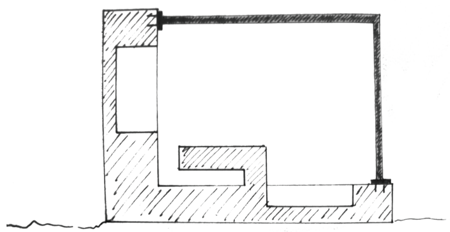
[ill.97] Squish studio, Saunders Architects, Fogo Island

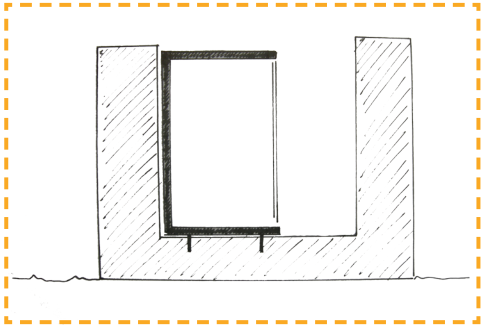
INTEGRATED FURNITURE

One of the advantages of using prefabricated systems is the possibility to integrate into the structure elements such as bathrooms, kitchens and stairs, making the assembly on site even easier and more accurate.
Since the beginning of the design process it was decided to exploit this approach, aiming to integrate most of the necessaries furniture in the dwelling in order to take advantage of the reduced space.

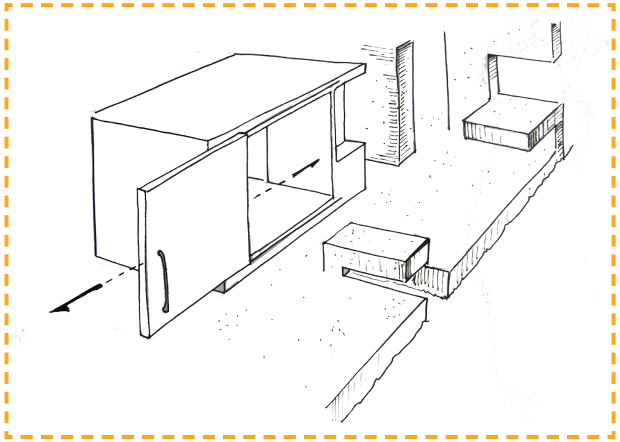
The illustration on the left [ill.95] display the first attempt to integrate the furniture such as dinner table, sink and bathroom, using the outdoor space in order to create a strong relation between the prefab house and the concrete structure.
Nevertheless, the further designs brought me to open even more the dwelling in order to dissolve the edge between outside and inside, but still keeping the concept of integrating the furniture in the prefab unities.

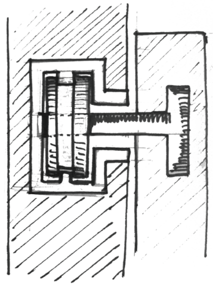


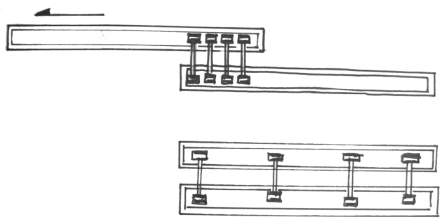




[ill.98]







INTERACTION PREFAB-STRUCTURE

The illustration on the left [ill.98] shows the relation that occurs between the wooden panels and the concrete. Initially the concrete was meant to be part of the internal area including in its thick wall some technical equipments or creating openings and shelves when it needed. In these cases the prefab dwelling was thought to be consisted of just wooden panels hanging from one wall to another. With this approach the structure become an imposing part of the house reducing the prefabrication to minimal elements.

However, the development of the concepts mentioned in advance originated an approach where the interaction between the panels and the concrete is outside.
In this case the prefab element is always linked to the concrete structure by means of the floor.
With this proposal all the furniture are integrated in the prefabricated unities that once are linked to the concrete structure, are ready to be used. The sliding walls will then become the element that creates the interaction between the two components.

Finally, the choice of using the concrete for the main structure may seams disrespectful for this context, but the contrast between this heavy element and the lightweight wood, underline even more the fragility of the dramatic nature.

DAYLISHT FACTOR STUDIES

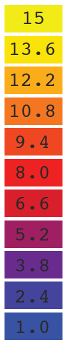
To conclude the final design phase some daylight studies were made to obtain an understanding of depth of the building according to width, floor height and the amount and proportions of windows, as well as the effect on the indoor daylight quality in terms of daylight factor and shadows/ direct sunlight. The daylight factor does not take orientation into account, but describes the relationship (unit: %) between the outdoor and indoor natural light.
What can be understood from this is how natural light is distributed in the room.

The results were also used to set the basic proportions of the dwelling's spaces.

For this investigation the room width and height is fixed to 3m.

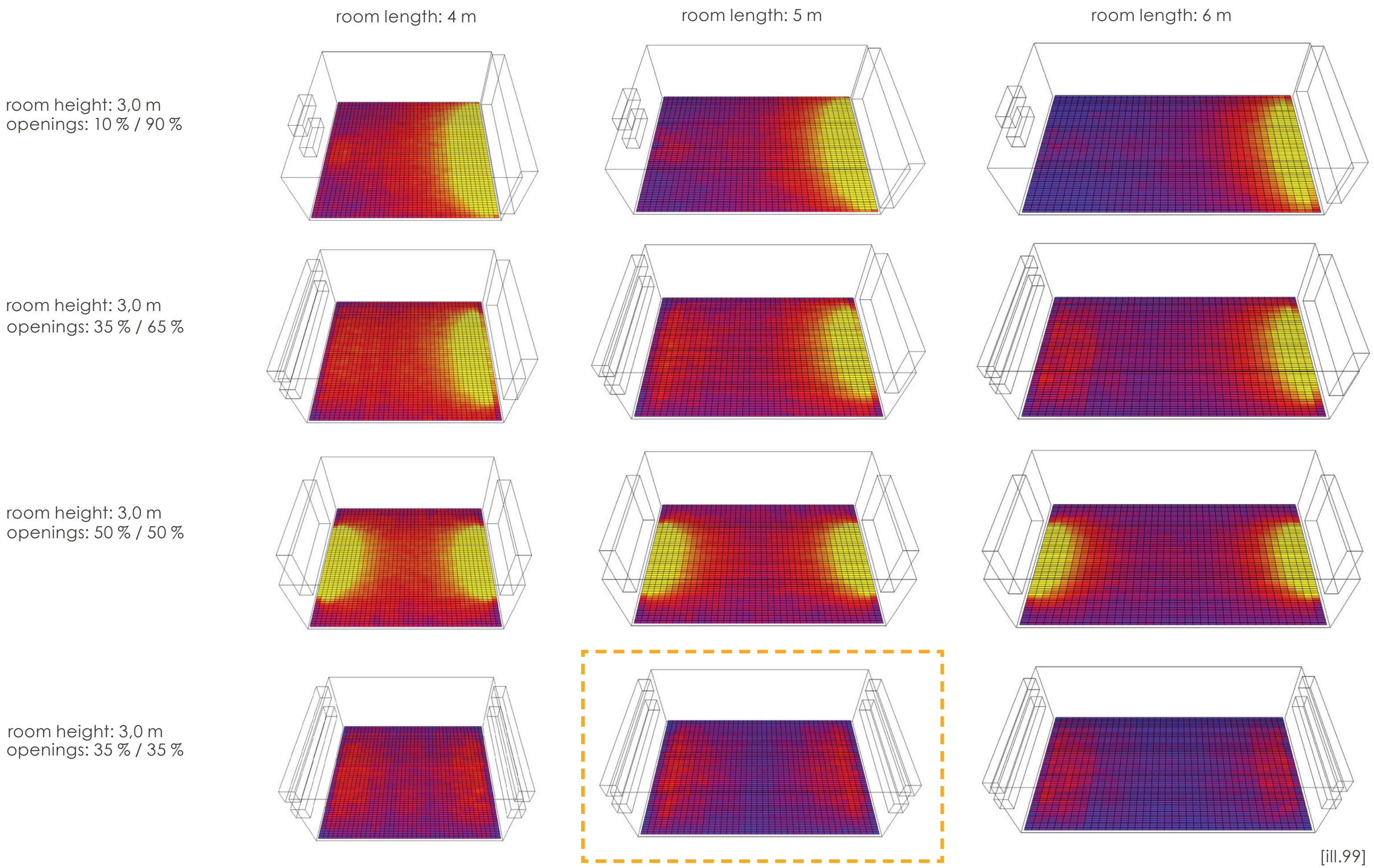
DESIGN METHOD

Ecotect Radiance: simulate and calculation of daylight factor with planar grid disposed 80 cm above the ground.



CONSIDERATIONS

From this investigation it seems possible to obtain good daylight conditions in a room with 3 m room height with a depth of 5 m and 35% openings from both sides.
In this case the light is well distributed but it does not allow good quality in terms of view and facade expression.
Therefor the final design is going to consider this basic studies, but in terms of proportion and placement of windows it will results important to take into account also aesthetic and functional considerations.



[ill.99]

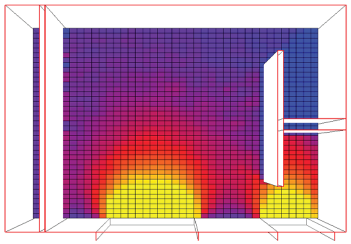
VERIFICATION

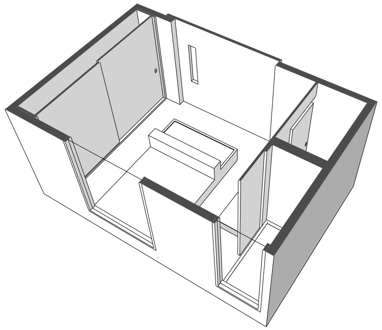
This page shows the light condition of the final design building where the analysis are performed for the three prefab unities: bedroom, living room and kitchen.

All the unities have the possibilities to be completely open through sliding walls, but in this case the investigation has been conducted considering all the rooms as closed.

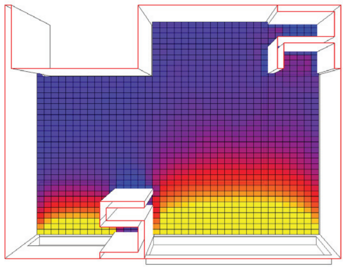
According to the Danish Building regulation, an average D.F. of 2% should be achieved, but the new standards indicated by the NetZeb (Net Zero Energy Buildings) brought the average value for primary room to 5%.
In this case the average D.F. for all rooms is around 6% which is a good achievement both in terms of light condition and views toward the surrounding landscape.

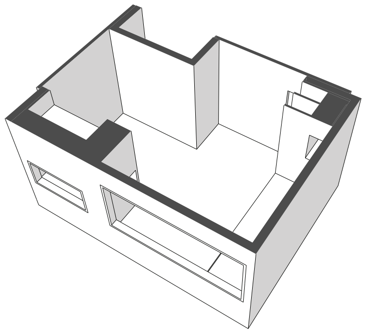
Nevertheless the average value can definitely increase by opening the sliding doors.
Too much light may cause overheating problems, but it needs to be considered that the concrete structure provide a shading device which avoid direct light to enter in the prefab unities.



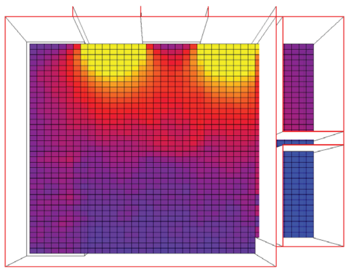


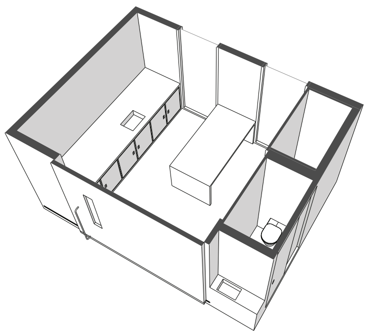
Bedroom
D.F. Average value: 5,7%
Openings: North-East 38 %



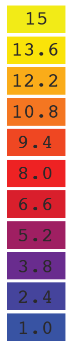


Living room
D.F. Average value: 6%
Openings: North-East 30%





Kitchen
D.F. Average value: 5,8%
Openings: South-West 35%

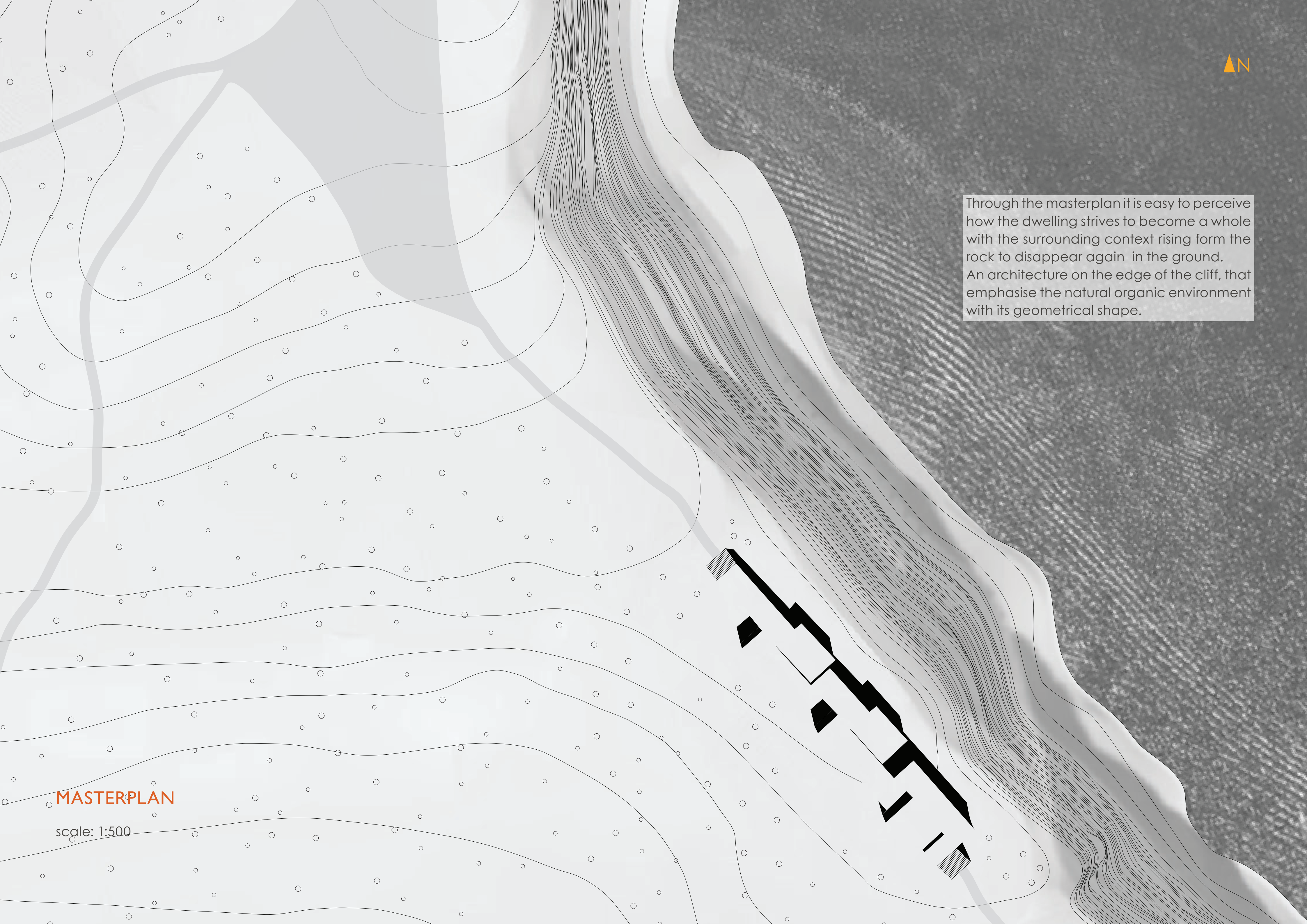


PRESENTATION

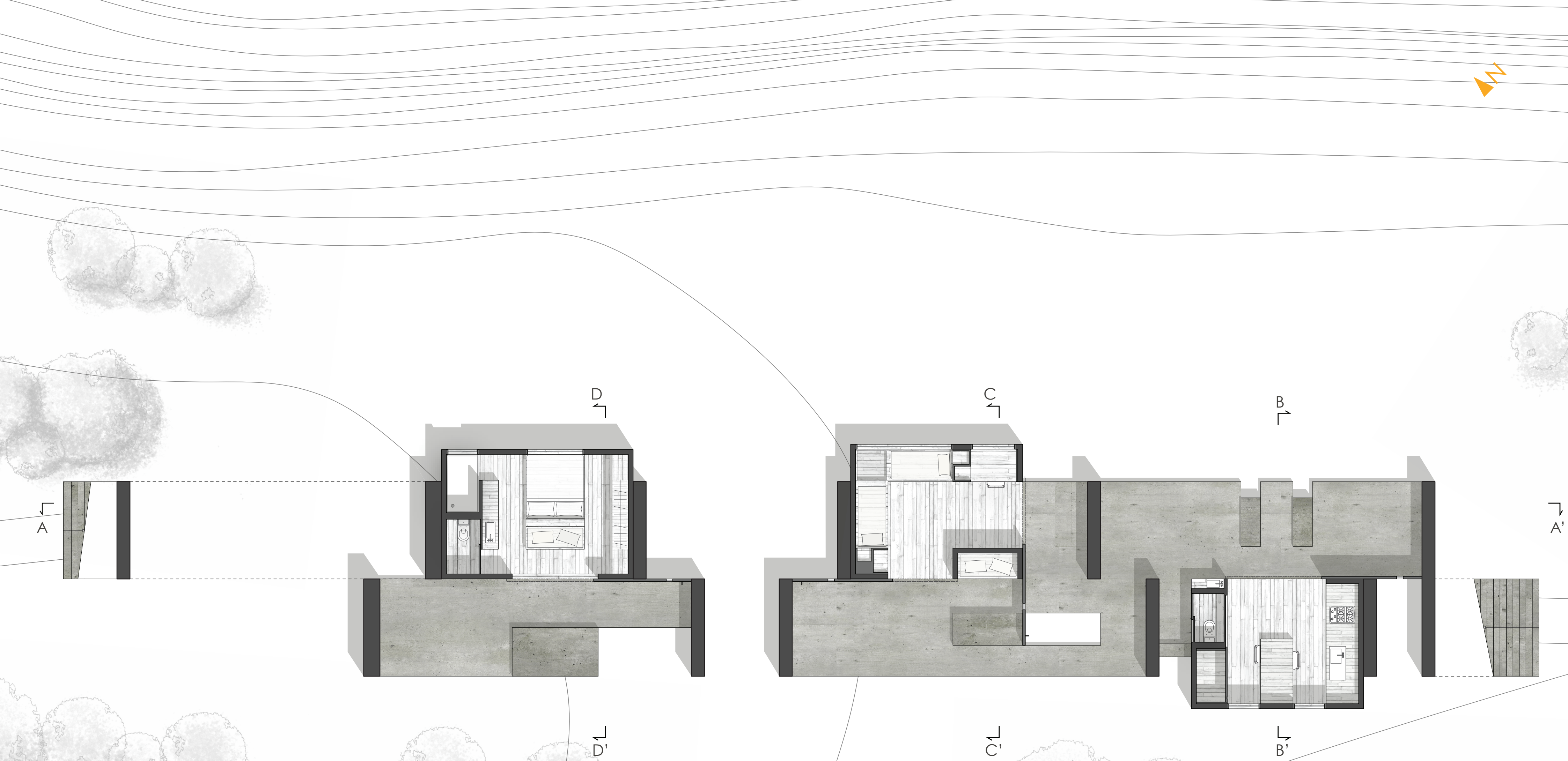
MASTERPLAN --- PLAN --- longitudinal and cross PROJECTIONS --- cross SECTIONS --- interior and exterior VIEWS --- STRUCTURAL SYSTEM --- construction DETAILS

MASTERPLAN

scale: 1:500



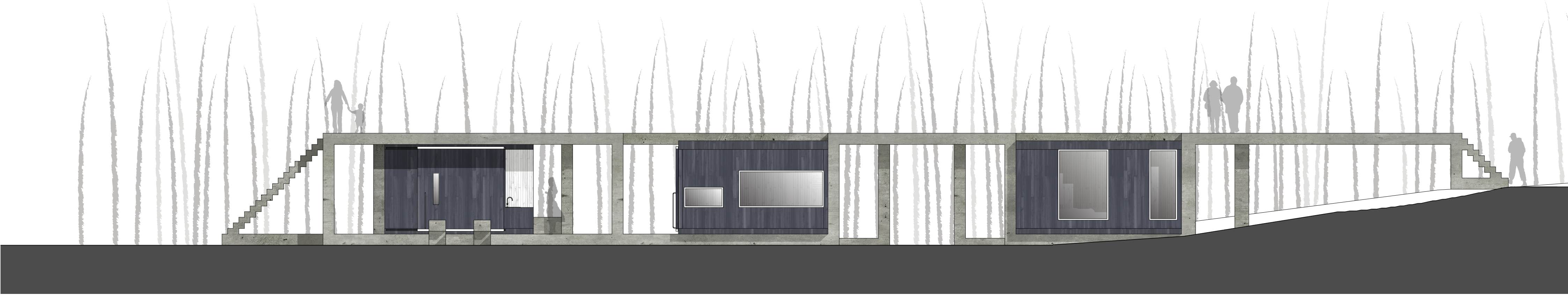
Through the masterplan it is easy to perceive how the dwelling strives to become a whole with the surrounding context rising form the rock to disappear again in the ground.
An architecture on the edge of the cliff, that emphasise the natural organic environment with its geometrical shape.



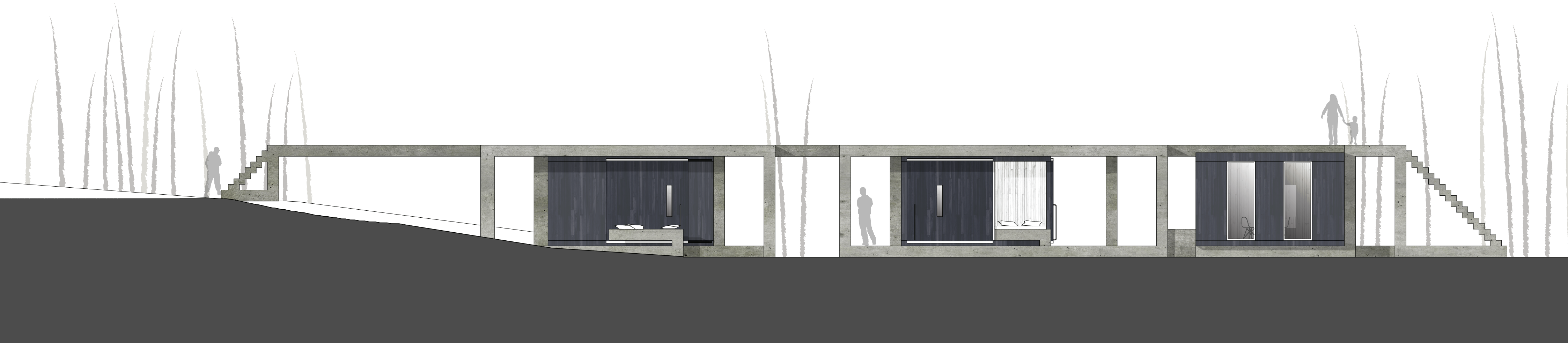
PLAN

scale: 1:150

By shifting the sliding walls it is possible to generate a strong connection with the outdoor space, while at the same time closing the passage from one room to another gaining in privacy.



NE facade, 1:200

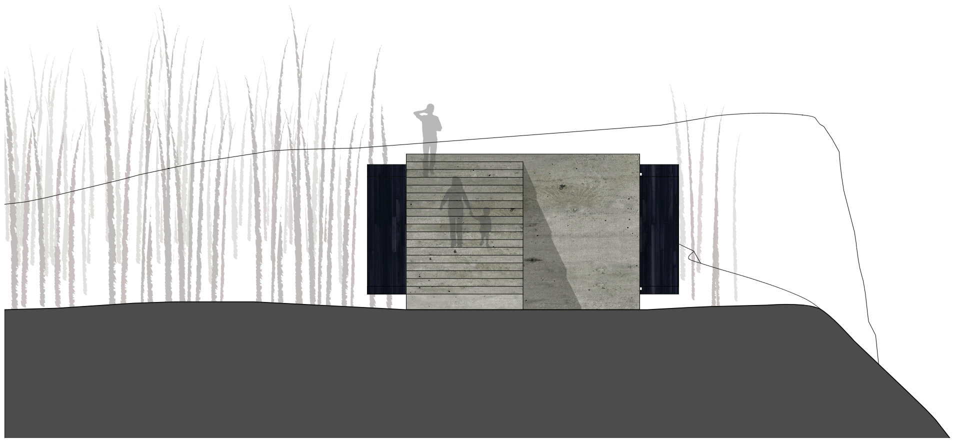


SW facade, 1:200

NW facade, 1:200

LONGITUDINAL PROJECTION

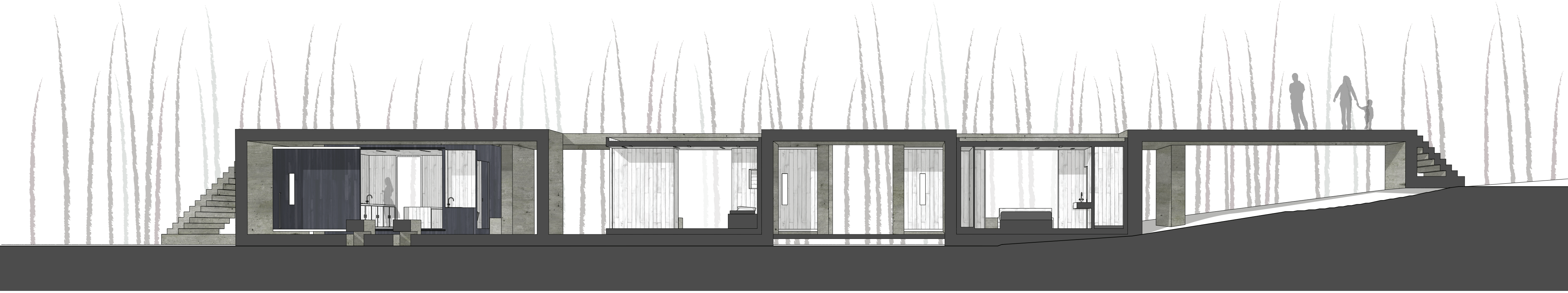
The concrete structure allow to continue the natural trail while at the same time it generates space for the dwelling underneath.
When the dwelling's sliding walls are closed, the living unities can be perceived as three separate and compact elements but, as it i shown in the longitudinal section (pag.86), the character of the house change completely when the rooms are opened.



SE facade, 1:200

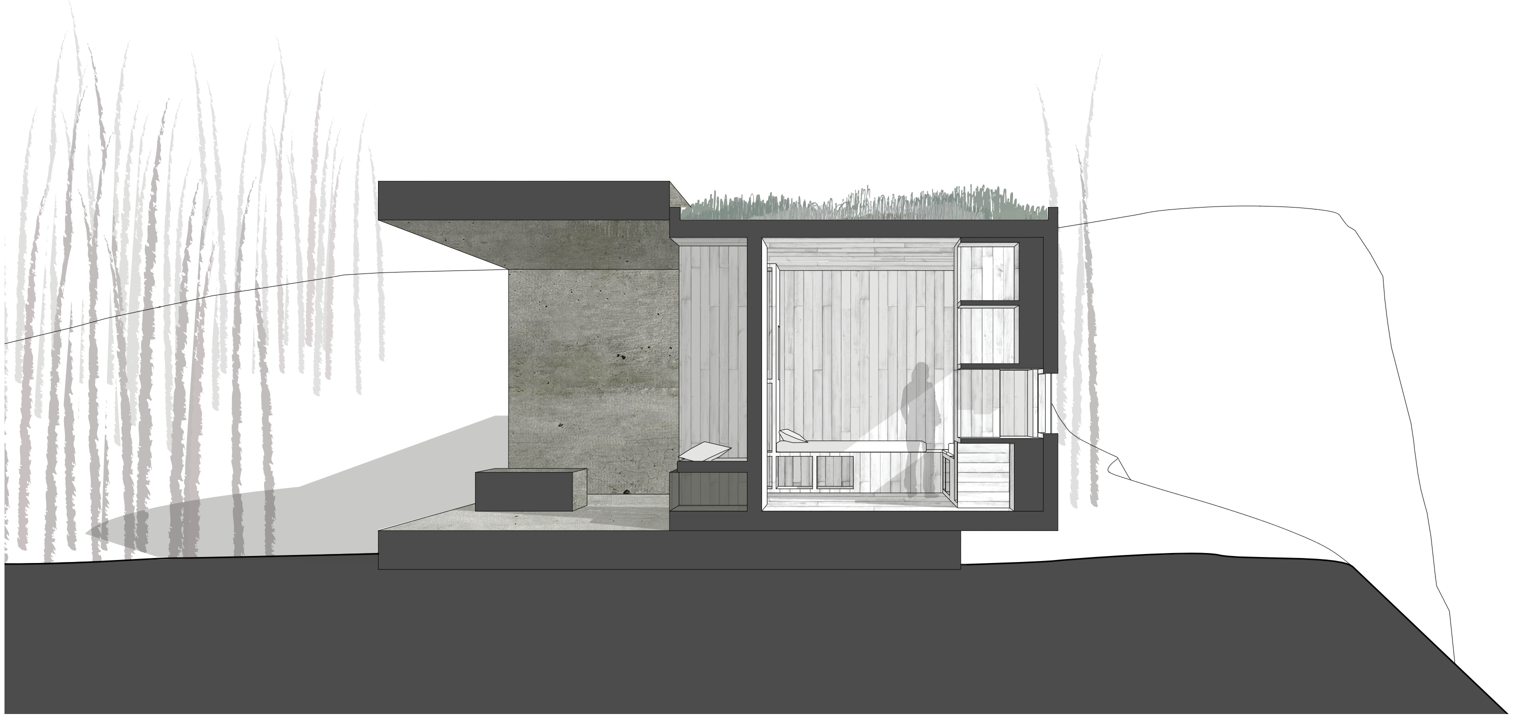
CROSS PROJECTION

From the South side the concrete stair invite to continue the path which reveal a 360° view.
Due to the slope the North side is then partially hided by the ground.
The prefab's hanging volumes that stick out from the concrete announce the visitor when the dwelling is plugged into the structure.



AA' section, 1:200

BB' section



CC' section

0.5m 1m

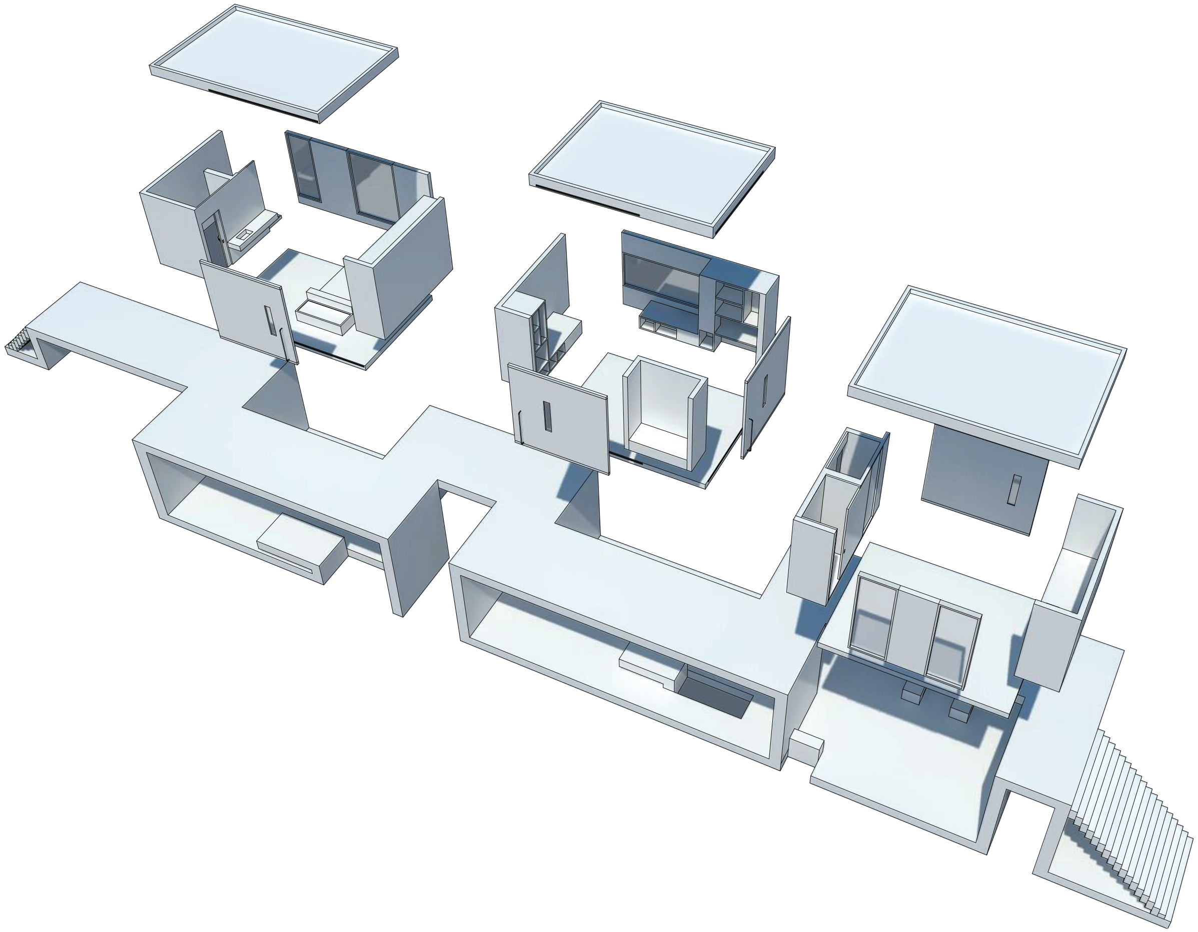
DD' section

CROSS SECTIONS

What is clear from the cross sections is the idea of integrating the furniture within the prefab structure and the interaction between the interior and the exterior space.

DETAILS

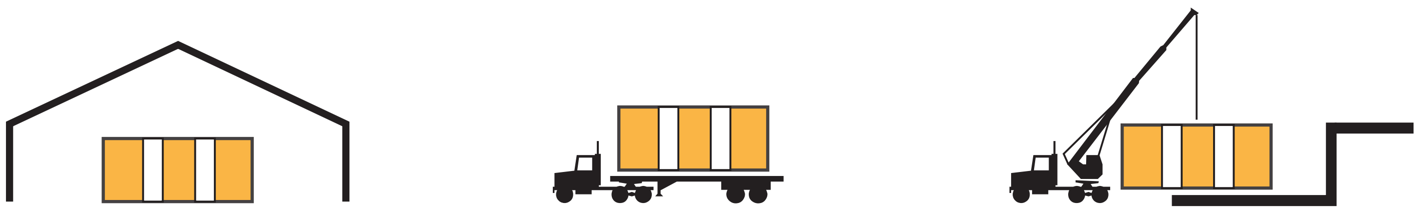
METHOD AND CONSTRUCTION SEQUENCE --- STRUCTURAL SYSTEM of prefab and concrete structure --- CONSTRUCTION DETAILS



METHOD AND CONSTRUCION SEQUENCE

While the concrete structure is meant to be built on site, the living unities will be transported by means of truck. The chosen construction method for the prefab architecture is the panellized system. As the benefit of using off-site architecture is to simplify the elements, the concept behind these unities is to divide them in basic components that will require a process of few assemblies on site. The unities are then composed of 5 main elements: floors (equipped with pillars to join the structure), perimeter walls (including window frame), furniture and equipments (linked to the walls), sliding walls and roof cover. All the unities have a commune width dimension of 4 m and a length that varies from 5 to 6 m. The decision of not exceeding certain dimensions is to facilitate the transport on site. Indeed this issue played a key role in the design phase.
The wish for using this method is to reduce the time assembly on site in order to decrease the costs of renting a truck and a crane.

Finally, the decision of using sandwich panels with a steel structural frame is to lighten even more the elements that will be easily bolted on site. This joint system will then facilitate the assembly and disassembly of the prefabricated.



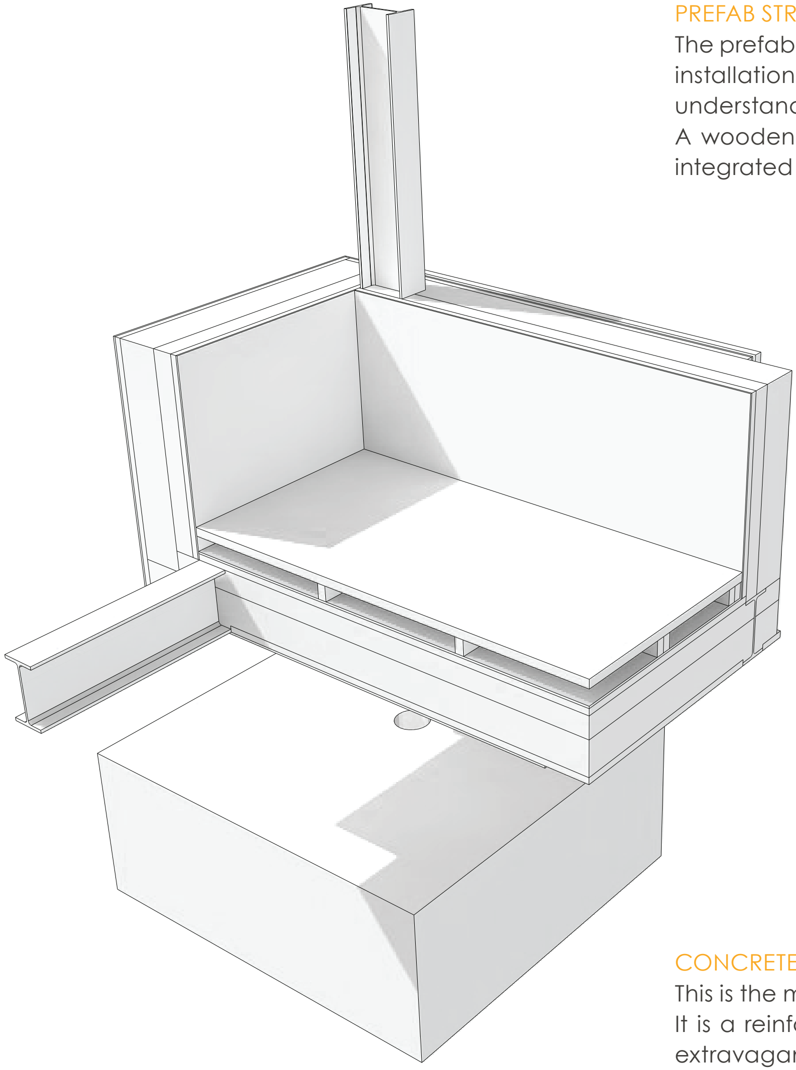
STRUCTURAL SYSTEM

The structural system of this project was considered as important as the prefabrication issue. In particular the relation between the prefabricated dwelling and a fix structure on site, which acts as anchorage base for the dwelling.
In order to create a clear structure within the project, different considerations are highlighted. These regards:

• The way loads are distributed down from the very top of the concrete structure to the ground (appendix 3).
• The concrete main structure is not hidden, but totally shown
• The way loads are distributed in the prefab dwelling structure, and how they influence the concrete one (appendix 3).
• How the material contribute to a solid and functional structure. Honest approach in regards of which requirements suit the structural elements.

A tectonic approach would also create the overall guide lines for a rational and well-thought-through approach where structures are elegantly exhibited as part of the building itself – and completely displayed when the concrete structure stand alone as a land art sculpture.

Regarding integrated design the prefab dwelling should be thought-in together with the concrete structure aiming towards a holistic and rational approach emphasizing the overall design.

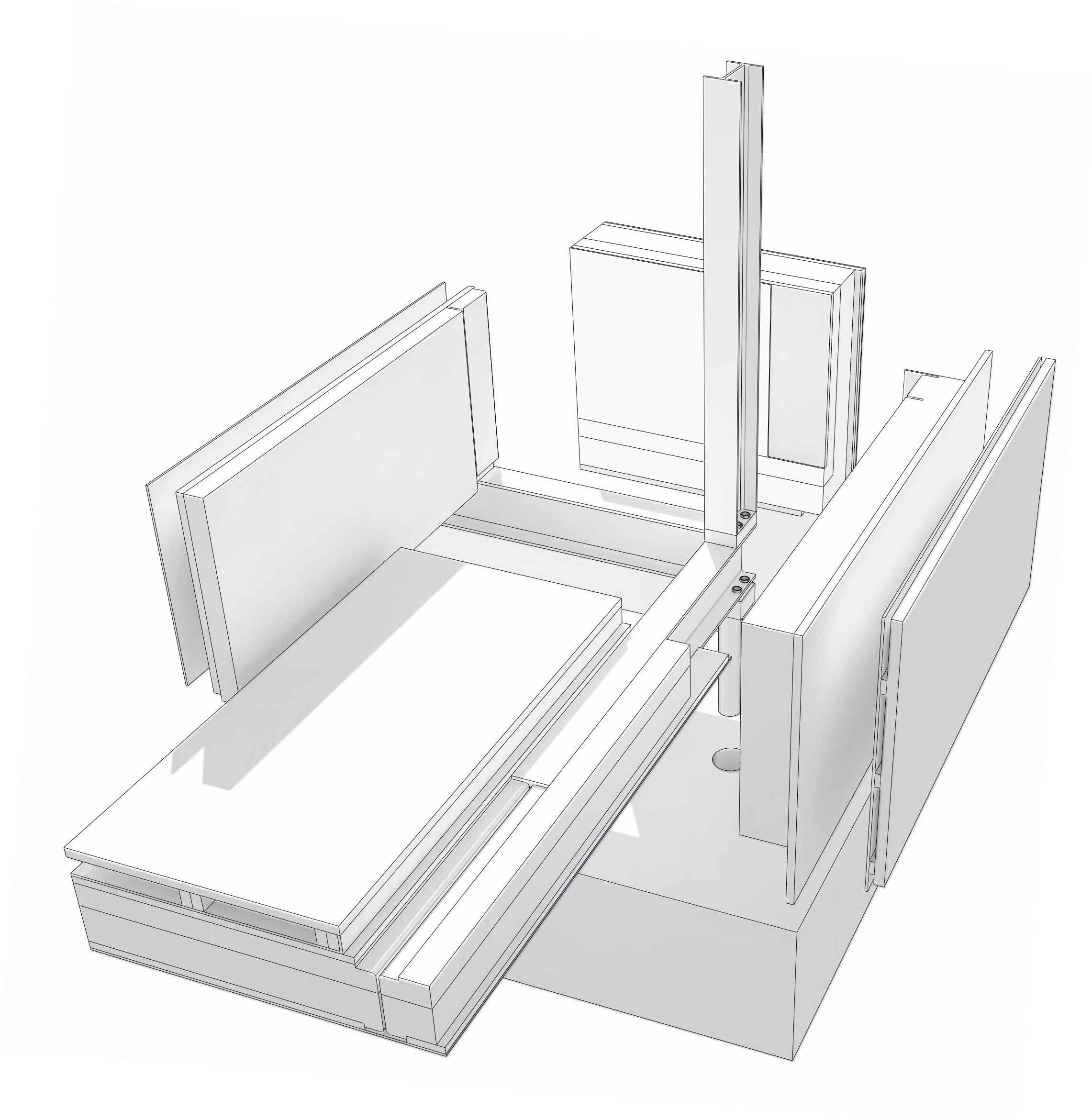


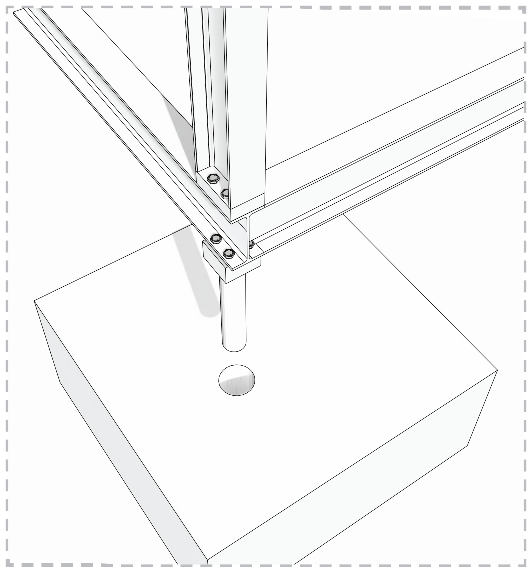
PREFAB STRUCTURE

The prefab structure is thought to be light and easy to carry in order to reduce installation time and complexity onsite. Its structurale principle it is easy to understand and it does not require any particular precautions.
A wooden cladding has been chosen in order to fulfill the concept of the integrated furniture within the unities.

CONCRETE STRUCTURE

This is the main structure, base for the anchorage of the prefab one.
It is a reinforced concrete slabs system. It is cast in situ. Even if there aren't extravagant loads, the whole is made with concrete and some holes allow the anchorage of the prefab structure.





CONSTRUCTION DETAILS

INSULATION CONCEPT

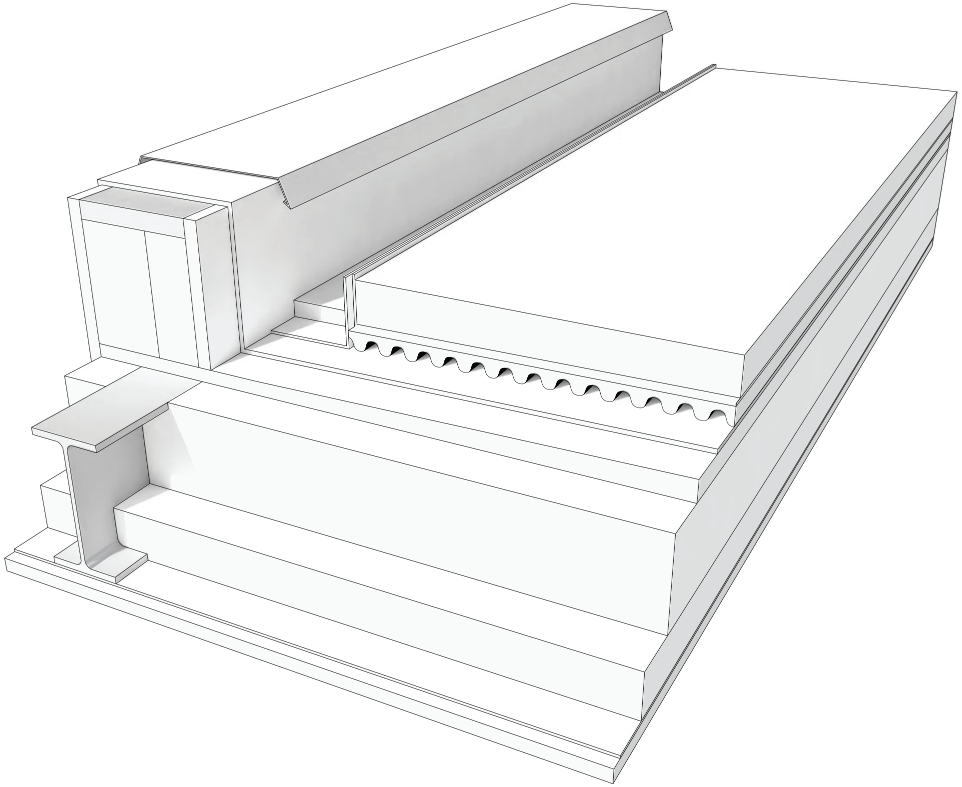
There are mainly two concepts that can be adopted:

- the insultation is placed in the inner side of the prefab wooden structure, which higher the possibilities of thermal bridges than the second system.

- the insulation is placed on the "cold side" and it is not interrupted, this enhance the termal performance. [Deplazes 2008]

In a mild climate zone such as the Garda Lake, even the first system can have good thermal results, having few possibilities of thermal bridges.
However, regarding holiday houses, could be more appropriate to adopt the second system, since these houses are unoccupied for long time and there is the need to warm them up very fast expecially in winter periods, than an everyday house.

Thermal insulation limitations and italian regulation are shown at appendix 1.



BUILDING ENVELOPE: steel structure

The chosen structure for the prefab dwelling is a steel structure.
Moreover, due to the previous consideration concerning insulation, an external insulation envelope have been chosen.
Regarding the architectural expression of the dwelling hard wooden panels have been chosen as external protective layer.

Every perimetral panel that composes the house is meant to be load-bearing.
The pro about using this system consists in the easy of assembly and its portability.
On the other hand using a sandwich panel do not allow to display the structure, indeed all the layers that compose the panels are hidden by a wooden cladding.
Nevertheless, from the architectural expression point of view, what it will be stressed is the temporality and the lightness of this structure.

CONCRETE SLABS

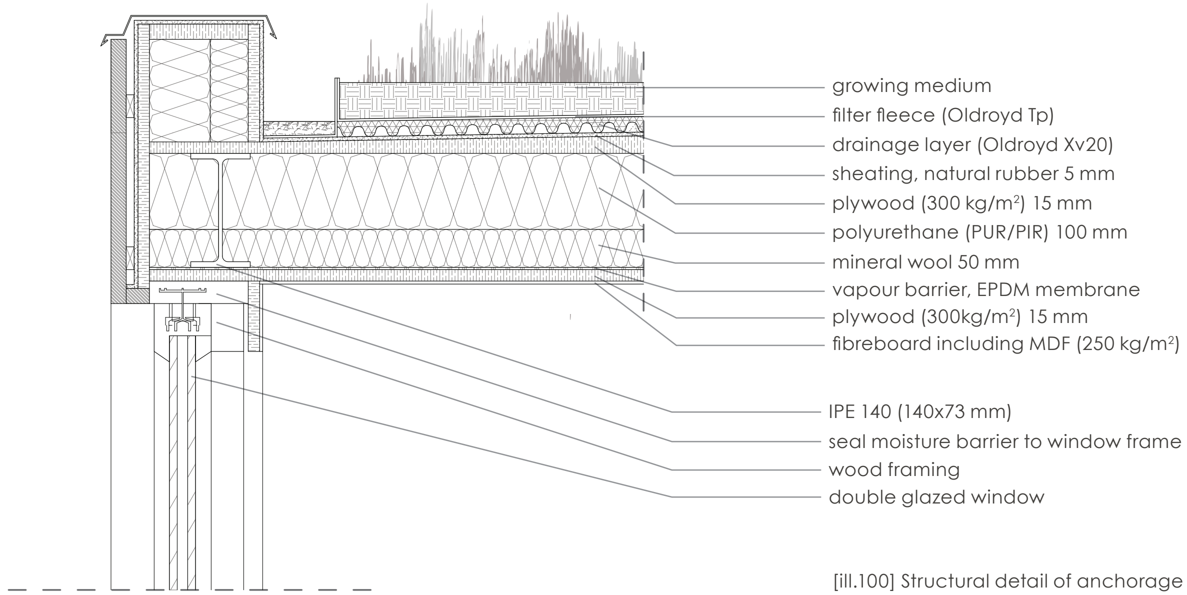
The main structure is reinforced concrete, and act both as external protection for the prefab structure against mechanical damage and climatic effects, and as structural element for the anchorage of the prefab structure.

Therefore the main loads are:
- the prefab volumes of the dwelling which affect the lowest horizontal slabs of the concrete structure.
- the snow and walking loads which affect the upper horizontal slabs of the concrete structure.

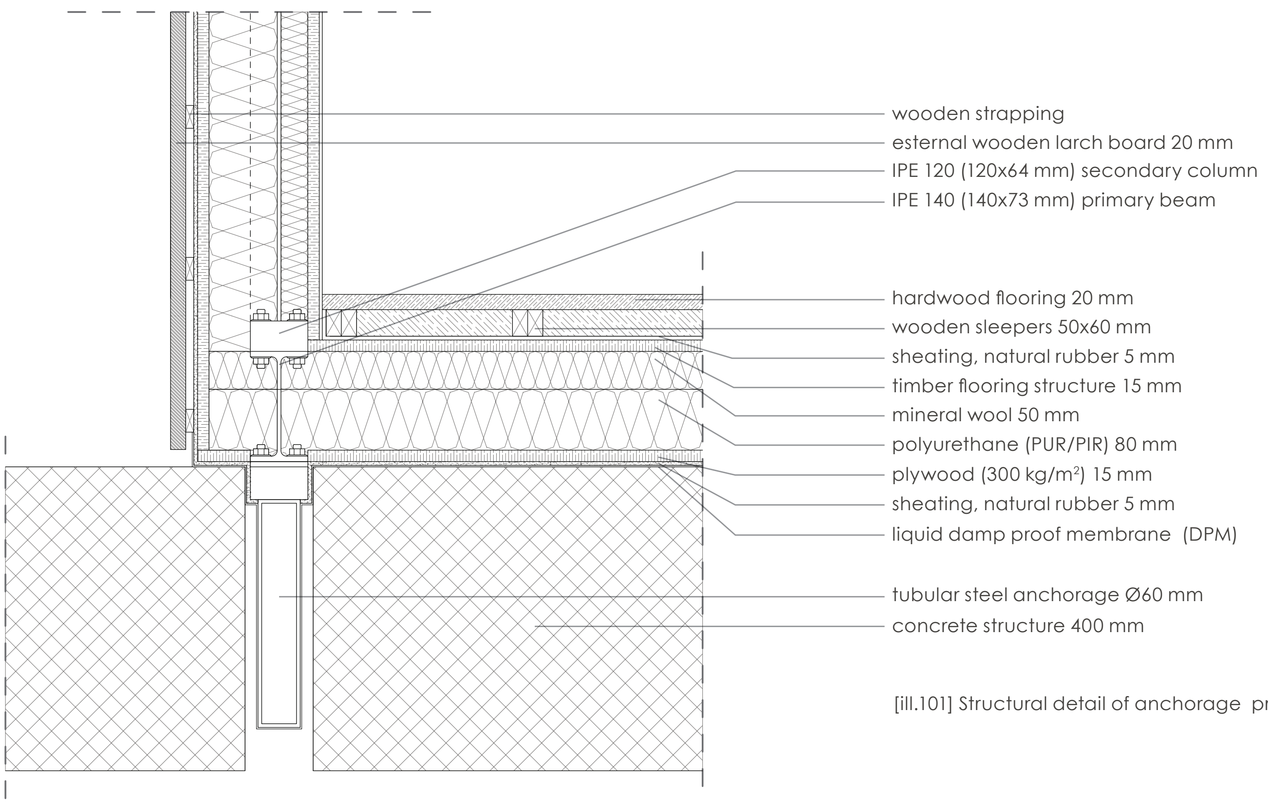
The width and max length of the slabs have been calculated according with these loads (appendix 3) and the minimum needed width (40cm) have been kept throughout the whole structure, to preserve the expression of a unique "folding paper".

ANCHORAGES CONCRETE-PREFAB

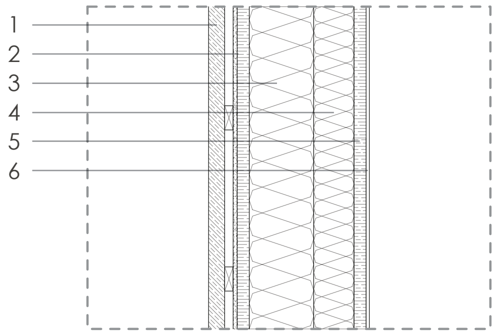
In the detail drawing on the right it is shown the possible connection between concrete and prefab structure, where the tubolar steel is introduced in the concrete anchoring the element from the bottom.



[ill.100] Structural detail of anchorage wall-window-roof



[ill.101] Structural detail of anchorage prefab-concrete

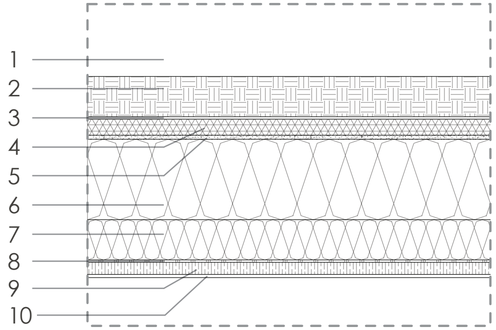


BUILDING ENVELOPE: regular

This is the building detail of a portion of vertical envelope, where the steel structure is not sectioned. Therefore some opening, when needed, can be placed.
The U-value of the whole package does not reach the limit imposed by the D.Lgs 192/05 of 0,34 W/ m²K. [appendix 2]

	material	thickness (m)	thermal conductivity (W/mK)	thermal resistance (m²K/W)
1	external wooden larch board	0,020	0,1	0,2
2	sheathing, natural rubber	0,005	0,17	0,03
3	polyurethane (PUR/PIR)	0,08	0,025	3,2
4	mineral wool (MW)	0,05	0,037	1,35
5	plywood (300 Kg/m²)	0,015	0,09	0,17
6	fibreboard including MDF (250 Kg/m²)	0,004	0,13	0,02

R_{tot} **5,1400**
U_{tot} **0,1946**
$Width_{tot}$ **17,4 cm**

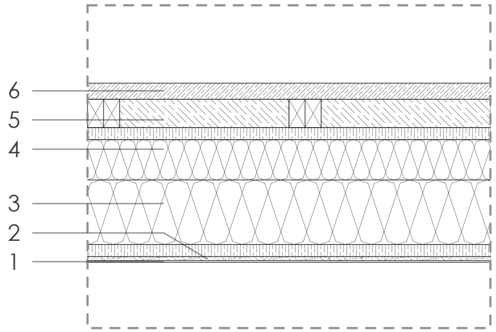


BUILDING ENVELOPE: roof

This is the building detail of a portion of roof. In this layer a vapour barrier is needed, as well as a thicker insulation layer, which include an acoustic barrier.
The resulting U-value does not reach the limit imposed by the D.Lgs 192/05 of 0,30 W/ m²K. [appendix 2]

	material	thickness (m)	thermal conductivity (W/mK)	thermal resistance (m²K/W)
1	grass layer			
2	growing medium	0,050	0,91	0,1
3	filter fleece (Oldroyd Tp)	0,003	0,8	0,004
4	drainage layer (Oldroyd Xv20)	0,03	0,5	0,1
5	sheathing, natural rubber	0,005	0,17	0,03
6	polyurethane (PUR/PIR)	0,1	0,025	4
7	mineral wool (MW)	0,05	0,037	1,35
8	vapour barrier, EPDM membrane	0,003	0,230	0,01
9	plywood (300 Kg/m²)	0,015	0,09	0,17
10	fibreboard including MDF (250 Kg/m²)	0,004	0,13	0,02

R_{tot} **5,8687**
U_{tot} **0,1704**
$Width_{tot}$ **26,0 cm**



BUILDING ENVELOPE: floor

This is the building detail of a portion of floor. The whole is prefabricated and since its structure needs to be anchored on the concrete structure, the package has to face both mechanical and physical damages.
The U-values does not reach the limit of 0,33 W/ m²K. [appendix 2]

	material	thickness (m)	thermal conductivity (W/mK)	thermal resistance (m²K/W)
1	liquid damp proof membrane (DPM)	0,002	0,06	0,03
2	sheathing, natural rubber	0,005	0,17	0,03
3	polyurethane (PUR/PIR)	0,08	0,025	3,2
4	mineral wool (MW)	0,05	0,037	1,35
5	timber flooring structure	0,05	0,14	0,357
6	hardwood flooring	0,020	0,13	0,15

R_{tot} **5,2908**
U_{tot} **0,1890**
$Width_{tot}$ **20,7 cm**

DISCUSSION

CONCLUSIONS

This chapter will present an overall conclusion comparing the final design proposal with the vision described at the end of the analytical phase.

The vision was divided in four different issues related to the themes of context, architectural expression, leisure and technical aspects.
The context has been one of the most challenging topic as the vision for this project was to design a compact leisure house which has to be strongly connected to a stunning landscape. The answer to this issue has been to divide the house in two separate elements: one completely rooted to the site that can works even when detached from the other component, and a temporary one that like a parasite exploit the spaces given by the former.
The main structure for the dwelling is then emphasized becoming the "main junction" between the place and the temporary architecture as well as a transition element that underline the connection among the forest and the lake.

The aspect of the leisure is then being analysed and interpreted by including wide outdoor spaces in the dwelling, blurring the boundaries between the nature and the artificial architecture while keeping at the same time an extremely compact space for the temporary house.

Finally, one of the scope and main aspect for this thesis was to make use of prefabricated tools and techniques in order to create a light temporary house for the spare time, suitable for a user who has the wish to invest in this building system.
In this specific case the design process led me to combine an on site structure with a prefab one. Even if this choice could be seen as out of topic, I believe that the interaction between this two contrasting elements has the power of accentuating the lightness and temporality of the prefab dwelling.
In terms of tectonics the project provides a constructional logic easy to understand and that, at the same time, underline the architectural main idea.

In conclusion, the resulting proposal is a leisure house that, in accordance with the stated scope, is highly connected to the context, rooted to the historic site in terms of material use: the rough concrete structure that merge with rock and the wood of the prefabricated unities easy to carry, assemble and disassemble.
A project thought over time that works in separate phases of its life cycle.

REFLECTIONS

In the end, this last section will reflect upon the final proposal and the design phase that brought to the ultimate project, analysing which part could have been done in a more efficient way.

The most challenging and time demanding part for this project was to understand which kind of relation should occur between the artificial element (represented by my dwelling) and the natural landscape characterized by no connection with other buildings, apart from the old Castle ruins.

The initial ideas of designing a simple prefab house that could gently lie on the ground would probably had a bigger impact compared to the final solution, not only in terms of visuality but also in terms of relation with the context.
A large amount of time was then spent to design the on site structure following the principle of the folding paper, which is extremely an interesting method, but also demanding as it require to be developed through practice.

The other relevant issue was to comprehend how to deal with a public trail crossing the project area. This dilemma, that at beginning was almost interpreted as unimportant, it becomes one of the major "generator" for the project.

Finally, the support of the house started to mutate from simple concrete plinths to a spatial structure that generate a strong relation with the context and the prefab architecture.
These two elements complement each other, creating a tension between the solid concrete and the fragile wood. Like a parasite, the prefab unities cannot work without the structure but the structure is meant to lie on the ground even when detouched from the house, serving as a public space.

When considering the overall project, it becomes clear that a large amount of time and effort was put into finding the "right architectural expression", neglecting some details that should have been explored more deeply. Moreover, deciding to work with the specific structural system of prefabrication, required a scrupulous analysis on a topic which is in continuous development and that require the involvement of different professional figures in order to be well executed.
This will be of great importance if I will have the opportunity to continue the project.

At the end of the process I am satisfied with the overall result even if some details could have been conducted in a better way.
In particular, the walking path on top of the structure and the connection between the concrete and the prefabricated house, where it would have been interesting to create more interaction. Anyway, these details will be reconsidered during the period between the delivery of the project and the thesis defense.

To conclude, producing a thesis project on my own, having the oportunity to develop the topic in the future, has been an incredible challenge that highlighted my potentials and weaknesses on which I have to work in order to grow as architect.

APPENDIX

appendix 1 JAPANESE ARCHITECTURE --- appendix 2 THERMAL INSULATION --- appendix 3 STRUCTURAL ANALYSIS

JAPANESE ARCHITECTURE

Working with the theme of compact house, brought me to analyse and understand the concept behind traditional and modern japanese architecture. These studies have been extremely helpful and inspiring for the project and here below are underlined some of the key issues of the japanese thoughts regarding the relation with nature, the lightness, the dynamism, the minimalism and the odd number.

RELATIONSHIP WITH NATURE

"While Western architects fight the elements of Nature, the Japanese, admiring their power, have found ways to use their charm." [Daniel Boorstin, The Creators]

Westerners, indeed, have traditionally chosen the stone, strong and resistant to overcome the Nature, producing monumental and eternal structures , while Japanese desire to be more in harmony with nature, choosing wood as main material for their constructions, hidden, light an enclosed in the nature. [web 01]

LIGHTNESS

Their lightness is a harmonious relationship with nature, it is not tamed by technology that tries to live with it.
For this reason the Japanese techniques, in contrast to others, do not avoid or hide their fragility and lightness. [web 02]

DYNAMISM

The beauty, for Japanese architects, is not something static, but dynamic. To appreciate the beauty of the building and the garden, one must get around and see them from different perspectives. Through the windows, then, nature becomes part of the house, a key element. Beauty is therefore dynamic because it adapts to Nature: always changing and asymmetric. [web 02]

MINIMALISM

Japan is the homeland of minimalist design and architecture. While Western architects have traditionally tried to make their buildings attractive with the addition of decorative accessories, organizing modules of different heights, Japanese architects are committed to make their architecture sublime and mysterious looking for the essential simplicity. [web 01]
Therefore this essentiality lies in the denial of the superficial beauty and the search for a deepest and most austere expression through the process of negation.

NEGATION & EMPTINESS

The essentiality of the japanese aesthetic, relies also in the variety and the research for the minimal and the remaining, coming from the "odd numbers". The odd numbers give indeed a possibility both to create variations coming from the remaining numbers, and the progression towards an unlimited minimizing.

[ill.102] N House, Suo Fujimoto, Oita - Japan, 2008

The minimization gives aesthetic to the expression of negative: the less vs the more, the silence against the noise. In other words, Japanese are attracted by the remaining (coming from the use of odd numbers) because it gives space to the emptiness, which is dignity, power and spirituality.

This last topic has been one of the most exciting and of great inspiration. Indeed while the prefab structure was meant to be completely designed in every single aspect, the concrete structure is thought to be my "odd number", the element that complement the house but that at the same time create empty spaces that can be used in an unpredictable way.

THERMAL INSULATION

In this chapter some relevant italian regulations and data for thermal comfort are grouped.

The main regulation for thermal comfort in Italy is the **DM 26 Gennaio 2010** issued on "Gazzetta Ufficiale 66". In this project it has been used to calculate and evaluate the thermal efficiency of construction elements, through the U-value calculation.

The U-value calculation has been used in the detailing phase of the project, in order to optimize the design of the construction element also in a technical manner. [see construction detail pag.98]

According with the regulation, these relevant data have been taken into consideration for the calculation:

- internal and external superficial resistance of **0,13 m²K/W** and **0,04 m²K/W**
- climatic zone **E**
- limit U-value for vertical of **0,34 W/ m²K**
- limit U-value for horizontal component (roof) of **0,30 W/ m²K**
- limit U-value for horizontal component (floor) of **0,33 W/ m²K**

$\mathbf{R} = s/\lambda\ [m^2\ K/W]$ | $\mathbf{U}\ [W/m^2\ K]$ | $\mathbf{U} = 1/(1/\alpha_i + \Sigma s_x/\lambda_x + 1/\alpha_e)$

U-VALUE CALCULATION

The U-value is a measure of thermal transmittance. It is the amount of heat which, in the unit of time (h), passes through the area unit (m²), when the temperature difference between the two faces is of a degree Kelvin (k). [Ediltec]

It is calculated through the expression:

$$\mathbf{U = 1/\ (Rsi + Rj + Rse)}$$

R_{si} : internal superficial resistance
R_j : resistance of each material layer
R_{se} : external superficial resistance

The internal and external superficial resistances are defined by UNI EN ISO 6949, and vary according to the placement of the element and the direction of the heat flow. The value are compiled in ill.103

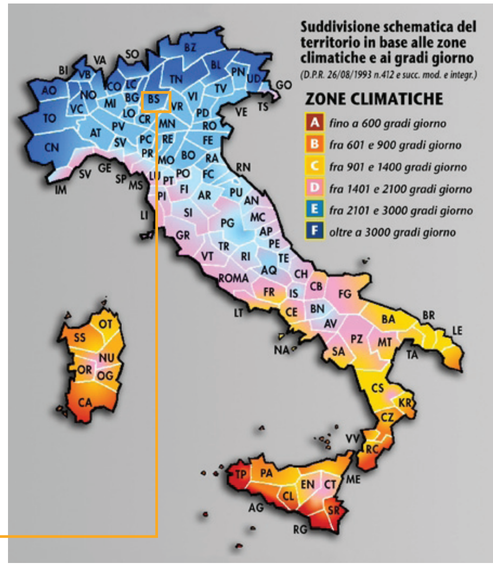
	Direzione del flusso termico		
	Ascendente	Orizzontale	Discendente
Resistenza termica superficiale interna (R_{si})	0,10	0,13	0,17
Resistenza termica superficiale esterna (R_{se})	0,04	0,04	0,04

[ill.103] Superficial thermal resistance values according to UNI ISO 6949

VALORI LIMITE U (dal 01/01/2010) - STRUTTURE OPACHE			
ZONA CLIMATICA	VERTICALI	ORIZZONTALI O INCLINATE DI COPERTURA	ORIZZONTALI DI PAVIMENTO
	U (W/m²K)	U (W/m²K)	U (W/m²K)
A	0,62	0,38	0,65
B	0,48	0,38	0,49
C	0,40	0,38	0,42
D	0,36	0,32	0,36
E	0,34	0,30	0,33
F	0,33	0,29	0,32

[ill.104] Limit U-value depending on thermal zones and components

The **D.Lgs 192/05**, from 1 January 2010, provides a minimum level of thermal performance.
These limits are expressed in primary energy consumption in kWh/m²/year, and come together with a series of tables of thermal transmittance values. The D.Lgs has 5 tables for the heated components of the building, including roofing, walls and floors [ill.104]. Each table shows the limit U-value depending on the climate zone: these give an immediate idea of the minimum thermal insulation required by the law and, moreover, simplify checks on site and allow a proper design. [Ediltec]



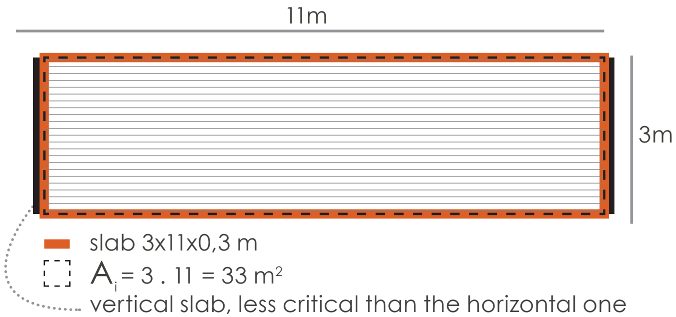
[ill.105] Climatic areas according to DPR 26/08/1993

STRUCTURAL ANALYSIS

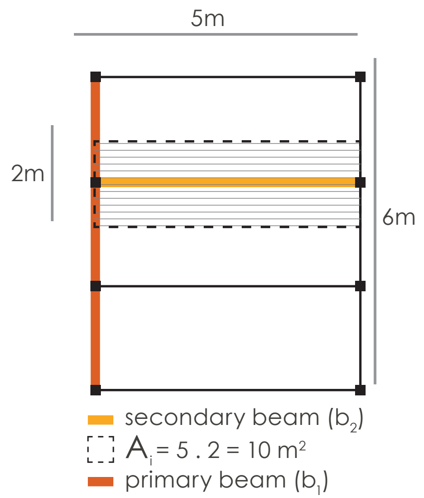
The structural analysis aims to verify the dimensions of the structures: both concrete and prefab. It has been considered the most critical cases according to loads and geometry. The dimensioning of these critical cases has fixed the dimensions for the whole structures.

The most critical case for the concrete structure it is the one in ill.106 where the slab has a span of 11 meter.
The most critical case for the prefab structure is shown in ill.107, in this case the dimensioning has been done on the floor beam of the steel structure.

Some further verification for the dimensioning of the concrete structure have been done considering the loads that this has to face when the prefab building is anchored on its top. The result will show which of this two is the most critical case, and the final dimension will be further adjusted or accepted.



[ill.106] concrete structure



[ill.107] prefab structure

CONCRETE STRUCTURE

Since the structural system is reinforce concrete (RC) two data are necessary to be set:

R_{ck} = 400 daN/cm² (=**40 kN/m³**)
σ_{max} = 60 + (R_{ck}-150)/4 =122 Kg/cm² (=**1,22 kN/cm²**)
[NP EN 1991-1-1-2009, Eurocode 1]

PERMANENT LOADS

Since the concrete structure is only composed of RC (and not other construction elements), the permanent load is only the self weight of the RC slab.
Therefore the self weight is given by:

$Q_s = V_s \cdot R_{ck}$
where V_s = volume of the slab

Therefore
Q_s = (3 . 11 . 0,3) . 40 = 396 kN
q_s = 396/11 = **36 kN/m**
where q_s = distributed self weight

The permanent load effecting the vertical slab is instead of:
Q_{sv} = (3 . 3,5 . 0,3) . 40 = 126 kN
q_{sv} = 126/3,5 = **36 kN/m**

LIVE LOADS

The live loads are given according to:
- the function of the building (and its value is defined by regulation)
- the wind loads
- the snow loads
- other live loads on the structure (which are not permanent)

After having the data of each live loads cathegory, it would be taken the most critical value in order to proceed with the dimensioning of the structural element.

BUILDING CATEGORY

The concrete structure belongs to category C2 (balconies, terraces and common staircases) [ill.108] and the regulamentar load is **4 kN/m²**. [NP EN 1991-1-1-2009]
When applied to the RC slab, the live load is:

$$Q_{LL} = Q_R \cdot A_i$$

where Q_R= regulamentar live load and A_i=area of influence

therefore
$Q_{LL} = 4 \cdot (3 \cdot 11) = 132$ kN
$q_{LL} = 132/11 =$ **12 kN/m**
where q_{LL} = distributed live load according to building category

WIND LOAD

The wind is considered as an horizontal load, therefore the A_i would be different than the other live loads, as well as the span of influence. The wind load is calculated according to the Eurocode 1, part 4. It is given by the expression:

$$Q_w = c_s c_d \cdot q_p(z) \cdot A_i$$

where:
$c_s c_d$= structural coefficient = 1,00 (the building height is less than 15m) [NP EN 1991-1-4-2010]
$q_p(z)$= dynamic pressure, according to construction height
A_i= area of influence

$$q_p(z) = c_e(z) \cdot q_b$$

where:
$c_e(z)$= exposition coefficient = $c_e(3{,}5)$= 1,2 [ill.109]
q_b= reference dynamic pressure, given by the expression:

$$q_b = 1/2\ \rho \cdot v_b^2$$

ρ= air density = 1,25 N/m³
V_b= wind speed = 10 m/s [areonautica]

therefore:
$Q_w = 1 \cdot (1{,}2 \cdot (1/2 \cdot 1{,}25 \cdot 10^2) \cdot (3 \cdot 0{,}3) = 56{,}25$ kN
$q_w = 56{,}25/11 =$ **5,11 kN/m**

The wind load which is effecting the vertical slab is instead of:
$Q_{wv} = 62{,}5 \cdot (3 \cdot 3{,}5) = 656{,}25$ kN
$q_w = 656{,}25/3{,}5 =$ **187,5 kN/m**

SNOW LOAD

The snow load is calculated according to Eurocode 1, part 3. It is given by the expression:

$$Q_s = \mu_i \cdot Q_{sk}$$

μ_i = coefficient of shape for snow load, in this case = 0,8 (flat)
Q_{sk}= snow characteristic value, at ground level, it is related to the location and its altitude.

Manerba del Garda is in Zone 1
and its altitude is 216 m s.l.
therefore:

$$Q_{sk}= 1{,}60 + 3\ (216-200)/1000 = 1{,}648 \text{ kN/m}^2$$

$Q_s = 0{,}8 \cdot 1{,}648 = 1{,}3184$ kN/m² = 43,5072 kN (multiplied by A_i)
$q_s = 43{,}5072/11 =$ **3,95 kN/m**

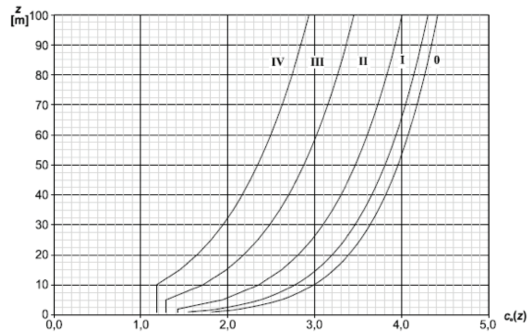
LOAD COMBINATIONS

The next step is to calculate throught the diagram of loads and reactions [ill.110], the maximum deflexion and maximum stress of the slab.
Since the material is RC, in the structure it would be necessary to calculate the diameter and number of reinforcement needed. However in this thesis, some generic formula for the RC will be used, the result has therefore to be considered correct but not completely refined.

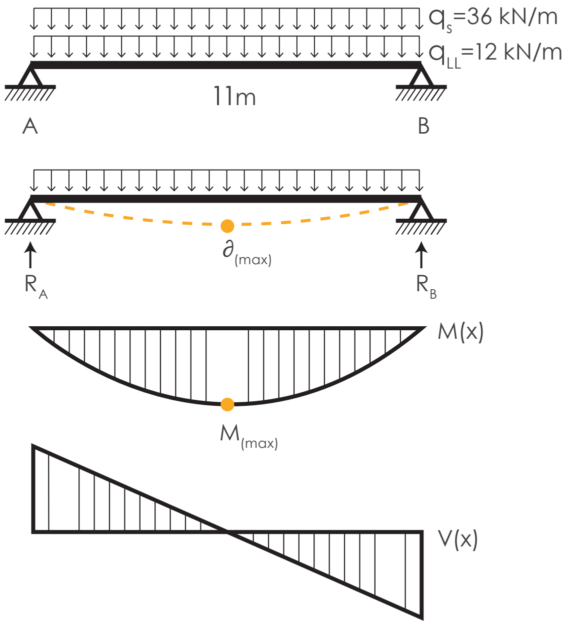
Cat.	Ambienti	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
A	**Ambienti ad uso residenziale.** Sono compresi in questa categoria i locali di abitazione e relativi servizi, gli alberghi. (ad esclusione delle aree suscettibili di affollamento)	2,00	2,00	1,00
B	**Uffici.**			
	Cat. B1 Uffici non aperti al pubblico	2,00	2,00	1,00
	Cat. B2 Uffici aperti al pubblico	3,00	2,00	1,00
C	**Ambienti suscettibili di affollamento**			
	Cat. C1 Ospedali, ristoranti, caffè, banche, scuole	3,00	2,00	1,00
	Cat. C2 Balconi, ballatoi e scale comuni, sale convegni, cinema, teatri, chiese, tribune con posti fissi	4,00	4,00	2,00
	Cat. C3 Ambienti privi di ostacoli per il libero movimento delle persone, quali musei, sale per esposizioni, stazioni ferroviarie, sale da ballo, palestre, tribune libere, edifici per eventi pubblici, sale da concerto, palazzetti per lo sport e relative tribune	5,00	5,00	3,00
D	**Ambienti ad uso commerciale.**			
	Cat. D1 Negozi	4,00	4,00	2,00
	Cat. D2 Centri commerciali, mercati, grandi magazzini, librerie…	5,00	5,00	2,00
E	**Biblioteche, archivi, magazzini e ambienti ad uso industriale.**			
	Cat. E1 Biblioteche, archivi, magazzini, depositi, laboratori manifatturieri	≥ 6,00	6,00	1,00*
	Cat. E2 Ambienti ad uso industriale, da valutarsi caso per caso	—	—	—
F-G	**Rimesse e parcheggi.**			
	Cat. F Rimesse e parcheggi per il transito di automezzi di peso a pieno carico fino a 30 kN	2,50	2 x 10,00	1,00**
	Cat. G Rimesse e parcheggi per transito di automezzi di peso a pieno carico superiore a 30 kN: da valutarsi caso per caso	—	—	—
H	**Coperture e sottotetti**			
	Cat. H1 Coperture e sottotetti accessibili per sola manutenzione	0,50	1,20	1,00
	Cat. H2 Coperture praticabili	secondo categoria di appartenenza		
	Cat. H3 Coperture speciali (impianti, eliporti, altri) da valutarsi caso per caso	—	—	—

* non comprende le azioni orizzontali eventualmente esercitate dai materiali immagazzinati
** per i soli parapetti o partizioni nelle zone pedonali. Le azioni sulle barriere esercitate dagli automezzi dovranno essere valutate caso per caso

[ill.108] value of live loads for different building cat.



[ill.109] value of live loads for different building cat.



[ill.110] diagram of loads and reactions

This diagram on the left shows the most critical loads which effects the RC slab. They are: the self weight of the RC slab (q_s) and the most critical live load between building cathegory load, wind load and snow load. In this last case q_{LL} is the worst.

MAXIMUM DEFLECTION

The resulting $\partial_{(max)}$ must be less than 1/250 of the span of the slab. To calculate the max allowed deflection (∂_{max}), it is necessary to know the $M_{(max)}$:

$R_A = R_B = 1/2\ Q = 1/2\ ((36+12)\ .\ 11) = 24\ kN/m = 264\ kN$

$M_{(max)} = (q\ .\ l^2)/8 = ((36+12)\ .\ 11^2)/8 = 726\ kNm$

It is also necessary to verify the predefined dimensions of the slab [1100(l)x300(b)x30(h)] before proceed further:

$b = r^2\ .\ M_{(max)}\ /h^2 = 0{,}232^2\ .\ 726000/30 = 10{,}02\ m$

The result suggest a base of 10 m. However this is not architecturally the wanted width for the "folding paper" structure. Therefore a new decision was to increase the height of the beam from 30 to 40 cm.
Moreover, a width of 10m by a height of 30 it wont be structurally stable as stated in the previous expression. And further analysis need to be done on the reinforcement.

Once stated the dimension for the slab the $\partial_{(max)}$ is calculated:

$\partial_{(max)} = (Q\ .\ l^3)/48(EI)$
where:
E = coefficient of elasticity = 33000 MPa
I = moment of inertia

$I = (1/12)\ b\ .\ h^3$
$= (1/12)\ 3\ .\ 0{,}4^3 = 0{,}016$

Therefore:
$\partial_{(max)} = (528\ .\ 11^3)/48\ .\ 33000000\ .\ 0{,}016 =$ **0,027 m**

$\partial_{(x\ max)} = l/250 = 11/250 =$ **0,044 m**

The resulting deflection is less than the maximum allowed. The geometry is therefore well thought.
Moreover, some further calculation of the reinforcement will help to better refine the whole structure, however in this thesis the calculations shown in these pages can be enough to have a correct dimensioning of the slab and the whole concrete elements.

MAXIMUM STRESS

The further step is to verify the maximum stress of the slab.
As stated at the beginning, the σ_{max} for a RC with an R_{ck} of 40 kN/m³ is: **1,22 kN/cm²**.

$\sigma = Q/A$
$= 528/330000 =$ **0,0016 kN/cm²**

The resulting stress is far below the limit value of the max allowed.

PREFAB STRUCTURE

Since the structural system is steel two data are necessary to be set:

steel S 355 JR
σ_{max} = **24 kN/cm²**
τ_{max} = **13,8 kN/cm²**
[NP EN 1991-1-1-2009, Eurocode 1]

LIVE LOADS

The most critical live loads present on the prefab floor belongs to category A, residential loads [ill.111] and the regulamentar load is **2 kN/m²**. [NP EN 1991-1-1-2009]
therefore
$Q_{LL} = 2 . (5 . 2) = 20$ kN
$q_{LL} = 20/5 =$ **4 kN/m**

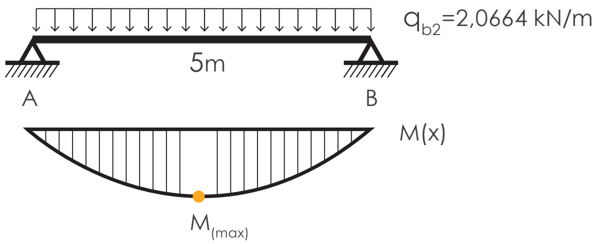
LOAD COMBINATION (b2)

The calcultation start from the dimensioning of the secondary beam (b2) and at last the primary beam (b1).
The permanent loads present on the floor structure are: self weight of the steel structure and permanent loads of the floor package [ill.112]. This package has an overall load of: **1,04 kN/m**.
While the self weight of the secondary steel beam (b2) is:

$Q_{b2} = q_{tot} . L_i + 5\%$
where L_i = length of influence
5% of the q_{tot}

Therefore
$Q_{b2} = (4+1{,}04) . 2 + 5\%(5{,}04) = 10{,}332$ kN
$q_{b2} = 10{,}332/5 =$ **2,0664 kN/m**

In order to dimension the beam, it is necessary to first now its module of minimum resistance (W_{min}) and then verify the maximum deflection allowed (∂_{max}).



MAXIMUM DEFLECTION (b2)

$M_{max} = q_{b2} . L^2 / 8$
$= 2{,}0664 . 5^2/8 = 6{,}4575$ kNm

$W_{min} = M_{max} / \sigma_{max}$

$= 6{,}4575 . 100/24 = 26{,}9$ cm³

The resulting W_{min} can correspond to an IPE 100. However a verification of this dimesioning needs to be done according with the max allowed deflection which is:

$\partial_{(max)} = L/200 =$ **0,025 m**

The minimum moment of inertia (J_{min}) it is necessary to know the max deflection of the beam:

$J_{min} = (5/384) . (q_{b2} . L^4) / (E . \partial_{(max)})$

$= (5/384) . (2{,}0664 . 625) / (2{,}06 . 10^8 . 0{,}025) = 326$ cm⁴

The closest IPE's J_{min} is **318 cm⁴** and belongs to an IPE 120.
Now it is possible to calculate the maximum deflection which has to be less than 0,025 m.

$\partial_{(max)} = (5/384) . (q_{b2} . L^4) / (E . J_{min})$
$= (5/384) . (2{,}0664 . 625) / (2{,}06 . 10^8 . 318) =$ **0,0024 m**

Cat.	Ambienti	q_k [kN/m²]	Q_k [kN]	H_k [kN/m]
A	**Ambienti ad uso residenziale.** Sono compresi in questa categoria i locali di abitazione e relativi servizi, gli alberghi. (ad esclusione delle aree suscettibili di affollamento)	2,00	2,00	1,00
B	**Uffici.**			
	Cat. B1 Uffici non aperti al pubblico	2,00	2,00	1,00
	Cat. B2 Uffici aperti al pubblico	3,00	2,00	1,00
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	Cat. C2 Balconi, ballatoi e scale comuni, sale convegni, cinema, teatri, chiese, tribune con posti fissi	4,00	4,00	2,00
	Cat. C3 Ambienti privi di ostacoli per il libero movimento delle persone, quali musei, sale per esposizioni, stazioni ferroviarie, sale da ballo, palestre, tribune libere, edifici per eventi pubblici, sale da concerto, palazzetti per lo sport e relative tribune	5,00	5,00	3,00
D	**Ambienti ad uso commerciale.**			
	Cat. D1 Negozi	4,00	4,00	2,00
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	Cat. F Rimesse e parcheggi per il transito di automezzi di peso a pieno carico fino a 30 kN	2,50	2 x 10,00	1,00**
	Cat. G Rimesse e parcheggi per transito di automezzi di peso a pieno carico superiore a 30 kN: da valutarsi caso per caso	—	—	—
H	**Coperture e sottotetti**			
	Cat. H1 Coperture e sottotetti accessibili per sola manutenzione	0,50	1,20	1,00
	Cat. H2 Coperture praticabili	secondo categoria di appartenenza		
	Cat. H3 Coperture speciali (impianti, eliporti, altri) da valutarsi caso per caso	—	—	—

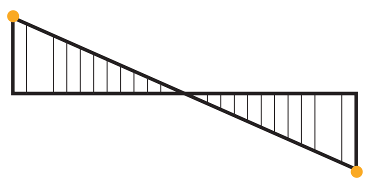
* non comprende le azioni orizzontali eventualmente esercitate dai materiali immagazzinati
** per i soli parapetti o partizioni nelle zone pedonali. Le azioni sulle barriere esercitate dagli automezzi dovranno essere valutate caso per caso

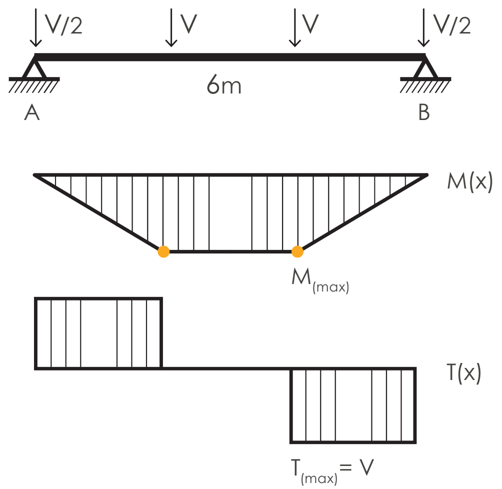
[ill.111] value of live loads for different building cat.

material	thickness (mm)	density (γ)	distributed load
liquid damp proof membrane	0,002	18	0,036
sheathing, natural rubber	0,005	17	0,085
polyurethane (PUR/PIR)	0,08	0,3	0,024
mineral wool (MW)	0,05	0,3	0,015
timber flooring structure	0,05	4	0,200
hardwood flooring	0,004	8	0,032

Tot. = 0,52 kN/m²
Q_p = 0.52 . 10 = 5,2 kN
q_p = 5,2/5 = 1,04 kN/m

[ill.112] distributed loads of the floor package





[ill.113] diagram of load and reaction of primary beam

MAXIMUM STRESS (b2)

The fissuring limit (τ) is calculated as:

$\tau = (T \cdot S_x)/(t_w \cdot J)$
where $T = q_{b2} \cdot L/2 = 2{,}0664 \cdot 5/2 = 5{,}166$ kN

$\tau = (5{,}166 \cdot 30{,}4)/(0{,}44 \cdot 318) =$ **$1{,}122$ kN/cm²**

The resulting stress is far below the limit value of the max allowed (**13,8 kN/cm²**).
Therefore the IPE which is going to be used for the secondary beams is an **IPE 120** (12 x 6,4 cm)

LOAD COMBINATION (b1)

This diagram on the left [ill.113] shows the diagrams of loads and reactions of the primary beam (b1), where:

$V =$ **5,166 kN**
which is the load carried by the secondary beams

$M_{max} = (V \cdot L)/3 = (5{,}166 \cdot 6)/3 = 10{,}332$ kNm

$W_{min} = M_{max}/\sigma_{max}$
$= 10{,}332 \cdot 100/24 = 43{,}05$ cm³

The result correspond to an IPE 120. However it needs to be verified

MAXIMUM DEFLECTION (b1)

The maximum allowed deflexion has to be less than:
$\partial_{(max)} = L/200 =$ **0,03 m**

$J_{min} = (23/648) \cdot (V \cdot L^3) / (E \cdot \partial_{(max)})$
$= (23/648) \cdot (5{,}166 \cdot 216) / (2{,}06 \cdot 10^8 \cdot 0{,}03) = 540{,}87$ cm⁴

The closest IPE's J_{min} is **541 cm⁴** and belongs to an IPE 140.

$\partial_{(max)} = (23/648) \cdot (V \cdot L^3) / (E \cdot J_{min})$
$= (23/648) \cdot (5{,}166 \cdot 216) / (2{,}06 \cdot 10^8 \cdot 541) =$ **0,029 m**

MAXIMUM STRESS (b1)

The calculated fessuring (with T = V = 5,166 kN) is:

$\tau = (5{,}166 \cdot 44{,}2)/(0{,}47 \cdot 869) =$ **0,56 kN/cm²**

The resulting stress is far below the limit value of the max allowed (**13,8 kN/cm²**).
Therefore the IPE which is going to be used for the primary beams is an **IPE 140** (14 x 7,3 cm)

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