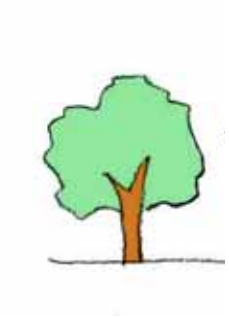

SETUBAL MUNICIPAL LIBRARY

Jibo Chen - Master Thesis Project

This master thesis is dedicated to those architects and scholars who have the same integrity as Jørn Utzon, resisting the injustice, superficiality and universality of world; to whom truly cherish architecture in the sake of nature, human culture and love.

master thesis

Project title	Setubal manicipal library
Project period	01.02.2014 - 28.05.2014
Main supervisor	Adrian Carter, architect MAA, associate professor, deparment of architecture, Aablorg University
Technical supervisor	Christian Frier, associate professor, department of civil engineering, Aalborg University
External supervisor	Pedro Sousa, principal, architectural studio TMA, Portugal
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Introduction

The Utzon Paradigm

'Utzon's work embodies a visionary approach that is site specific and poetic, tectonic and humane; informed by a profound appreciation of nature and diversity of human cultures, as sources of inspiration and analogy, combined with a sense of architecture as art and an innovative approach to the use of technology'
(Carter, A. 2009)

Jørn Utzon is an internationally distinguished Danish architect. He has created one of the great iconic buildings in the twentieth century, Sydney Opera House, which is humane, poetic and monumental. In addition to this masterpiece, Jorn Utzon also designed number of major works of architecture, including Bagsværd Church, Kingo Courtyard houses, Kuwait National Assembly etc. These works exemplifies a phenomenological approach with a deep connection to nature and human-existence.

My mentor Prof. Adrian Carter, the director of Utzon Research Center, as well as main supervisor of this master thesis, has provided me with insights about Utzon and his approach. Also in my working experience with Mr. Liu Jiakun, the principal of Jiakun architects, his architecture contained the phenomenological approach rooted in nature, human-being and traditional craftwork just as Utzon had exemplified. With all these influences, it is my personal ambition to study Utzon's works and learn from his design process.

According to the Utzon Paradigm as proposed by Adrian Carter and Roger Tyrrell, the study of Utzon's oeuvre could be defined as two distinct yet interconnected frameworks: Archɛ and Techɛ. Both of them derive from Greek and combine as the meaning of Architect etymologically.

Archɛ interrogates the core phenomena that architecture confronts, the essence back to its primitivism, In Utzon's architectural interpretation, the idea of Archɛ also responses to Heidegger's essay on 'Building, Dwelling, Thinking' that architecture become the medium for human to understand their existence in-between sky and earth. Technɛ expresses the concept of realizing the idea in tangible form from a metaphysical stage. It is worthy to mention our mother nature provides Utzon in his childhood and career with fantastic inspirations. With this appreciation, Utzon learned how to master different materials and light also becomes a material to implement in Utzon's buildings.

These two frames of reference are respectively extended as follows within Archɛ: Nature, Landscape and Place, The Primitive, Transcultural Influence, Ethics Humanity and Community; while in Techɛ: Nature and Form, Making, Form and Structure, Material and Light, Geometry, Addictive Architecture and Prototyping.

Furthermore, two authors concluded that the synthesis of Archɛ and Technɛ is what makes Utzon's architecture unique and poetic (Tyrrell, R; Carter, A. 2013). In here, I would continue from their point of view to emphasis that the relationship between Archɛ and Technɛ is not only as dualism, i.e. binary opposition. Rather, it also contains as binary complement as in Chinese philosophy of Taoism, which symbolizes as the Taiji diagram (Fig). The distinguish lies in the oriental philosophy of balance, and where two opposites co-exist in harmony and are able to transmute into each other (Laozi, 6BC). So as to say, the poetic synthesis of architecture generated from both Archɛ and Technɛ must be understood as a unity in the Utzon paradigm without being apart.

Hence, Archɛ, Technɛ and its poetic synthesis could be potentially developed not only a tool of analysis but a tool of design. For architecture that has soul, and could touch people. This thesis then tends to develop a project by referring to the Utzon paradigm as a structure and template. At the same time, the understanding on how Utzon made architecture and solved the problem at different stages in the design process can be gained

The resistance

'In his core, it is also clear that Utzon's approach to life and his work was underpinned by a clear sense of ethics that he maintained despite considerable pressures to the contrary. In his forced self-removal from the Sydney opera house project, he performed an act of considerable courage…What remains with the reader is a sense of political intrigue, economy of truth and huge injustice. ..Utzon remained clear as to his decision '

(Tyrrell, R; Carter, A. 2013)

As exemplified by Jørn Utzon's life, it is inevitable that this world is far more complicated than anticipated and so many things are beyond an architect's actual control, however, Utzon provides us with the perfect example of an individual who confronts such difficulties with an unyielding resistance based on his integrity.

Even though as a new generation of architect I might not experience the same situation as Jorn Utzon, and it seems an over-reaction to discuss 'the resistance'. But still, based on my personal experience and witness on contemporary China, a critical perspective required to clarify within today's biggest context, namely globalization. The 'International Style' architectures proliferate rampantly within metropolis, separating itself from traditional culture, ignoring the natural environment, and consequently becoming soulless. Nevertheless, contemporary China is not the only example of this in the world.

Perhaps, the paradoxical question from Paul Ricouer is what needs to answer: 'how to become modern and to return to sources; how to revive an old, dormant civilization and take part in universal civilization.' As Kenneth Frampton suggested, critical regionalism serves as a buffer zoon in between globalism and regionalism, with the antithetical critique to universal modernism, placelessness, reactionary populism, the capitalist culture of consumption. Critical regionalism should adopt modern architecture, critically, for its universal progressive qualities but at the same time value should be placed on the geographical context of the building, which should be on topography, climate, light; on tectonic form rather than on scenography (i.e. painting theatrical scenery) and should be on the sense of touch rather than visual sense (Frampton, K. 1983).

Critical regionalism hereby provides a process rather than a product, which is non-stylistic and applicable to a range of situations. However, the following question is where would this thesis project be developed within such an architectural resistance? The answer is nowhere else but Portugal.

Not only because there are profoundly talented architects such as Femando Tavora, Alvaro Siza Vieira and Edurado Souto de Moura (just to name a few), but mainly lies in the fact that contemporary Portuguese architecture has never been lost its specific characteristic rooted in the geography of its territory and culture. From the House of Music in Porto by OMA, we see the superficial expression of using Portuguese traditional ceramic tiles and the universal strategy of winning a design competition, and compared it with most of the buildings by Siza Vieira though his austere yet exquisite interpretations of nature and culture.

The Homogenous or the Particular? I think the design from Jørn Utzon and Alvaro Siza can actually inspire contemporary Chinese architects in retrospect to fertile historical and cultural resources as well as topographical contexts.

Tectonic approach

Based on the study guide of MSc4 in Department of Architecture and Media Technology, Aalborg University, this master thesis is developed within the theme of Tectonic Design. As the previous discussion on Techne of the Utzon Paradigm, this chapter is seen as to elaborate Utzon's tectonic approach with reference particularly of Kenneth Frampton.

Derived from 'teckton' in Greek, the term tectonic is originally for carpenter or builder. Through the undergone of different understandings to the term since mid-nineteenth century, one of the latest and common approaches is from Kenneth Frampton, who describes tectonic as a clear structural expression: the overall construction should be logical and easy to read. For this, material honesty, tactile quality and architectural detailing should be respected and taken into consideration in design. To the contrary, the scenography way of making spaces leads to an undistinguished fact of material, craftwork and gravity. Besides, Frampton also refers the tectonic approach to the awareness of topography, i.e. site specific, to make place, to dwell not only physically but also poetically. Again, this idea interrogates human existence based on Heidegger's phenomenological thinking on architecture (Frampton, K. 1995).

Jørn Utzon's tectonic approach to architecture underpinned by a deep understanding of craftwork from his father as a ship craftsman. In respects to the honesty of material, he knew materials not only by their innate property practically, but also engaged with a metaphysical level of how material can contribute to the architectural quality (Tyrrell, R; Carter, A. 2013). Similar to his pioneer Alvar Aalto, Utzon received inspirations from nature and developed it into a logical generation of form: Additive Architecture; Influenced from exotic culture e.g. Islamic, Oriental civilization, Utzon interpreted and applied into his design, providing architecture with variable meanings in a transcultural level, which is especially impressive by me as a Chinese architect. With inspiration from these many transculture sources, Utzon then tests his different design solutions though the physical process of model making, evolving his ideas through the cooperation of eyes, hand and mind.

Methodology

As problem based learning (PBL) is the fundamental study process taught in Aalborg University. Based on that, the Integrated Design Process (IDP) is developed in order to achieve the goal of the integration between architectural idea and engineering performance. During the process, different phases will be going through and taking back and forth from problem formulation, analysis phase sketching phase, synthesis phase and then presentation phase (Knudstrup. M.A, 2004). In previous study, IDP is beneficial while applying in a team work as to guide the design step by step and ease the communication between members.

Within the individual thesis, Integrated Design Process will still be applied as to fulfill the engineering requirement according to the MSc4 study guide. However, it is important to state that architectural design is as one of design activities making both decision and instinct. Decision comes from the rational or scientific mind of thinking, while instinct from the accumulation of knowledge or so-called 'wild thinking' Therefore, sketching phase will be highly emphasized in here, both consciously and unconsciously, in a way of organizing thoughts and searching for solutions towards problem, eventually formulating the design proposal (Pallasmaa. J, 2009).

Besides, a two-week study trip to Portugal with first-hand experience of the site is also carried out during the thesis. It has prominently influenced to this project and gained an understanding of architecture and culture in a phenomenological perspective, which might not be able to be fully documented in the report, yet worthy to mention.

Case study

Alvaro Siza, SAAL Social Housing, Porto, Portugal (1975 - 77)

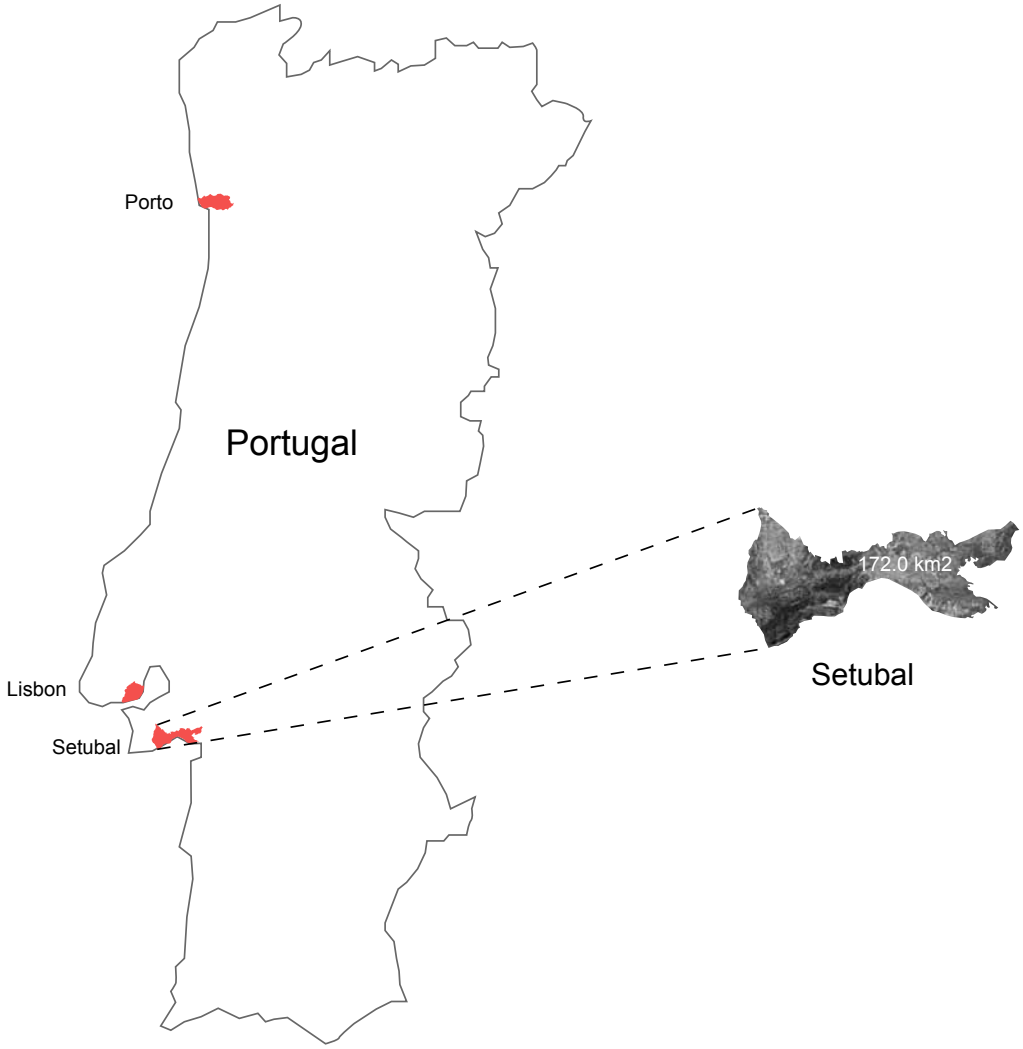
Alvaro Siza is one of the greatest Portuguese living architects. His architecture is firmly integrated with nature and geographical territory and culture, which leads to an abstract tectonic approach with the use of local and low-cost material. However, the way he expresses material has never been monotonous. Though the complex mixture with light and practical materials, the great nature commonly offers his architecture with a sense of human and harmony.

Project vision

The master thesis project is developed under the theme of "Tectonic Design", as part of an open competition in 2013– the municipal library of Setúbal. Setubal is the main city in Setubal Municipality in Portugal, Only 40 kilometers from Lisbon, the capital of Portugal, with the area of 172.0 km2 and the population of 135,000.

The project site locates in the city center of Setubal, Portugal, along the main avenue Avenida Luísa Todi, in a public square Largo José Afonso that originally bounded by existing buildings of 2 and 3 floors. According to the competition program, the new library has a gross floor area of 3000 square meters with maximum of three levels above the ground. Building program should at least include: 1) lobby, cafeteria that directly related to outside; 2) reading area of adults and children section; 3) working area, office and meeting room.

The aim of this competition is to create a library that benefits the whole area and to articulate itself as a landmark building with a formal language combined with a contemporary aesthetic.



Design process

Setubal

Setubal is the main city in Setubal Municipality in Portugal, with the area of 172.0 km2 and . Only 40 kilometers from Lisbon, the capital of Portugal, it serves as a significant connection in bridging the south of Portugal, with excellent accessibility by national highway, railway, maritime and river transport.

During the 19th century, Setubal has undergone a tremendous grows and then in the beginning of the 20th century, it became the most important center of Portugal's fishing industry. From the existing maritime ports and the vibrant ocean, its tradition can still be easily distinguish and revealed.

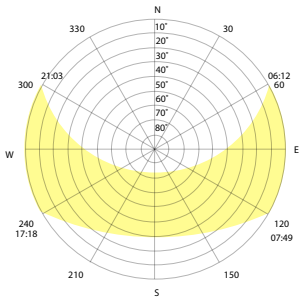
Since that population of the municipality of Setubal increase in decades, the old municipal library operated in 1948 has the difficulties to afford appropriate space and function for the ongoing citizens. It therefore emphasizes a need of a new library in Setubal (competition program).

Setubal is an impressive city for visit, embraced with abundant natural resources as well as its rich cultural and historical respects. The Arrabida Mountain, located in the west part of the city, is a landscape of exceptional esthetic value, and one of the most beautiful and significant Mediterranean natural spaces. While in the core of the city, the wall of bastion in Setubal built in 17th century, with the purpose of military. Although some have been sunk underground, the existing part still manifests its historical impact and thus influences on urban transformation between the old city center and the new urban area in the river front.

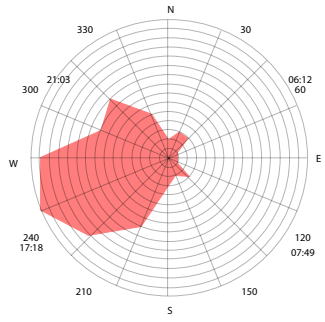
Abbrabia Mountain

Project site

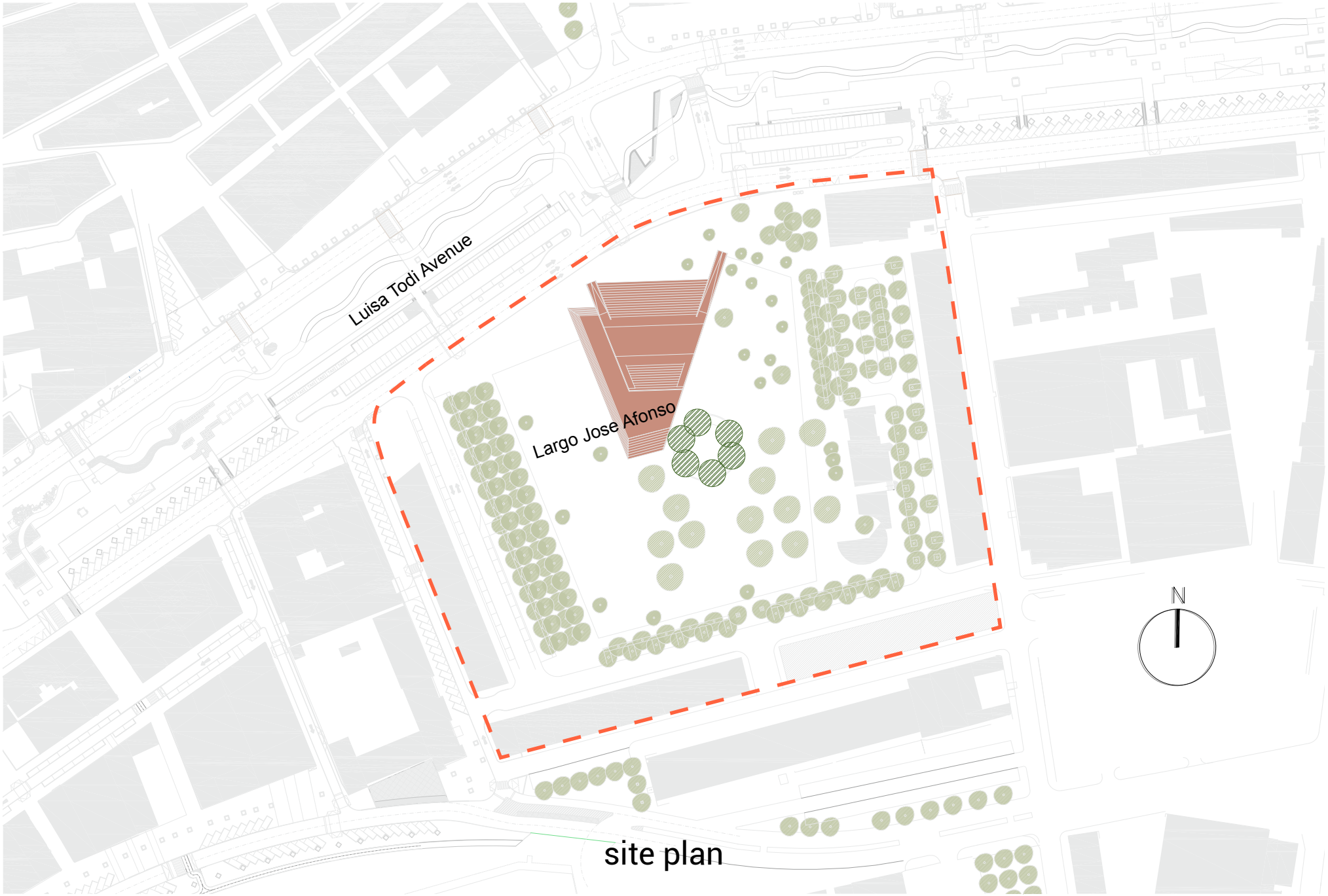
The wall of bastion in Setubal



sun path diagram



wind distribution

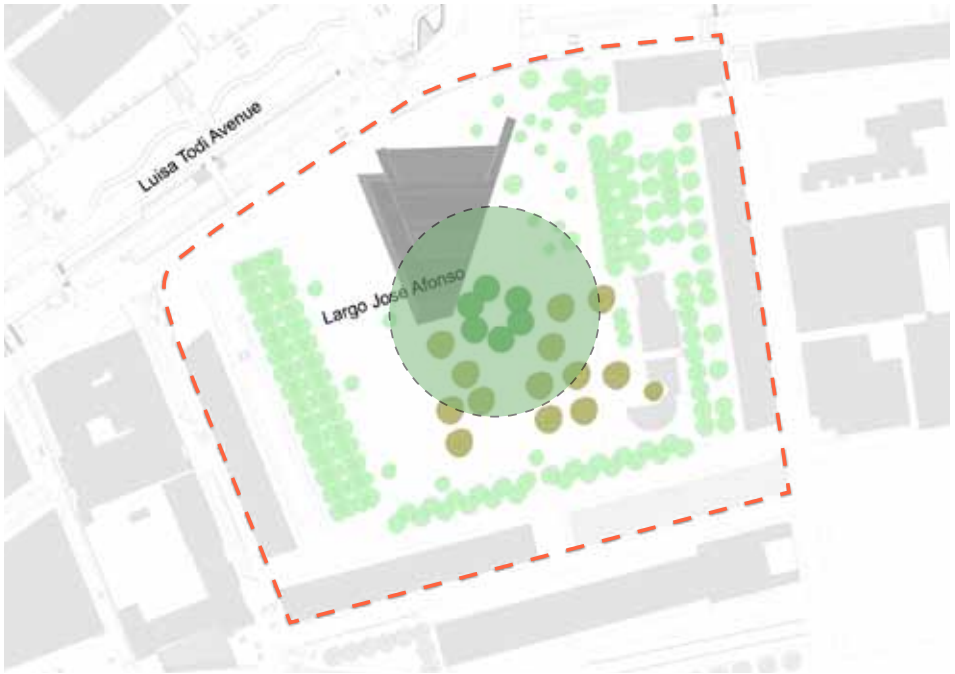


site plan

1. limited area

The spot is situated in the conjunction of historical preserve area and new river front area of the city. Nowadays in Setubal, tourism becomes one of the main industries and thus raises the significance to protect its natural as well as cultural resource. Therefore I mark the area in color according to the suggested boundary of the underground city wall, where might not be appreciate to put new buildings. Also, a huge structure centered in the marked area, Largo Jose Afonso, services as the open auditorium for concert and other events functionally. All these elements identify the site by its historical and cultural impact in Setubal.

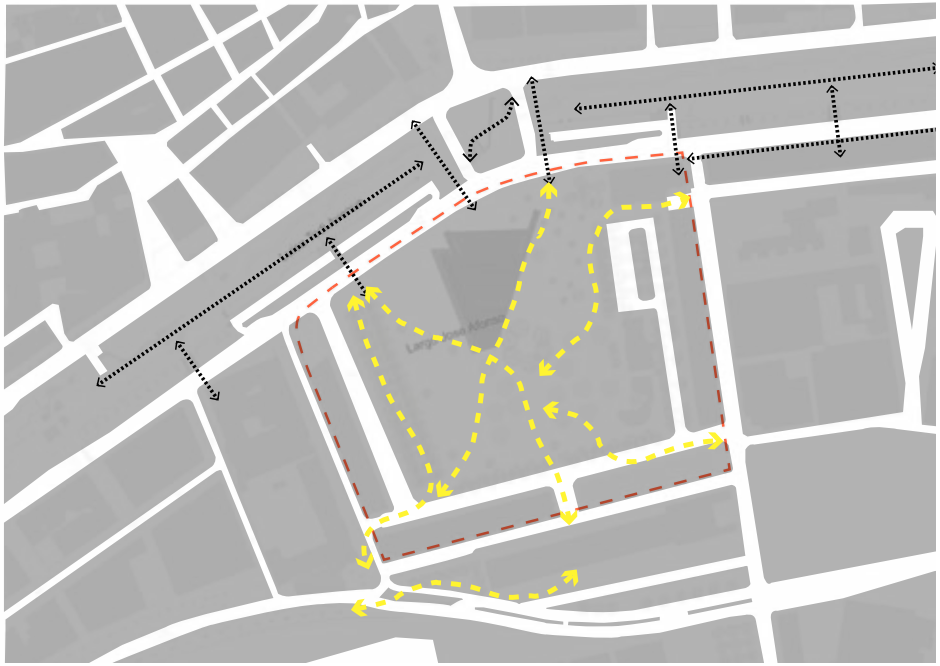
existing construction area
project area
historical protected area
city wall of bastin in Setubal
boundary of the protected historical area



2. vegetation type

Vegetation hereby treated as an important factor of the site. The reason being there contains not only existing big trees, but also some small saplings plant under the plan of future vegetation suggested in the square. In the old park of Largo Jose Afonso, six 10-metre tall cedar trees plant around a fountain. A 50 meters zoon suggests the protection around the fountain and cedars, proved by the National Forestry Authority of Portugal.

under the program
small tree
cedar
Portuguese oak



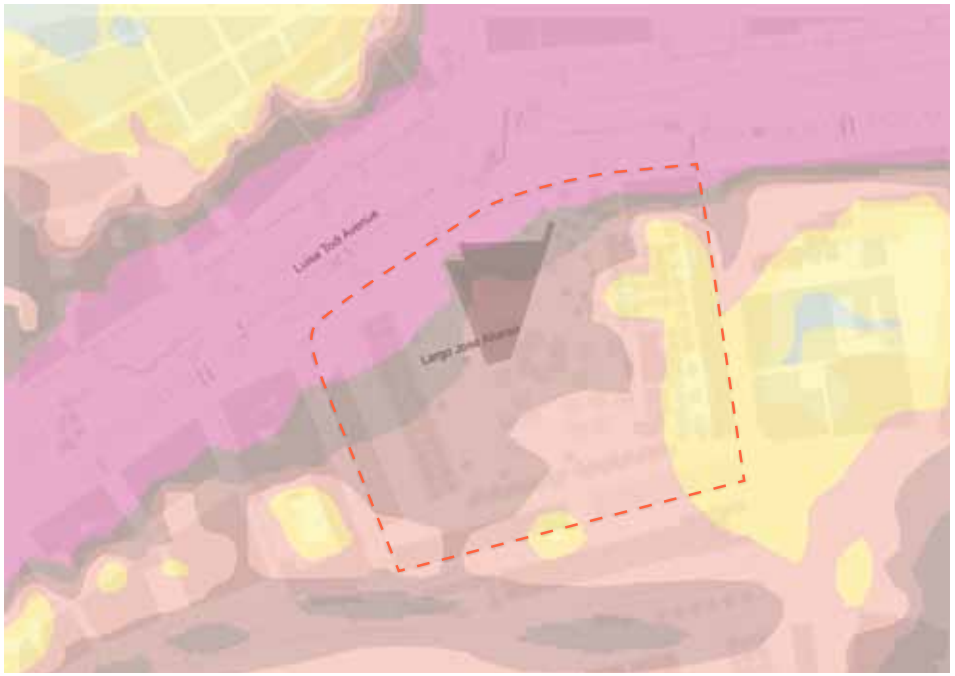
3. urban circulation

pedestrian flow from Avenida Luisa Todi

pedestrian flow on the site

This mapping illustrates pieces of land are filled within color, and the circulation in-between.

Right next to Luisa Todi Avenue, one of the main boulevards in Setubal, the project site is of flexible accessibility. The black flows suggest different ways of pedestrian entering the site by Luisa Todi Avenue that you can either walk into the green zoon and encounter with nature, or strolling along one of the best city tours and enjoy a panorama view of the public square; while yellow flows show more various possibilities to the site from the other side of the city, and it is efficient to reach the river front from the site as well.



4. noise level

[0 ; 45] dB (A)

[45 ; 50] dB (A)

[50 ; 55] dB (A)

[55 ; 60] dB (A)

[60 ; 65] dB (A)

[65 ; 70] dB (A)

[70 ; ...] dB (A)

The level of noise is considered as one of the critical qualities of a library, where requires a quiet and comfort environment for its users. Thus it would be beneficial to indicate a reflection on different performance of noise within the area. These standards could help to decide the location and function of the library in later design.

In the diagram, it shows the level of noise in the surrounding of Largo Jose Afonso during the period of 0h – 24h. Data acquired from the competition program.

design criteria

1. building co-exists with trees

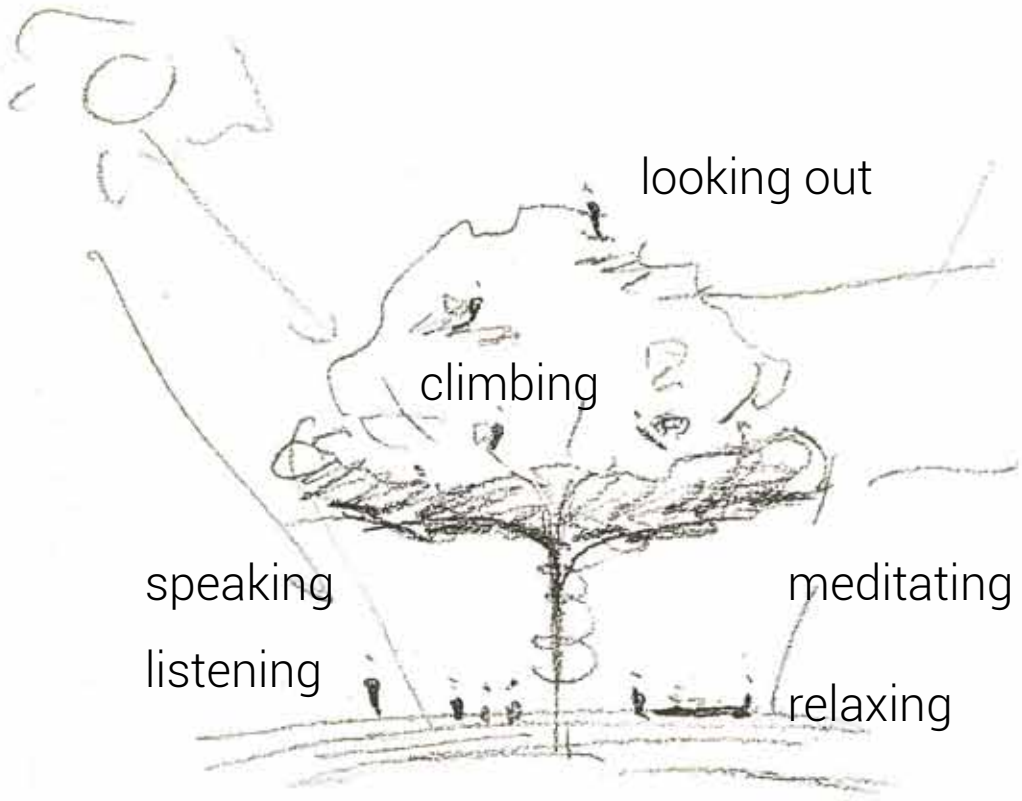
2. preserving much of the natural site as possible

The Arrabida Mountain, in the west part of the city, Setubal.

Primitive

Related to the study of this project, the comprehensive images and instinctive sketches bring me a correlation between the site and the landscapes of Arrabida Mountain sited in the west of Setubal, which has a great sense of nature that could be found in both places.

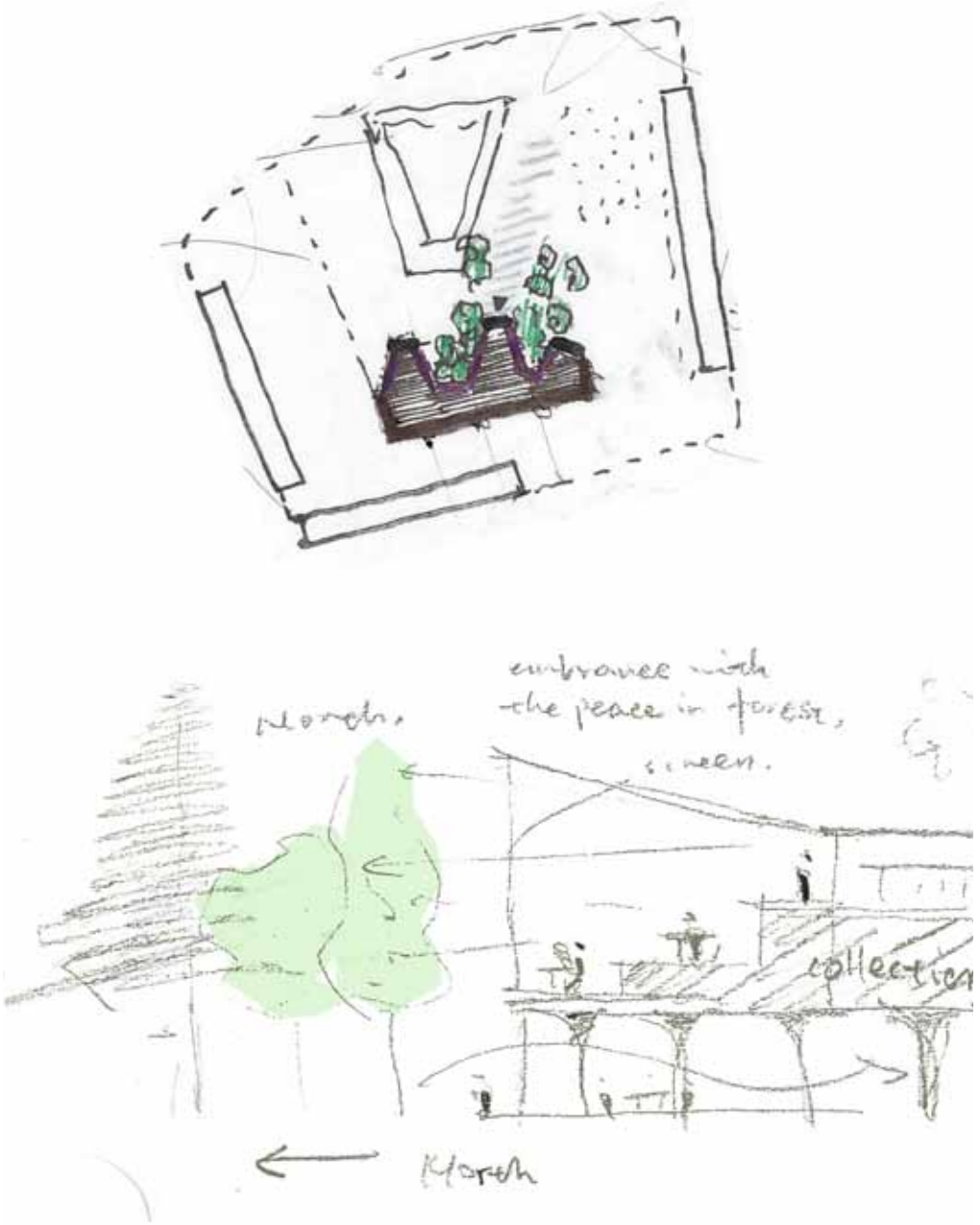
As Louis Kahn says, 'I think of school of an environment of spaces where is good to learn. School began with a man under a tree, who did not know he was a teacher, discussing his realization with a few who did not know they were students…the existence-will of school was there even before the circumstances of a man under a tree. That is why is good for the mind to go back to the beginning, because the beginning of any established activity is its most wonderful moment (John, 2000).' It is impressive for me since the first time I saw these sentences, encouraged by his idea of architecture were not inert configurations of form and space but living organic entities, created by the architect for human use. This 'human institutions' lied in the philosophical point of view in function, mainly considering the essence of human perception and behavior that a building should serve.



genius loci

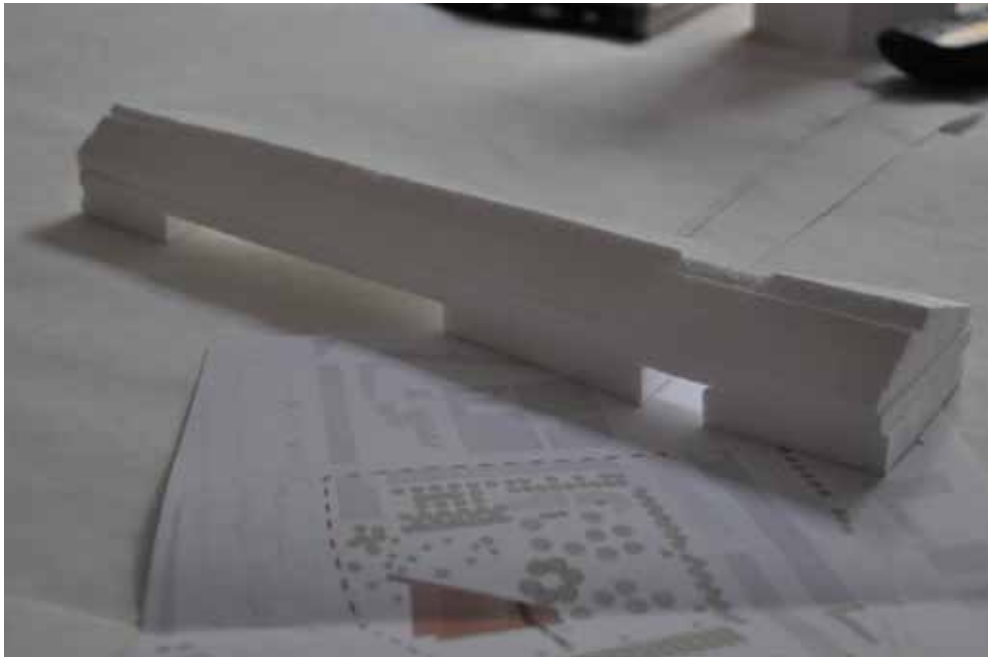
I saw the site a treasure of trees. People can instinctively have numerous possibilities engaged with a single tree. And here are many. Isn't it the best place for studying, reading, meditating or having a picnic with friends? Last, a citation of Kahn once again 'what does the building want to be?' and I would declaim in here, where in the site of Setubal, the library was already there, inside the harmonious sense of trees.

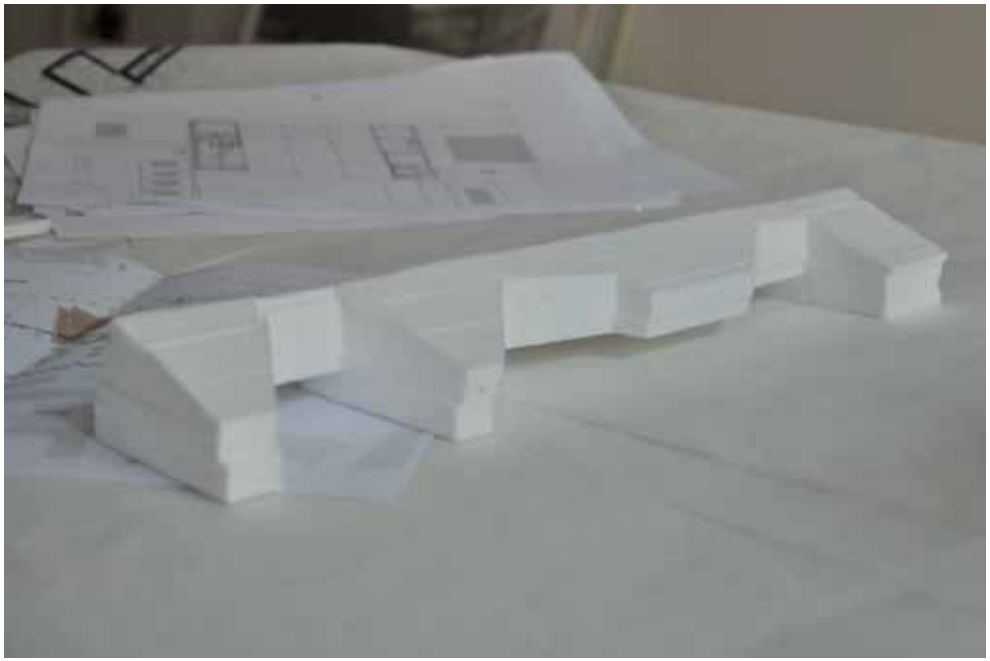
From the mapping 2: vegetation type, it shows there are many existing trees on the site. Inspired by Luyeyuan stone sculpture museum designed by Chinese architect Liu Jiakun, with highly preservation of the existing trees, my intention here is not only to integrate the new building into the ambient environment and avoid cropping down existing plants, but also to interpret the building as a tree, making it a coherent route / space from outside to inside. Thus, the initial architectural concept is to lift up the main volume with minimal functions of coffee, reception hall, multi-functional room on the ground floor, as the experience of being under the tree. Reading section for adults and children is considered in the upper floors. The interior of the upper volume tends to have different hierarchies of heights, as the experience of living inside the tree-crown.

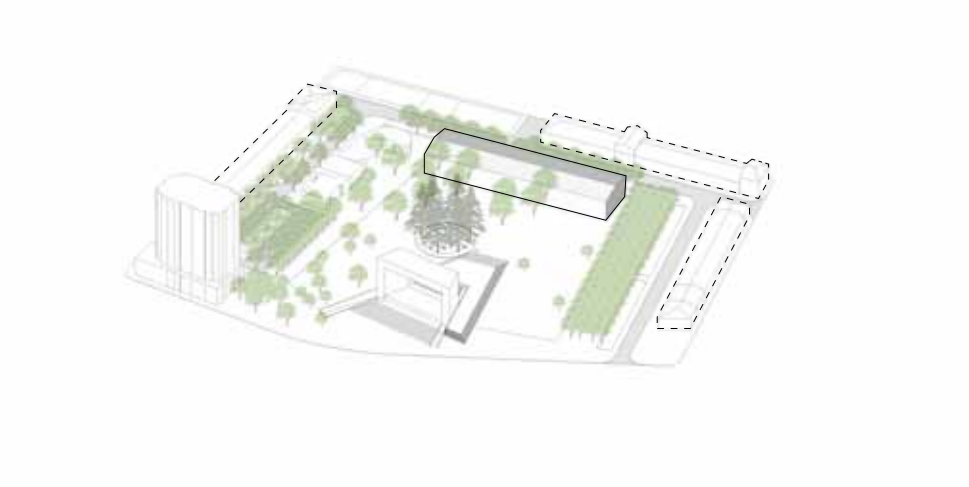


Volume study

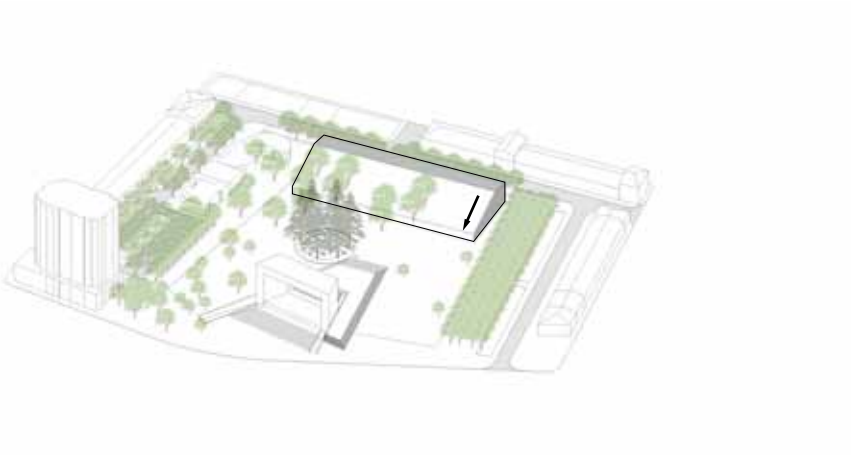
Based on the previous analysis and concept, a volume study is conducted to explore the conceptual design. As the new building is sitting at the south edge of the square, with one regular façade facing to the other side of the street, the inner side of the facade becomes more dynamic in response to the trees.



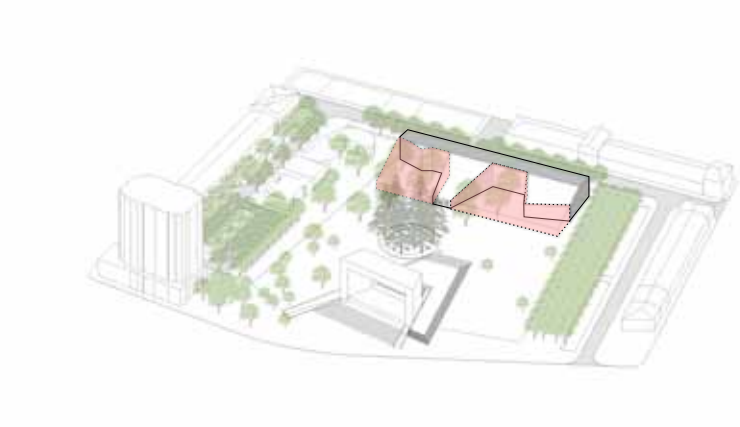




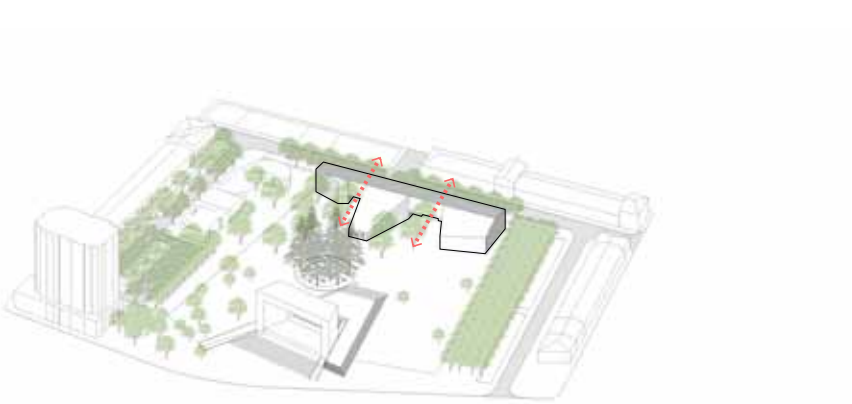
1. derive the volume from ambient buildings with double pitched roof



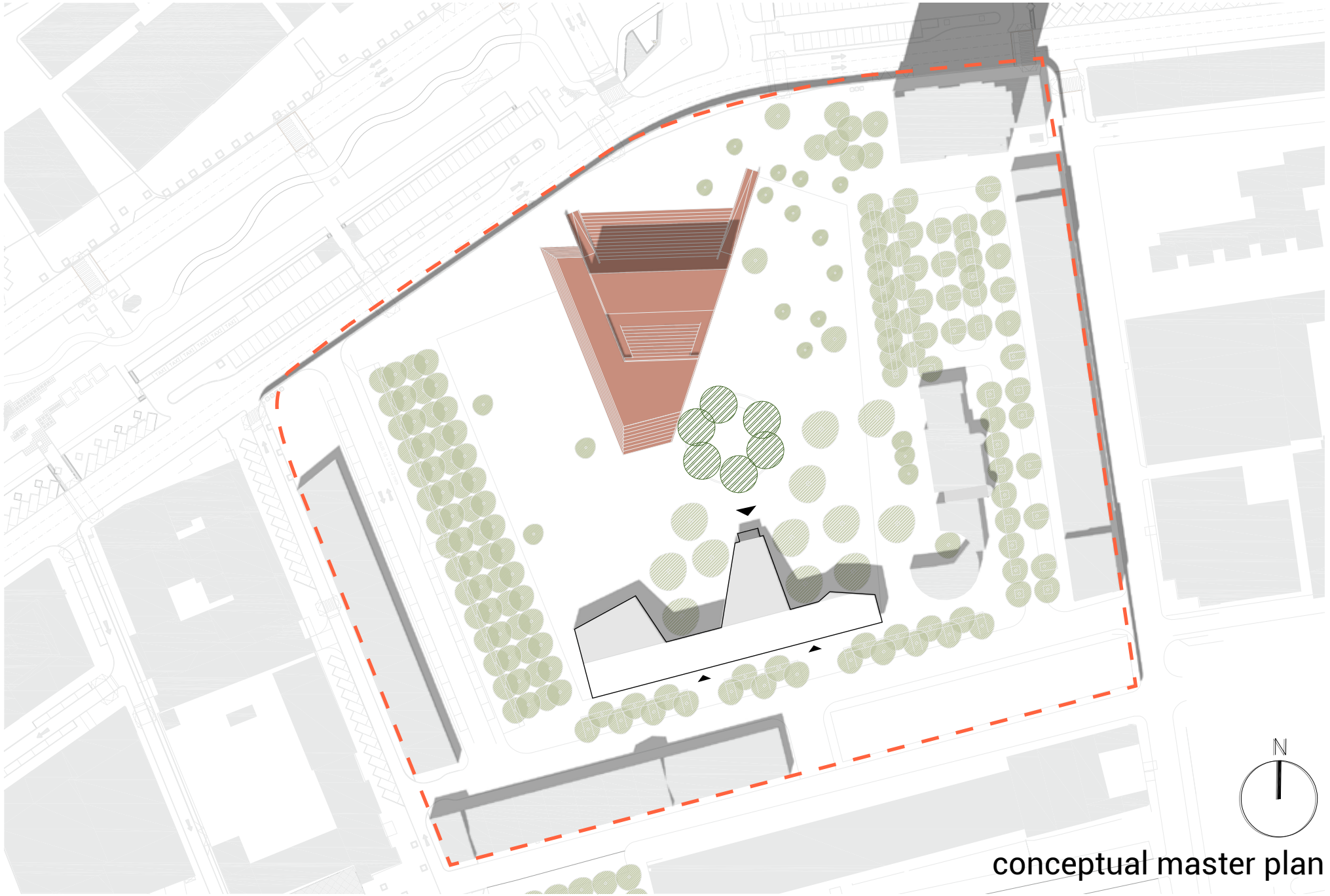
2. extrude one side of the volume to get in touch with trees



3. remove some parts of the volume where the existing trees planted



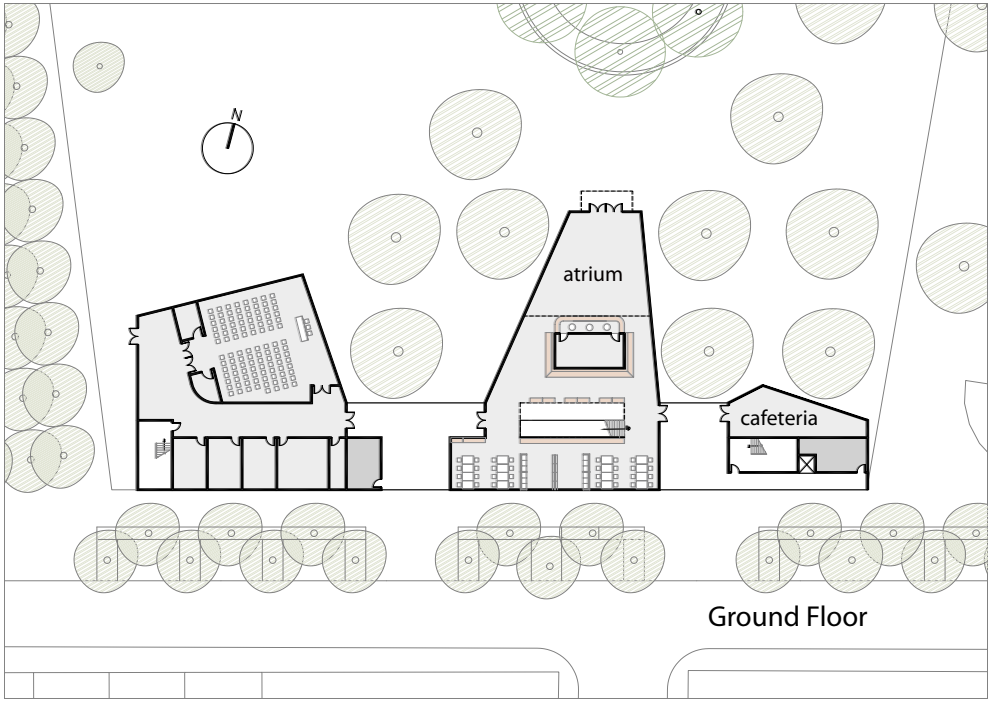
4. creating public access in the ground across the volume from one side to another



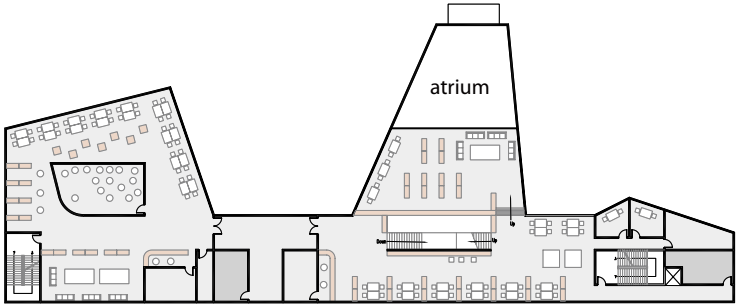
conceptual master plan

Conceptual layouts

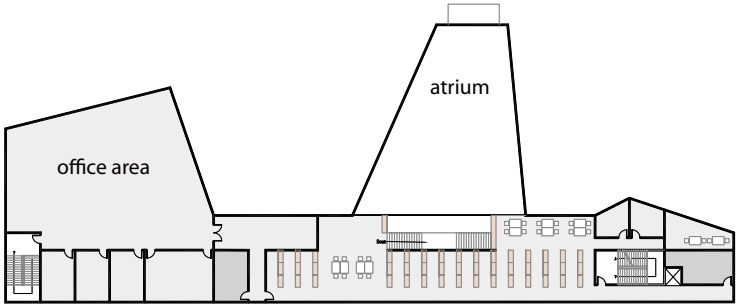
The conceptual layout was presented during the midway critique. Building function is mainly arranged individually as three parts on the ground floor, respectively for conference, cafeteria and the main library function in the middle. With two accesses through the building freely, the main entrance is yet located at the cente, in between those threes.



Ground Floor



First Floor

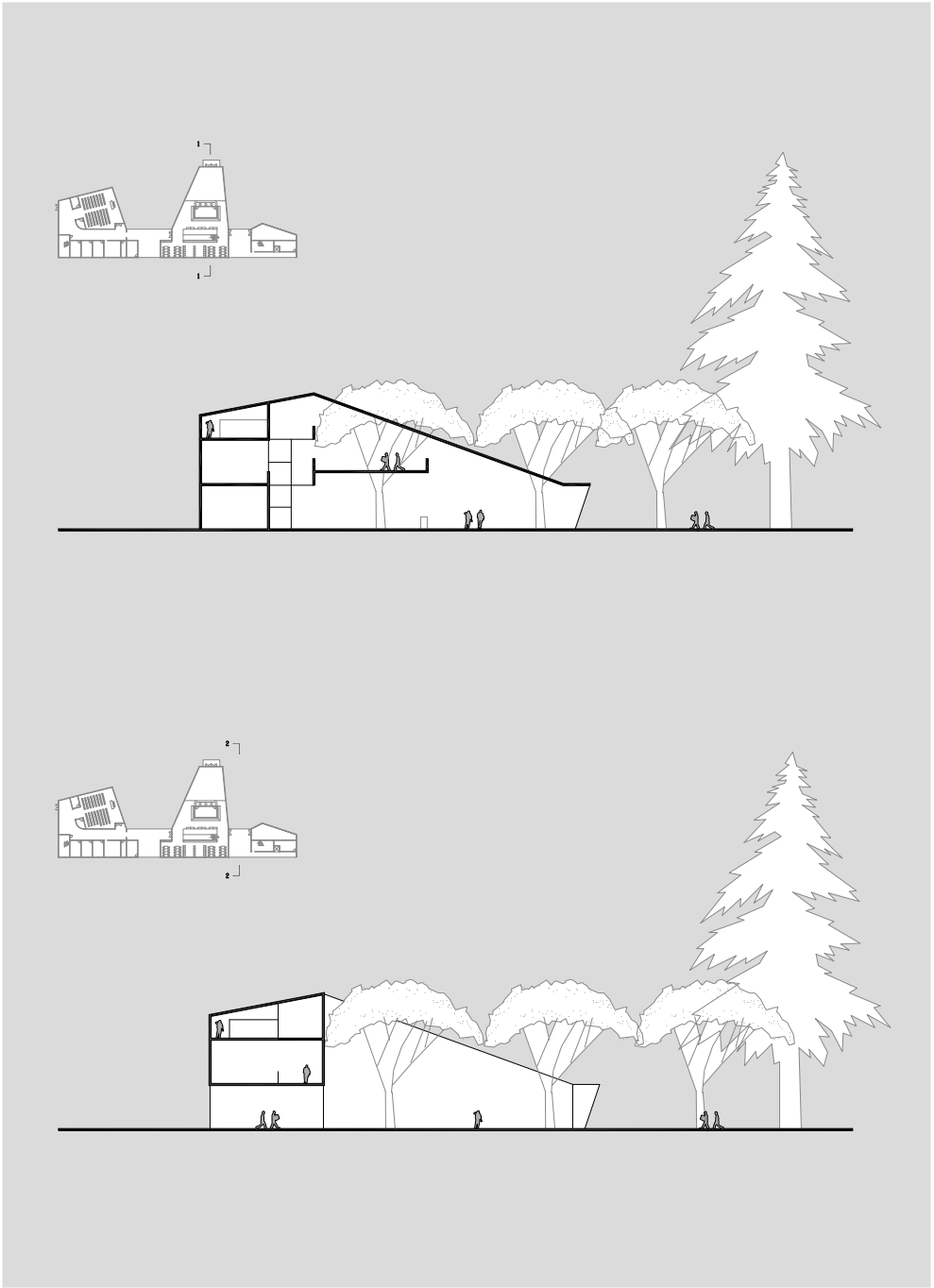


Second Floor

Conceptual section

The conceptual section shows the main reading hall is in a three-floor-height open space, underneath of the big pitched roof. Just as the concept suggested human's engagement with trees, the library here provides people with different characters to experience the nature within different floors.

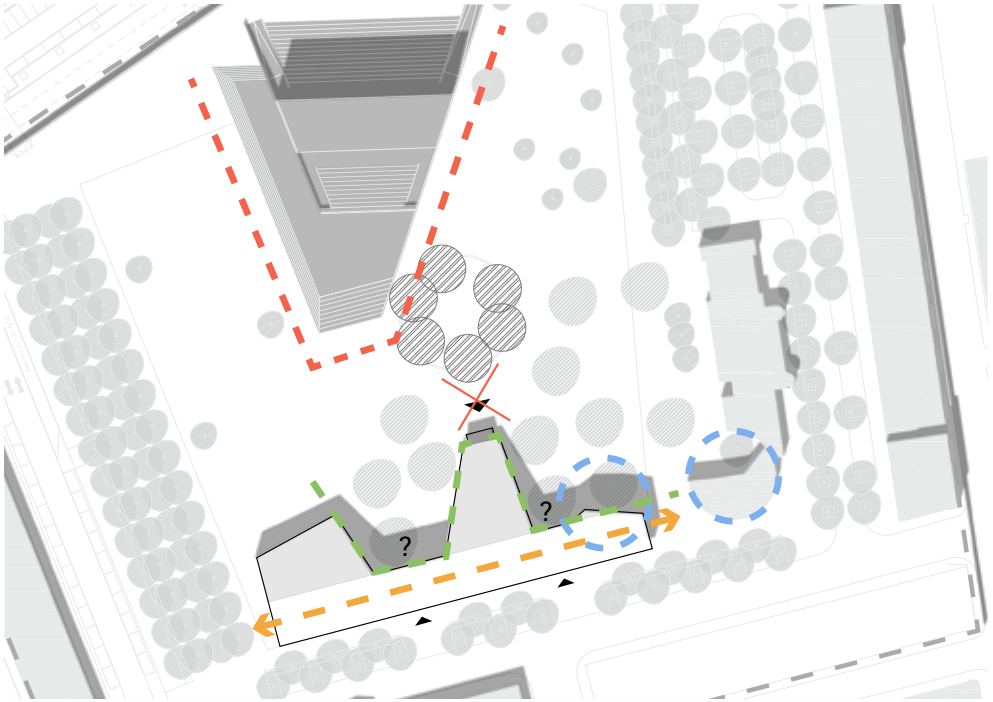
In section 2, it shows a clear ground access from one side to another. This is hence as to create more connections in the context and activate the use of Largo Jose Afonso square.

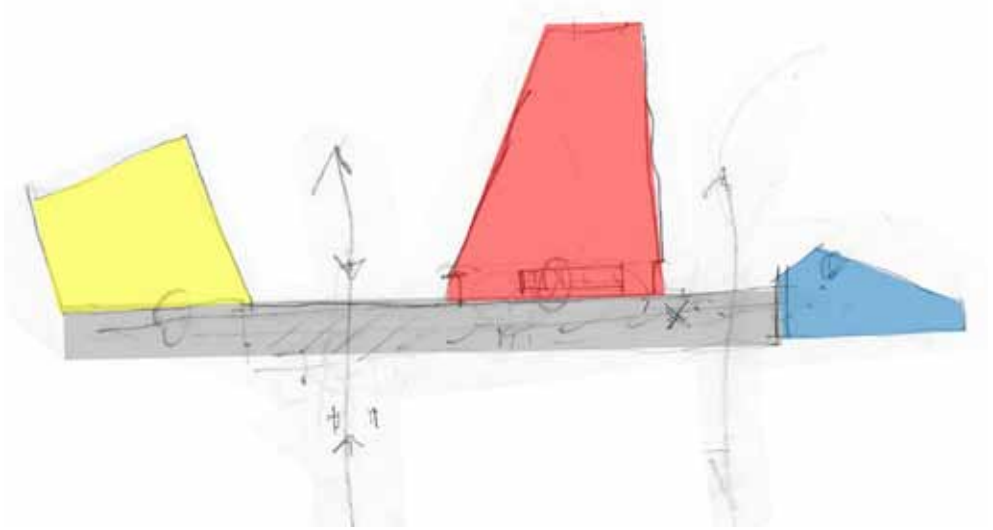


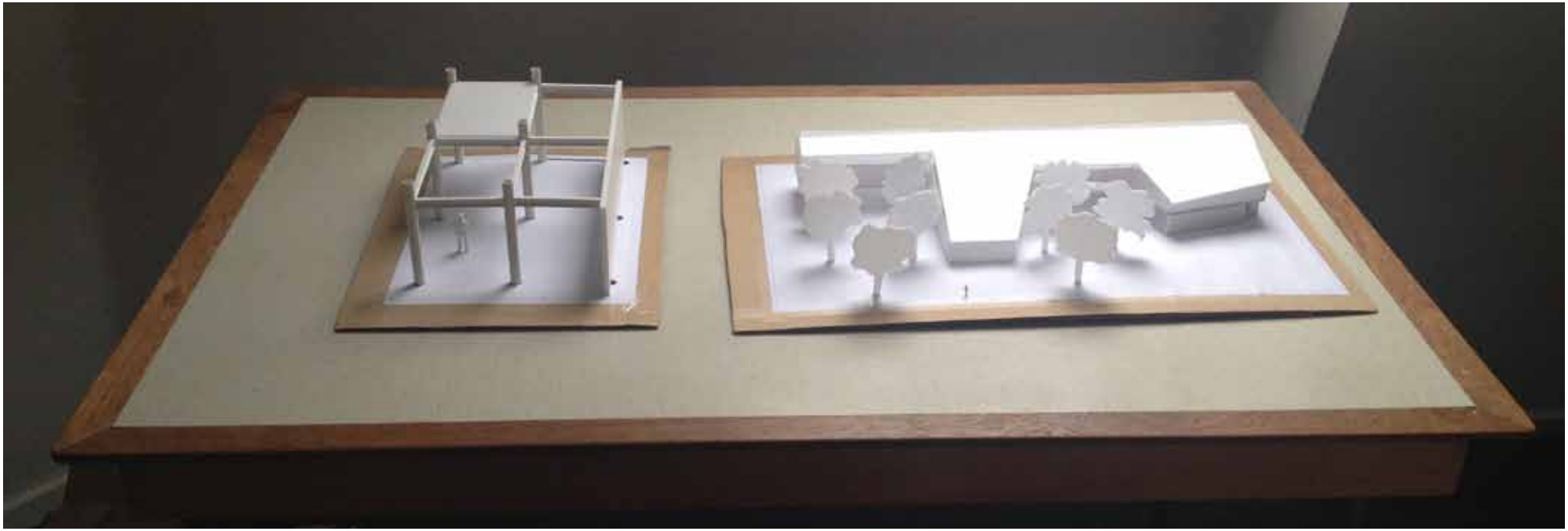
critique from mid-way

The critique during the mid-way presentation was focus on the function arrangement, pointing out the problem as the main entrance of this building. The reason is being there have been two entrances already for ground circulations, and this main entrance seems a bit unnecessary but also disturbs the calmness of the reading room.

Taking this critique as well as some approvals for this conceptual proposal, the mid-way presentation serves as a division bringing the project into further development.

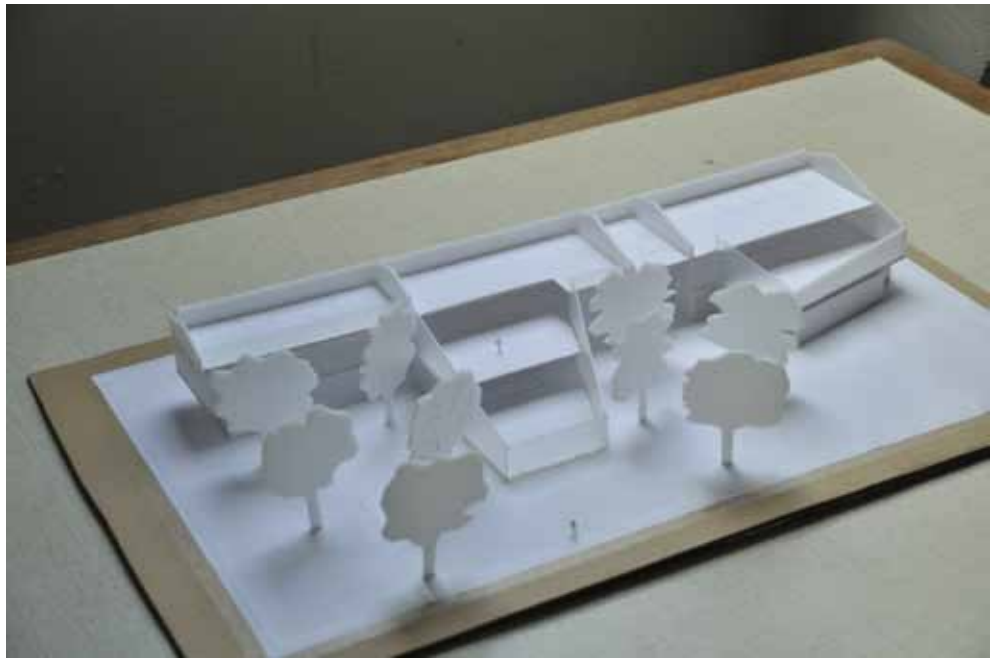






Design development

Under the design development, the study mainly results in two parts: 1), adujst the function at the same time providing architectural quality; 2), defining the typology of the structure, element dimension and how its influence to spatial efforts, which is the core of the theme of tectonic. Physical model making, computer analysis along with the hand sketching serves parallelly as the tools for design.

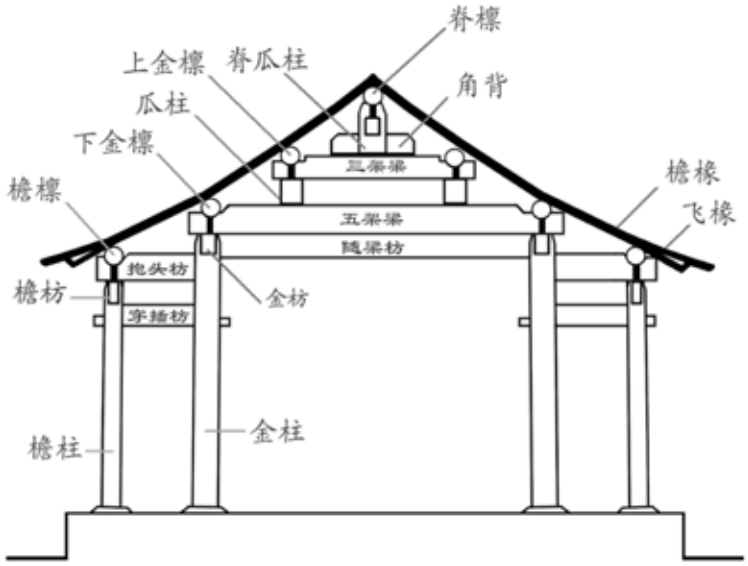


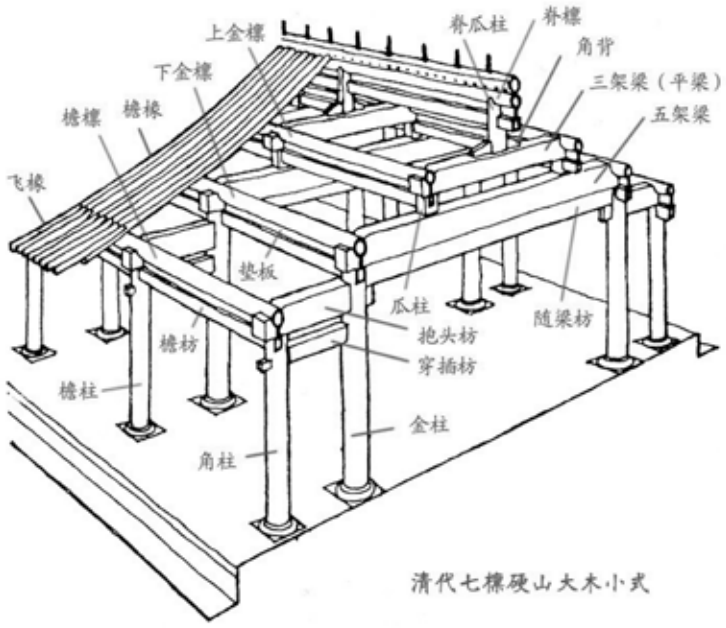
Chinese traditional architecture

As Frampton stated, : 'Utzon's drive towards additive prefabricated form was inspired by traditional Chinese architecture, wherein sculptural roofs with varying pitches are invariably arrived at not through the use of trusses as is common in western building practice but rather by an arrangement of stacked beams stepping up towards the ridge of the roof (Frampton, 1995)'

Under the study of transcultural influence by Utzon, the intension here to learn from Chinese traditional architecture is here generated. In such a stair-case like structure exposed from interior, the emphasis of the big pitched roof is therefore gained, and principally, it provides the possibility to achieve additive architecture.

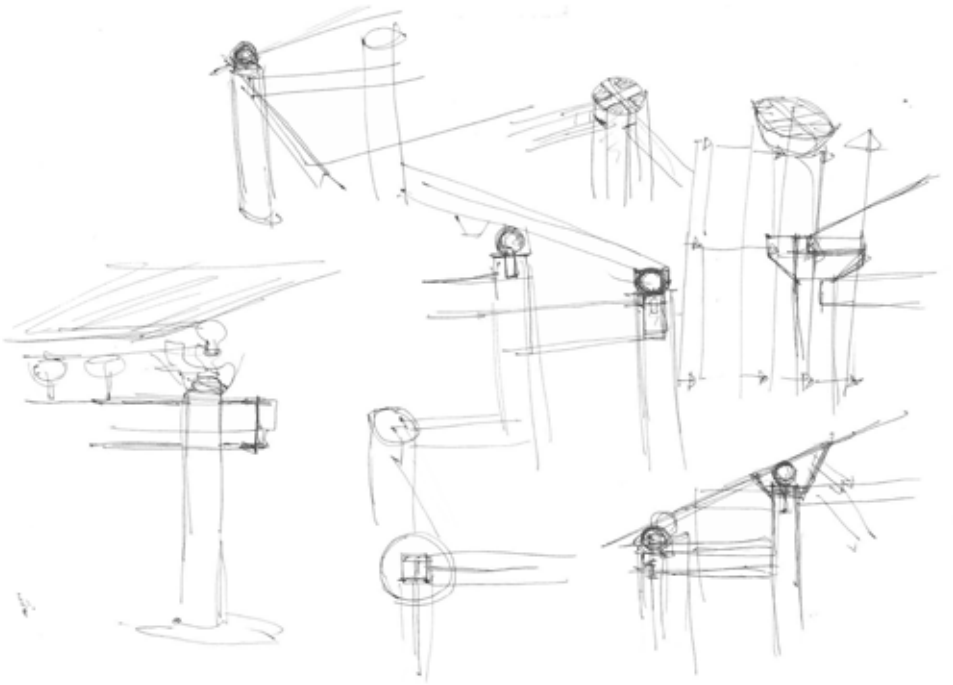
fig, Jorn Utzon's sketch shows his impression of Chinese traditional architecture: a big roof floating above the platform

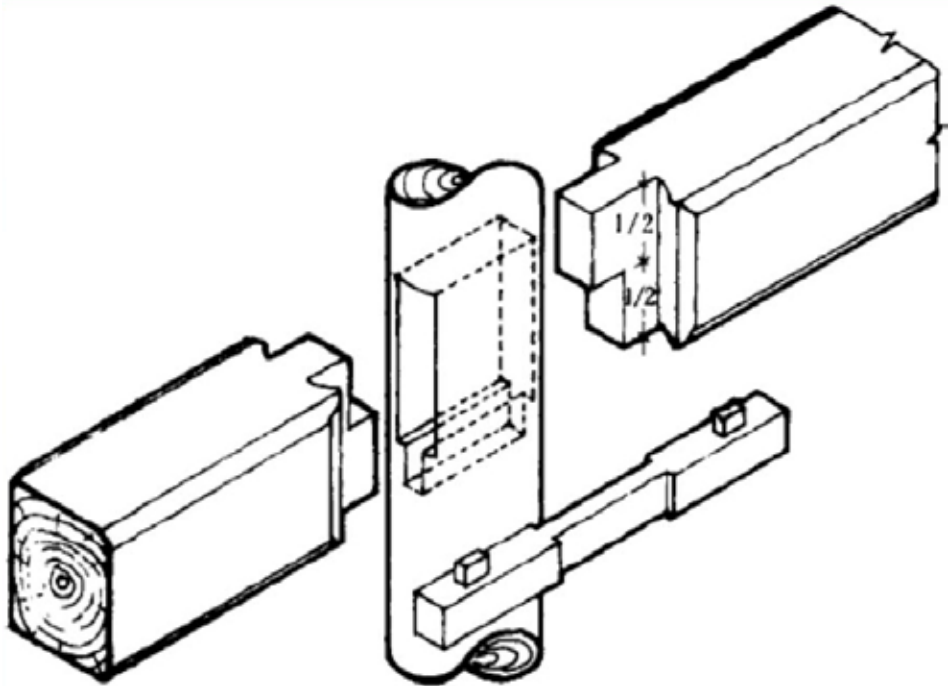




Joint detail of column and beam

Timber as the main material is widely applied in the traditional Chinese architecture. Commonly with the round column and square profile beam, intersected in-between each other. While in this context, the effort is to avoid the similarity of appearance, yet still in its principle application. The use of different material combinations such as concrete and steel is preferred.

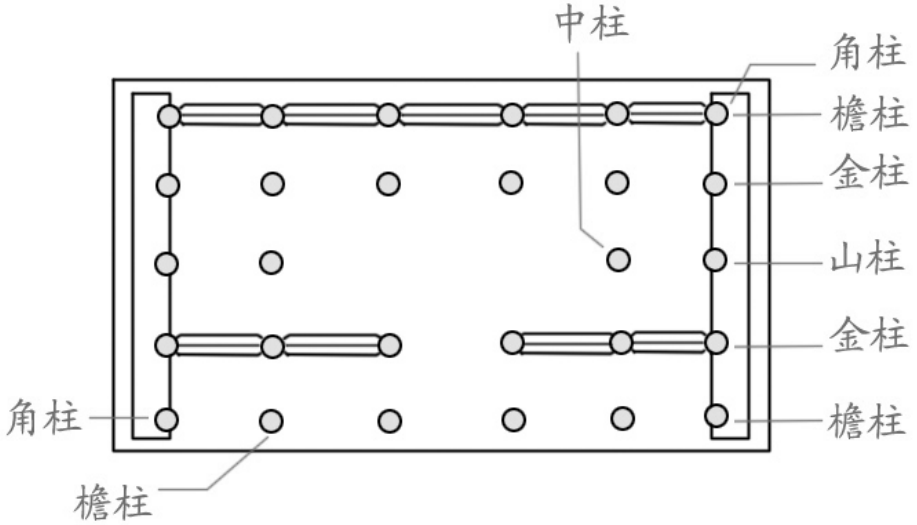


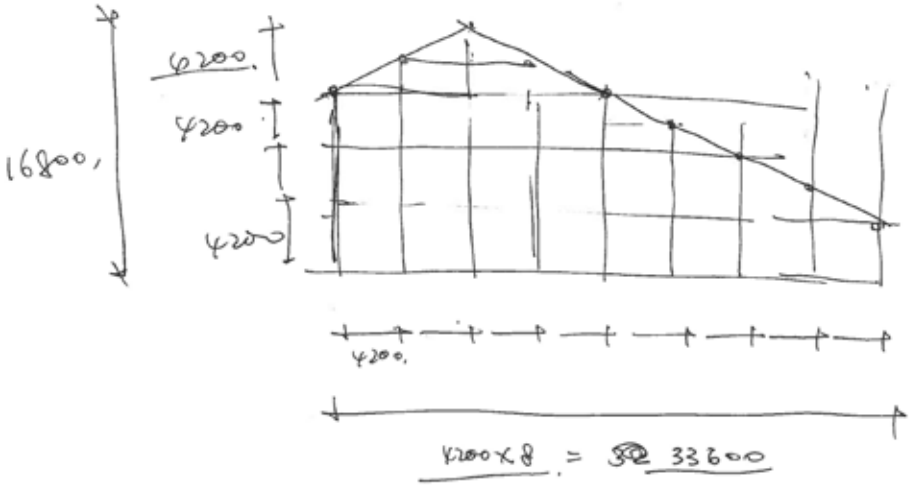


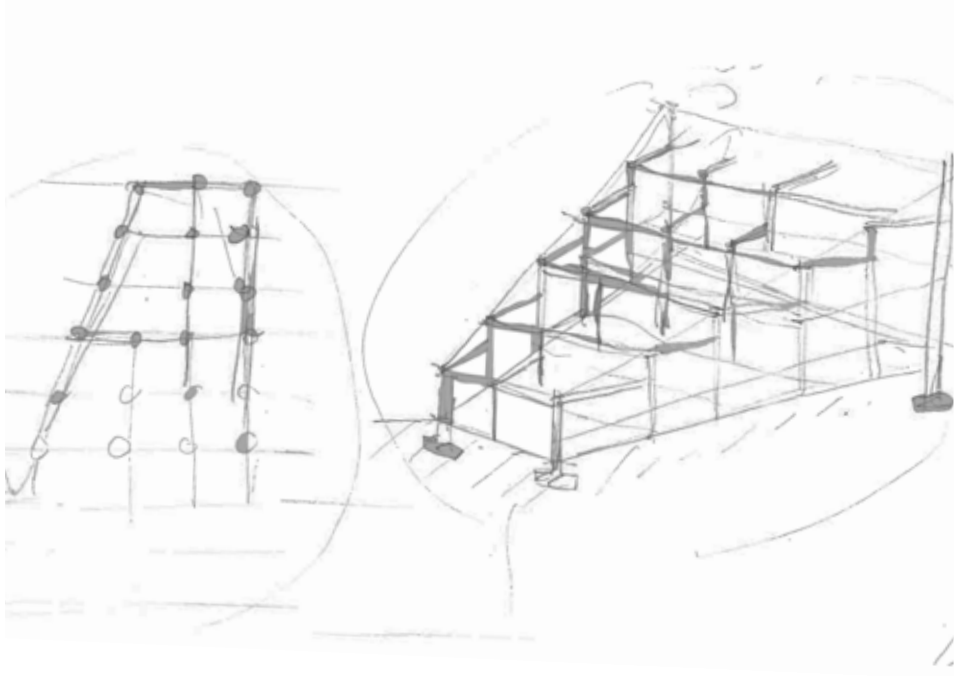
Modular grid

Another principle for traditional Chinese architecture is in its modular system. Traditionally, the dimension of the layout is strictly defined according to different types of the building as well as the owner's social position. According, the dimension of different elements is also defined, which could be understood as an interesting culture value, also as to apply additive system more efficiently.

In here, the modular grid is applied not only in plan, but also in section. A conceptual idea for additive architecture is emerged.



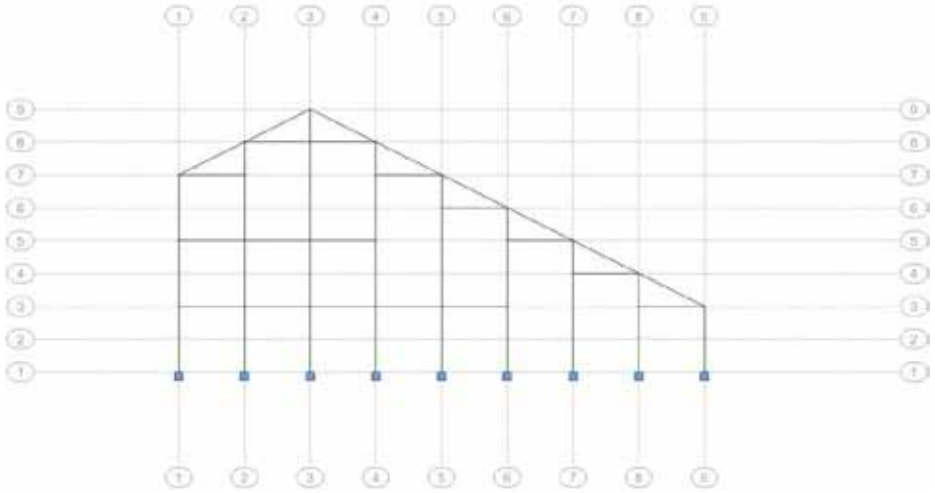




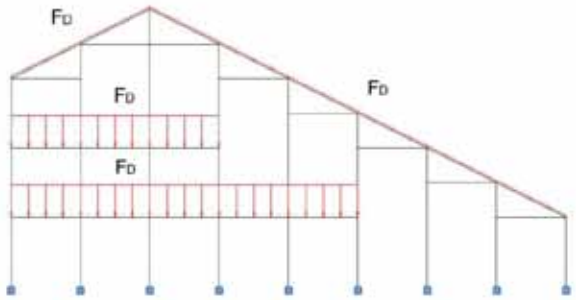
Structural expression

Consequently, three types of combination is tested graphically to see its expression on appearance. There are: option 1 with concrete beam and column, option 2: I-profile steel beam and concrete column with hap joint, option 3: I-profile steel beam and concrete column with minimal joint.

Considering Setubal as an industry city previously, a more historic and industrial like character is preferred in here. Also within the principle of Chinese traditional architecture, different element was articulated as its structural forces. Therefore, option 3 is chosen as further developed and applied calculation on it.



Figure, longest section in the building



Figure, roof and desk load in the building

- ## Dead load

  The structure self-weight is being automatically calculated in the Robot.

1. Roof layer:

- Zinc density: 7200 kg/m^3

  Zinc layer:

  $= 7200\ kg/m^3 \times 6{,}3m \times 0{,}7 \times 10^{-3}m \times 9{,}8\ N/kg = 0{,}31\ kN/m$

- CD Grade Plywood substrate:

  Plywood density: 700 kg/m^3

  Plywood substrate layer:

  $= 700\ kg/m^3 \times 6{,}3m \times 19 \times 10^{-3}m \times 9{,}8\ N/kg = 0{,}82\ kN/m$

- Acoustic panel ceiling: 48 kg/m^3 or 96 kg/m^3

  Panel density:

  $= 96\ kg/m^3 \times 6{,}3m \times 102 \times 10^{-3}m \times 9{,}8\ N/kg = 0{,}60\ kN/m$

- Thus, roof layer:

  $= 0{,}31\ kN/m + 0{,}82kN/m + 0{,}60kN/m = 1{,}74kN/m$

2. Floor layer:

- CD Grade Plywood substrate:

  Plywood density: 700 kg/m^3

  Plywood substrate layer:

  $= 700\ kg/m^3 \times 6{,}3m \times 19 \times 10^{-3}m \times 9{,}8\ N/kg = 0{,}82\ kN/m$

- Concrete desk:

Concrete density: 2400 kg/m^3

$= 2400 kg/m^3 \times 6{,}3m \times 0{,}1m \times 9{,}8N/kg = 14{,}82\ kN/m^2$

- Acoustic panel ceiling: 48 kg/m^3 or 96 kg/m^3

  Panel density:

  $= 96\ kg/m^3 \times 6{,}3m \times 102 \times 10^{-3} m \times 9{,}8\ N/kg = 0{,}60\ kN/m$

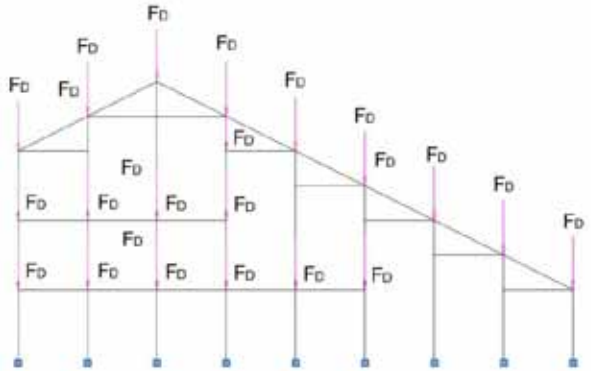
- Interior concrete wall:

  The maximum for interior wall

  $= 2400 kg/m^3 \times 4{,}2m \times 0{,}1m \times 9{,}8N/kg = 9{,}88\ kN/m$

- Thus, the uniform load for roof layer:

  $= 0{,}82kN/m + 14{,}82kN/m + 0{,}60kN/m + 9{,}88kN/m = 26{,}12kN/m$



Figure, beams in another direction load in the building

3. Beam

- IPE 400 steel beam in another direction rested on the column within a span:

  IPE 400 nominal weight: 66,3kg/m

  Notable force on a column:

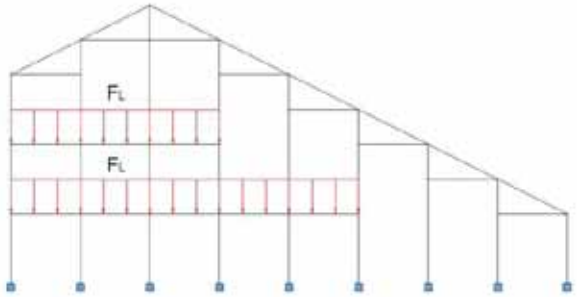
  $= 66{,}3kg/m \times 6{,}3m \times 9{,}8N/kg = 4{,}1kN$

- UPE 360 in other direction weighted on the load bearing wall within a span:

  UPE 400 nominal weight: 61,2kg/m

  Notable force on the connection:

  $= 61{,}2kg/m \times 6{,}3m \times 9{,}8N/kg = 3{,}78kN$



Figure, live loads in the building

- Live load:

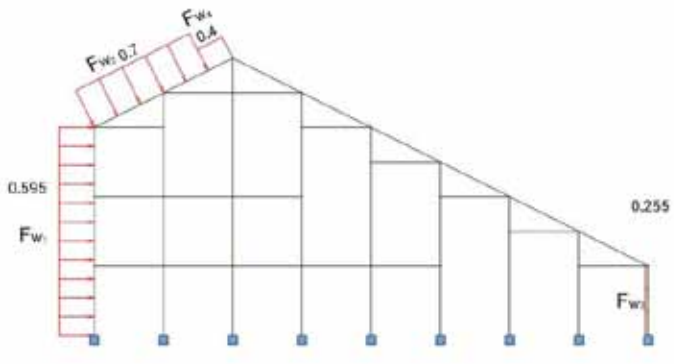
According to DS-EN 1991-1-1-2007, Categories of use, C5 where areas susceptible to large crowds has been taken into consideration as $5\ \mathrm{kN/m^2}$; E1 where areas for storage of books, is 7,5 kN/$\mathrm{m^2}$

Therefore, the extreme case will be:

$q_k = 5\mathrm{kN/m^2} + 7{,}5\ \mathrm{kN/m^2} = 12{,}5\ \mathrm{kN/m^2}$

For each floor, the live load calculated as:

$$F_L = 7{,}5\ \mathrm{kN/m^2} \times 6{,}3\mathrm{m} = 47{,}25\ \mathrm{kN/m^2}$$



Figure, wind loads affect the building

- Wind load:

For the peak velocity pressure of wind $q_p(z)$, according to DS-EN 1991-1-4-2007

$$q_p(z) = \left(1 + \frac{7}{\ln\left(\frac{z}{z_0}\right)}\right)\frac{1}{2}\rho\left(v_b k_r \ln\left(\frac{z}{z_0}\right)\right)^2$$

Where:

$k_r = \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07}$ (terrain factor depending on the roughness length)

$z_{0,} = 0{,}05\mathrm{m}$, (roughness length)

$z_0 = 0{,}05\mathrm{m}$ depends on the terrain category when area with low vegetation such as grass and isolated obstacles (trees, buildings)

$\rho = 1{,}25\ \mathrm{kg/m^3}$ (air density)

$z = 4{,}2\mathrm{m} \times 4 = 16{,}8\mathrm{m}$ (building height)

$v_b = 24\mathrm{m/s}$ (air velocity)

So, in this case:

$q_p(z) = 0{,}968\ \mathrm{kN/m^2} \approx 1\mathrm{kN/m^2}$

For the effected surface, wind as uniform load:

$F_W = 6{,}3\mathrm{m} \times 1\mathrm{kN/m^2} = 6{,}3\mathrm{kN/m}$

It of course has to consider and compare with different cases and wind directions in reality, but in here, only the critical case that maximum wind load effect the cross section is considered for wind load calculation.

According to the Eurocode, values of external pressure coefficients for façades and roof has been calculated and applied in Robot FEM calculation.

Factors as follow:

$F_{w1} = 0{,}595$ (D zoon façade in windward side)

$F_{w2} = 0{,}7$ (G zoon roof in upwind face)

$F_{w3} = 0{,}255$ (E zoon façade in leeward side)

$F_{w4} = 0{,}4$ (H zoon roof in upwind face)

- FEM calculation

This FEM calculation proves that the module with the dimensions 21x28x9m is stable in a cross section. A two-dimensional static system represents one of two frames in the longitudinal direction of the vierendeel truss module. The joints are to be conceived as rigid towards moment forces unlike a triangular truss, in which forces are non-eccentric to the joints.
Load combinations are according to Eurocode DS-EN-1990 and consequence class CC3 is chosen as in this case for a public library.

- Data

Beam: IPE 400
Material: Steel S275

Column: round reinforcement concrete column with 500 mm in diameter
Material: C25

For the chosen steel beam profile IPE 400 with S450,

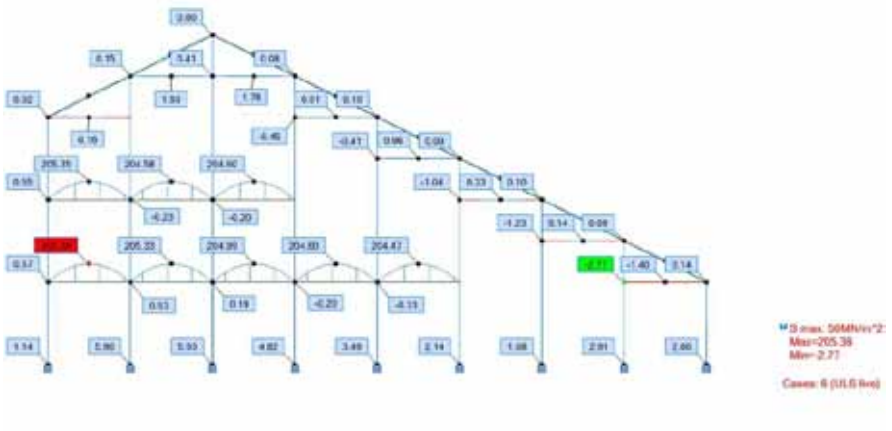
$$f_{yd} = \frac{f_y}{\gamma_s}$$

Where
f_y = 275MPa (characteristic value of S450)
γ_s= 1,10 (partial coefficient)

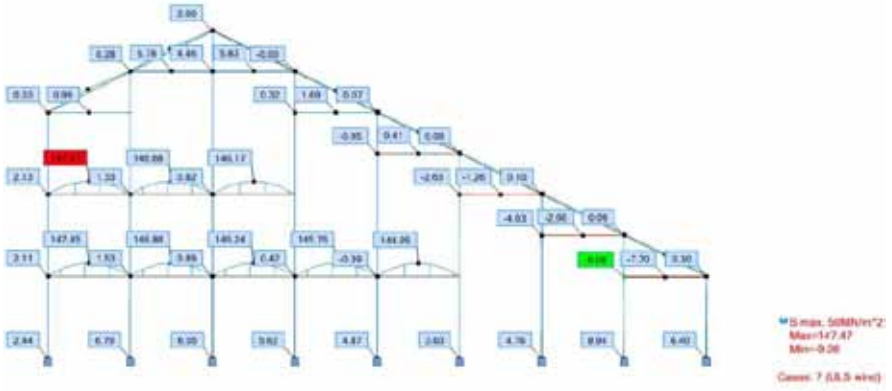
So, the design value $f_{yd} =$ 250MPa

- Load combination:

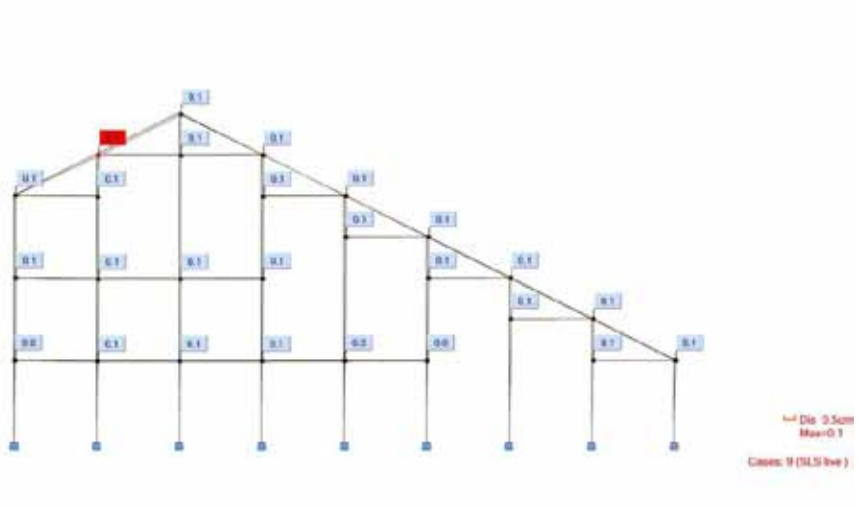
Three different load combinations of Ultimate Limit State and two load combinations of Serviceability Limit State are applied to the structure in Robot, considered as degree of safety in class CC3 for the building.



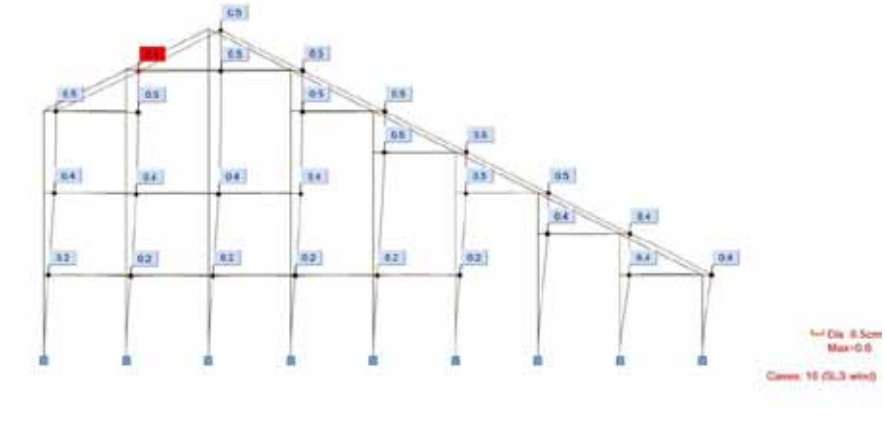
Figure, ULS live load dominant stage: maximum stress 205,38 MPa in the beam



Figure, ULS wind load dominant stage: maximum stress 147,47 MPa in the beam



Figure, SLS live load dominant stage: maximum deformation 1mm in the beam



Figure, SLS wind load dominant stage: maximum deformation 6mm in the beam

The Ultimate Limit State load combinations are used in the structure calculation to see the material does not fail in different load dominant case. Thus, the maximum stress of the structure element must be lower the design value, $f_{yd} = 250MPa$.

- Live load dominating:
  $1{,}1 * F_D + 1{,}5 * 1{,}1 * F_L + 0{,}45 * 1{,}1 * Fs + 0{,}45 * 1{,}1 * F_W$
- Wind load dominating:
  $1{,}1 * F_D + 0{,}9 * 1{,}1 * F_L + 1{,}5 * 1{,}1 * F_W$

The highest stress recorded is under the live load dominant load combination at 205.38MPa < 250MPa which is acceptable.

The figures show the weak points of the structure as the largest stress occurs in the beam where loads 1st and 2nd floor. As the architectural expression required that all the beams in unique dimension, it is worth remarking that those beams with highest stress could use higher material characteristic value f_y to ensure the entire structural safety.

Load combination for the SLS:

- Live load dominating:
  $1 * F_D + 1 * F_L + 0{,}3 * F_W$
- Wind load dominating:
  $1 * F_D + 0{,}5 * F_L + 1{,}5 * F_W$

At the service limit state the deflection is considered and must be less than
L / 300 = 147000mm / 300 = 490mm

The deformation of SLS live load dominant stage for 1mm $<$ 490mm;
The deformation of SLS wind load dominant stage for 6mm $<$ 490mm.

Therefore, the result is acceptable.

- largest beam span calculation:

Beam span distance: 13,86m
As previous calculation, IPE 400 steel beam in another direction rested on the column within a span:
Notable force on a column:
$= 66{,}3\text{kg/m} \times 6{,}3\text{m} \times 9{,}8\text{N/kg} = 4{,}1\text{kN}$

The largest span beam located in the reading room only loads for roof layer.
Roof layer:

- Zinc density:
  $= 7200\ \text{kg/m}^3 \times 4{,}7\text{m} \times 0{,}7 \times 10^{-3}\text{m} \times 9{,}8\ \text{N/kg} = 0{,}23\ \text{kN/m}$

- CD Grade Plywood substrate layer:
  $= 700\ \text{kg/m}^3 \times 4{,}7\text{m} \times 19 \times 10^{-3}\text{m} \times 9{,}8\ \text{N/kg} = 0{,}61\ \text{kN/m}$

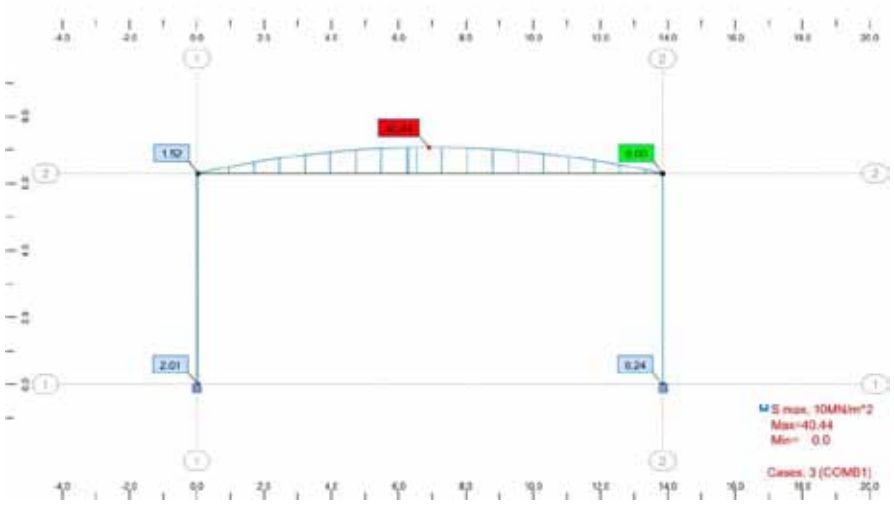
- Acoustic panel ceiling:
  $= 96\ \text{kg/m}^3 \times 4{,}7\text{m} \times 102 \times 10^{-3}\text{m} \times 9{,}8\ \text{N/kg} = 0{,}45\ \text{kN/m}$

- Thus, roof layer:
  $= 0{,}23\ \text{kN/m} + 0{,}61\text{kN/m} + 0{,}45\text{kN/m} = 1{,}30\text{kN/m}$

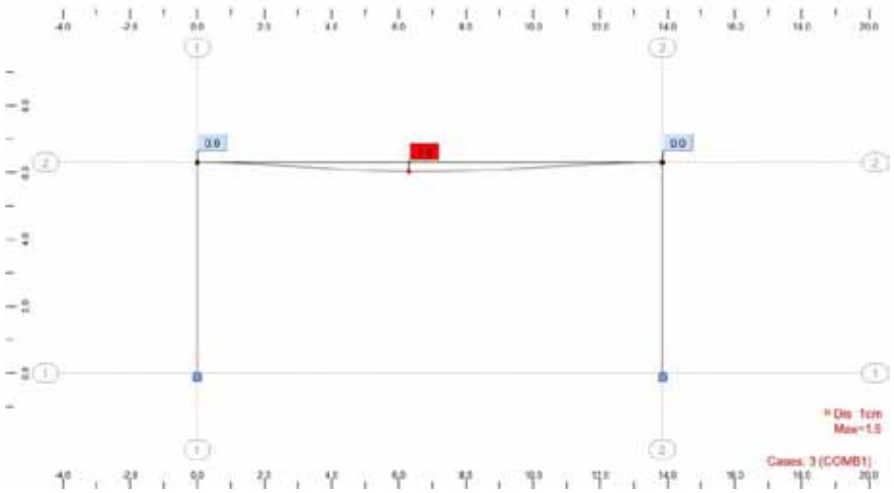
Applying the below loads into the structure, maximum stress of beam 40,44MPa, is below the design value 250MPa.

While in the deformation, $19\text{mm} < \frac{\text{L}}{300} = \frac{13860}{300}\text{mm} = 46{,}2\text{mm}$

Therefore, the result is acceptable.

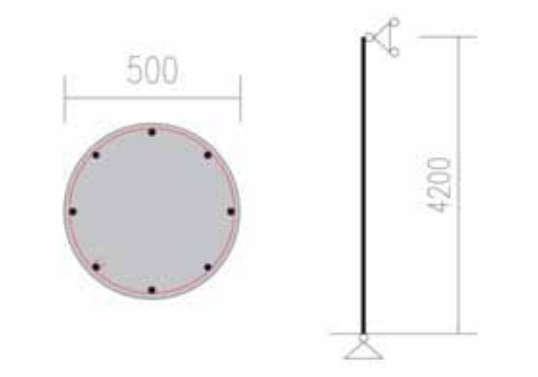


Figure, SLS live load dominant stage: maximum deflection 1mm in the beam



Figure, SLS live load dominant stage: maximum deflection 1mm in the beam

- reinforcement concrete column hand calculation



Figure, column plan section and elevation

From the Robot calculation, the maximum reaction for a column is 1020kN, where the column in the group floor next to the load bearing wall against wind load.

The following hand calculation is conducted in order to exam the dimension of a column. Equation and factor based on Eurocode and Teknisk Stabi.

- Characteristic values:
  Concrete material: C25 $f_{yk} = 500\ \text{MPa}$

$$f_{cd} = \frac{25}{1{,}4} = 17{,}9\ \text{MPa}$$

$$f_{yd} = \frac{500}{1{,}2} = 417\ \text{MPa}$$

$$\alpha = \frac{E_{sd}}{E_{cd}} = \frac{E_{sd}\varepsilon_{c1}}{f_{cd}} = \frac{200 \times 2{,}1}{17{,}9} = 23$$

The reinforcement ratio, with 8 ø 20 steel:

$$\rho = \frac{A_{sc}}{A_c} = \frac{2513}{196350} = 1{,}30\% \begin{cases} \geq 0{,}2\% \\ \leq 4{,}0\% \end{cases}$$

where $A_{sc} = 8 \times \pi \times \left(\frac{20}{2}\right)^2\ \text{mm}^3 = 2513\ \text{mm}^3$

$$A_c = \pi \times \left(\frac{500}{2}\right)^2\ \text{mm}^3 = 196350\ \text{mm}^3$$

Slenderness ratio:

$$\lambda = \frac{l_0}{i} = \frac{4200 \times 4}{500} = 33{,}6$$

Elastic modulus:

$$E_{ocr} \leq \begin{cases} 1000 f_{cd} \\ 0{,}75 E_{cod} \end{cases} = \frac{1000 \times 17{,}9 = 17900}{0{,}75 \times \frac{51000}{1{,}40} \times \frac{25}{25+13} = 18000}$$

In this case, the smaller parameter is chosen as 17900.

Column critical stress and tension reinforcement is calculated as follow:

$$\sigma_{cr} = \frac{f_{cd}}{1 + \frac{f_{cd}}{\pi^2 E_{0cr} \lambda^2}} = \frac{17{,}9}{1 + \frac{17{,}9}{\pi^2 17900} \times 33{,}6^2} = 16{,}13\ \text{MPa}$$

$$\sigma_s = 23 \times 16{,}13 = 371\ \text{MPa} < 417 MPa$$

The load capacity of the column is determined as:

$$N_c = A_c \sigma_{cr} = 196350 \times 16{,}13 \times 10^{-3} = 3167\ \text{kN}$$

$$N_s = A_{sc} \sigma_s = 2513 \times 371 \times 10^{-3} = 932\ \text{kN} < \frac{1}{2} 3167\text{kN}$$

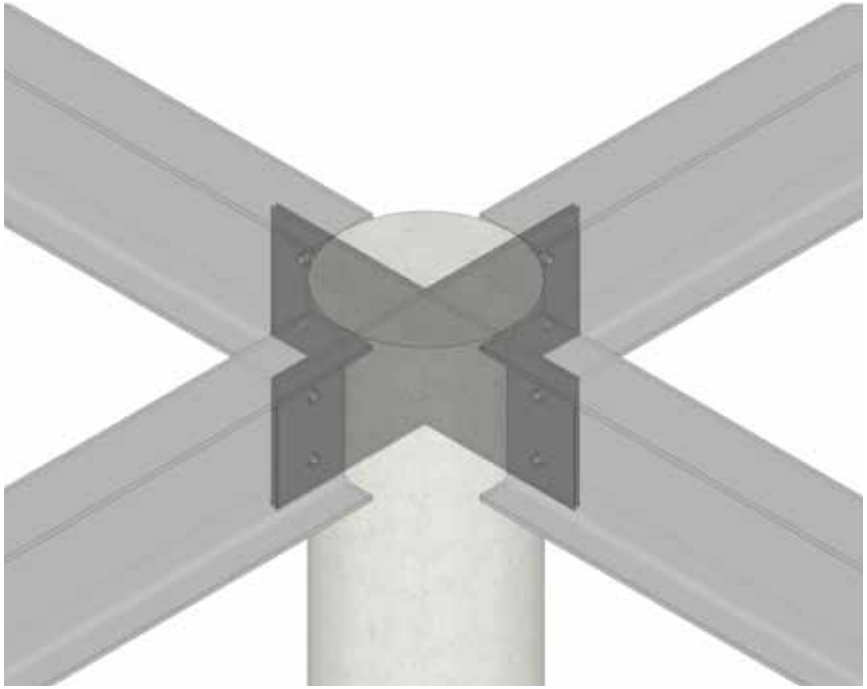
$$N_{cr} = N_c + N_s = 4099\ \text{kN} > 1020\ \text{kN}$$

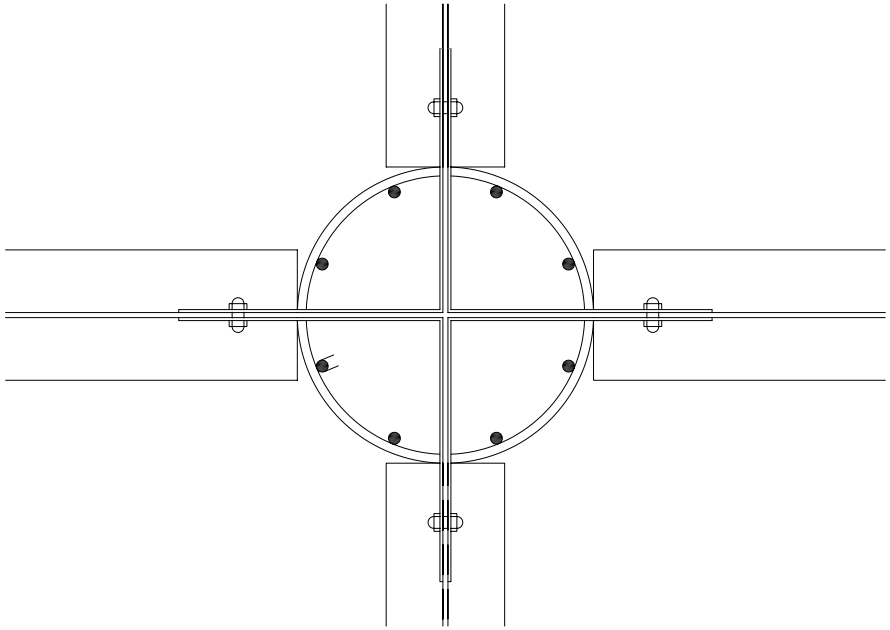
Therefore, the result is acceptable.

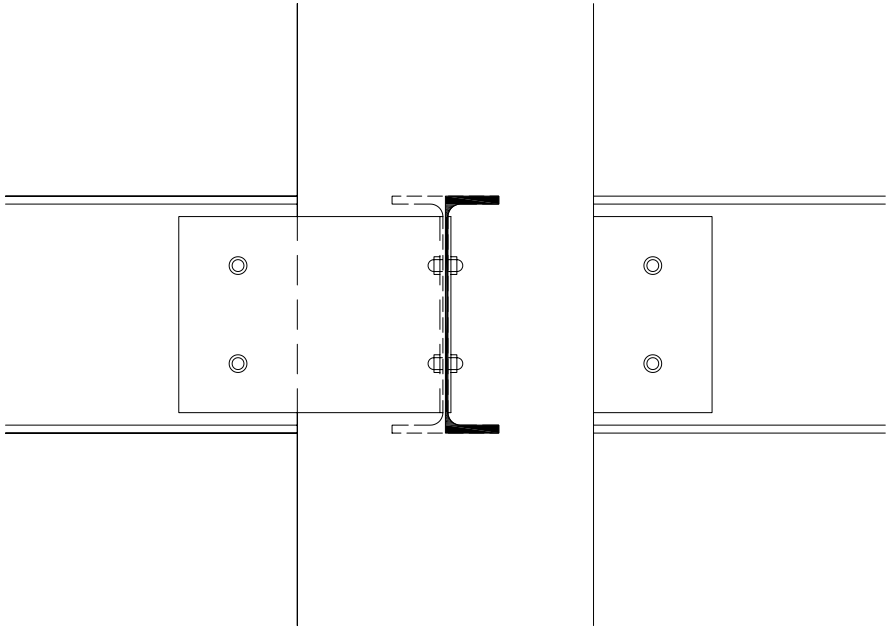
Joint design

The principle of the joint is to insert a metal unit that cast together with concrete column. In this way, the joint will also be able to fit with different angles of the connection of the beam.

As for the joint dimention design, It has to state hereby that the beam will transfer the force through the cross joint to the concrete column and the material of concrete should be able to resist it.

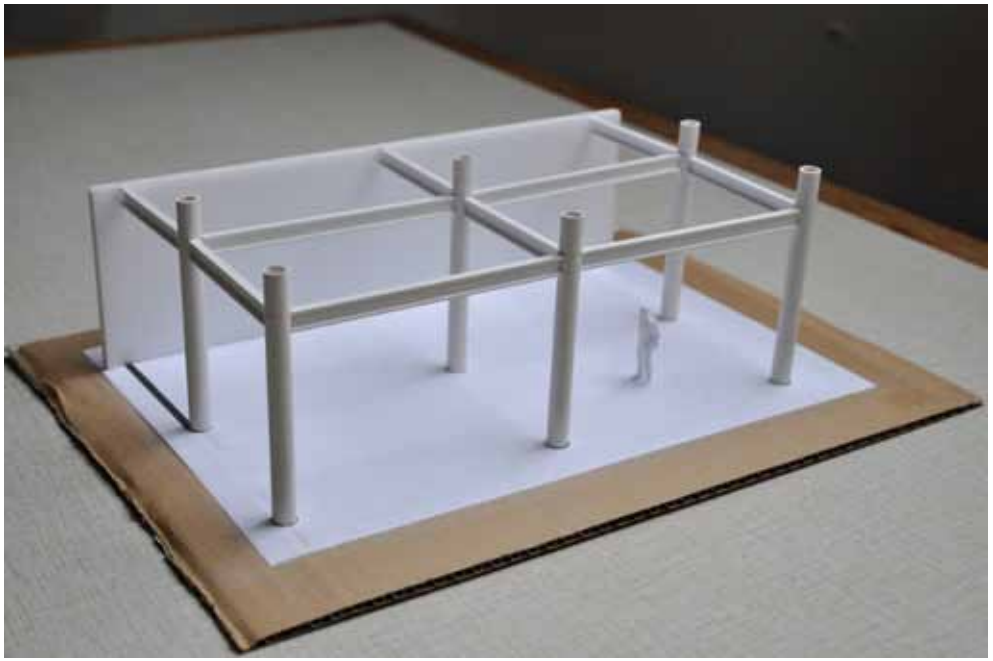


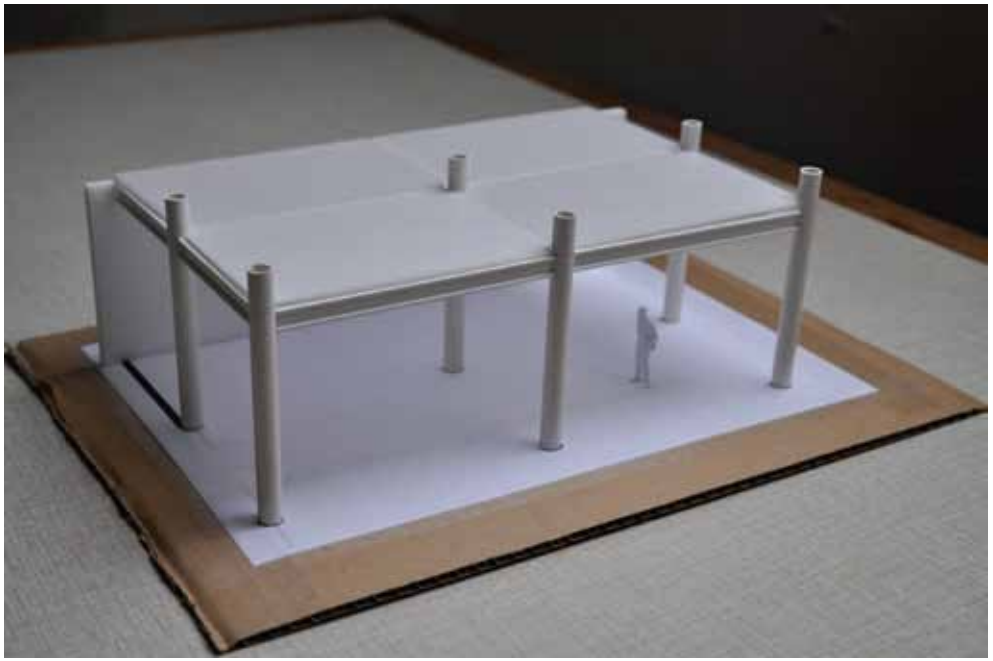




Construction process

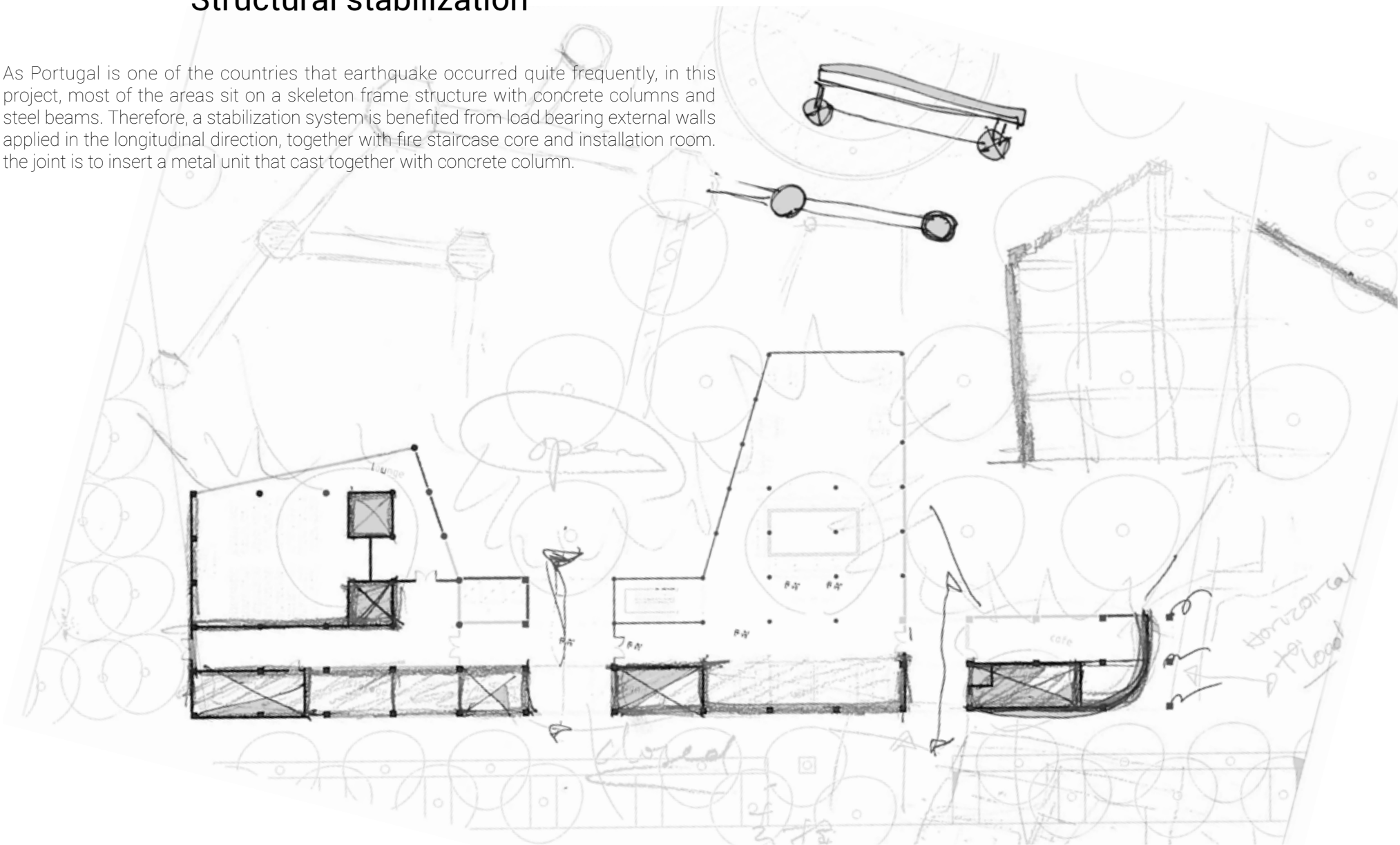
The principle of the construction process is by firstly casting the in-situ concrete column, and then installed the I-profile beams with minimal joint. Based on this Skeletal framework and modular system, prefab concrete slab and timber desk floor, finishing ceilings etc could be able to applied practically and additively.





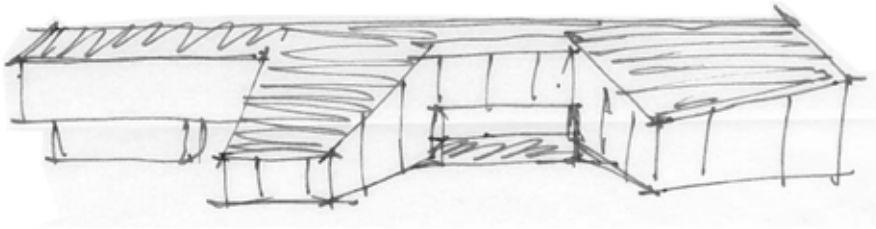
Structural stabilization

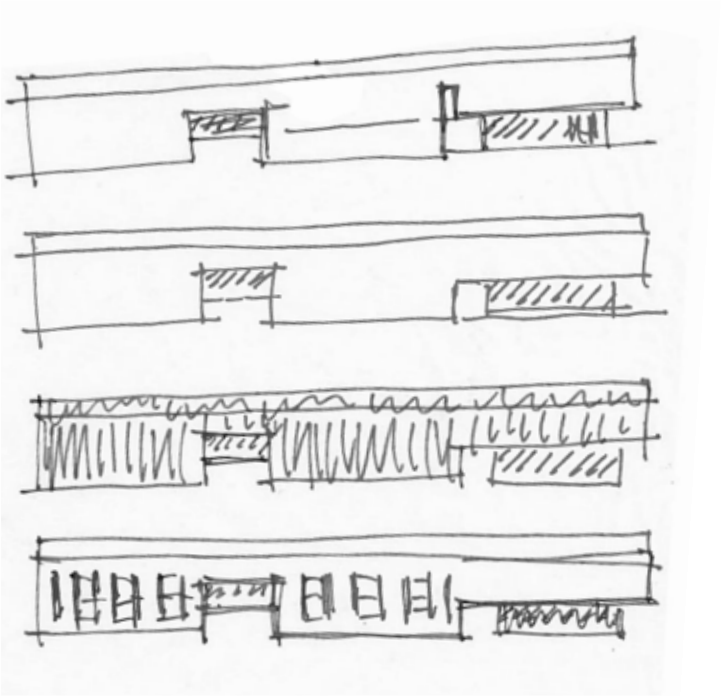
As Portugal is one of the countries that earthquake occurred quite frequently, in this project, most of the areas sit on a skeleton frame structure with concrete columns and steel beams. Therefore, a stabilization system is benefited from load bearing external walls applied in the longitudinal direction, together with fire staircase core and installation room. the joint is to insert a metal unit that cast together with concrete column.

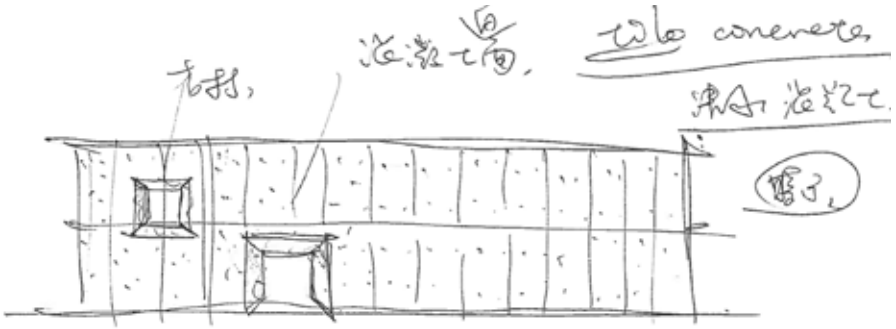


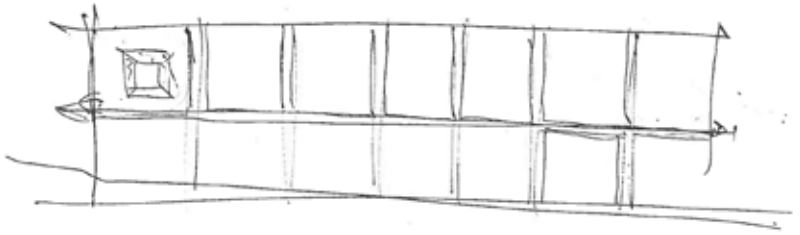
Façade expression

The façade expression study is carried out for two main façades respectively. For the north façade, the idea is to create a transparent impression covered by a big pitched roof; while for the south façade as the strong contrast between shadow and light, the intension for a sculptural feeling is considered, inspired by Alvaro Siza's architecture expression in Portugal. Exterior material suggests as tile concrete, so as to imply the modular grid and interior structure from outside.





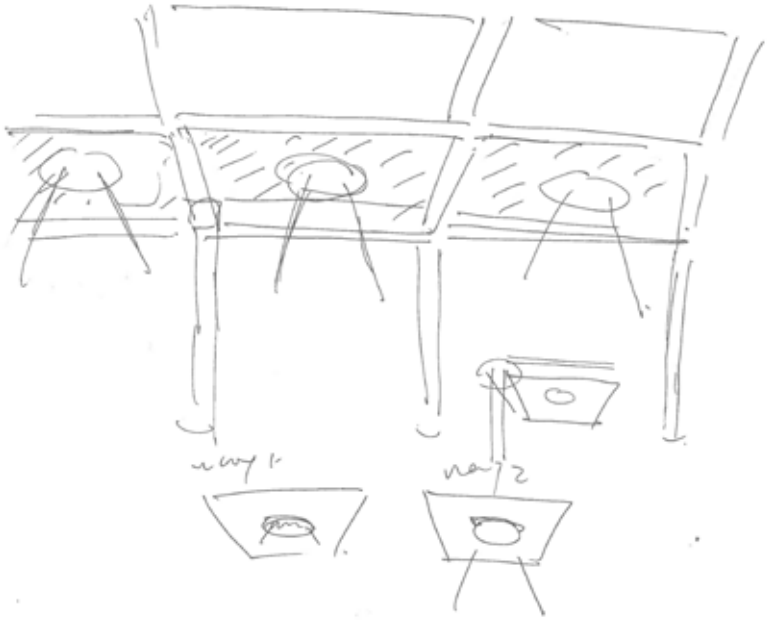




Lighting

The lighting system considers as both natural light and artificial lighting. Due to the fact that the north glazing façade is dominant, together with horizontal sky window on top of the upper floor, it will take most of the diffuse natural light from north. It is confident to say this building has a sufficient natural lighting. Within this context, the south façade would be placed with vertical windows preventing from direct sunlight and façade expression consideration.

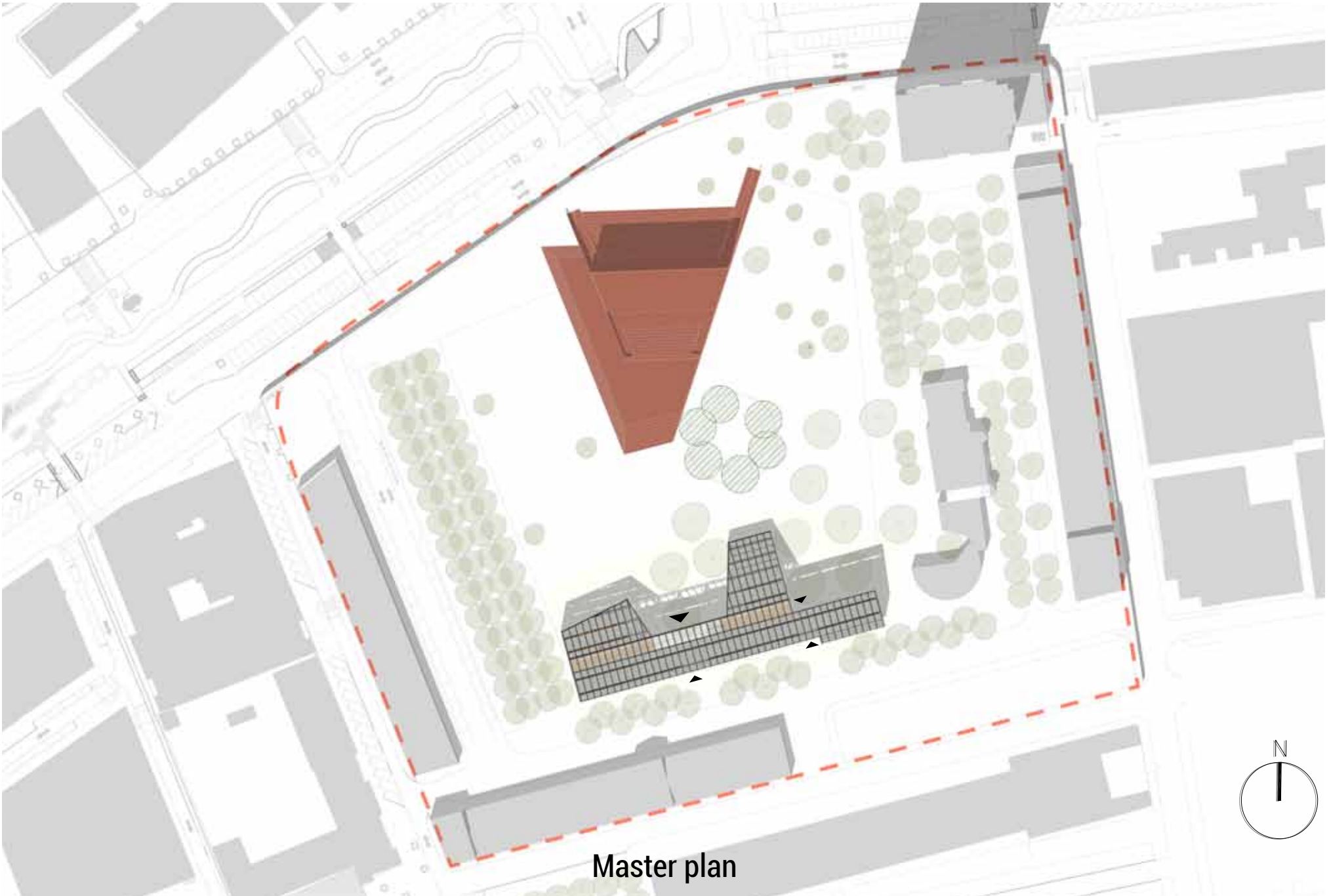
As for the artificial lighting, hidden light inside the suspended ceiling is designed to provide a sense of quietness without disturbing the structure.



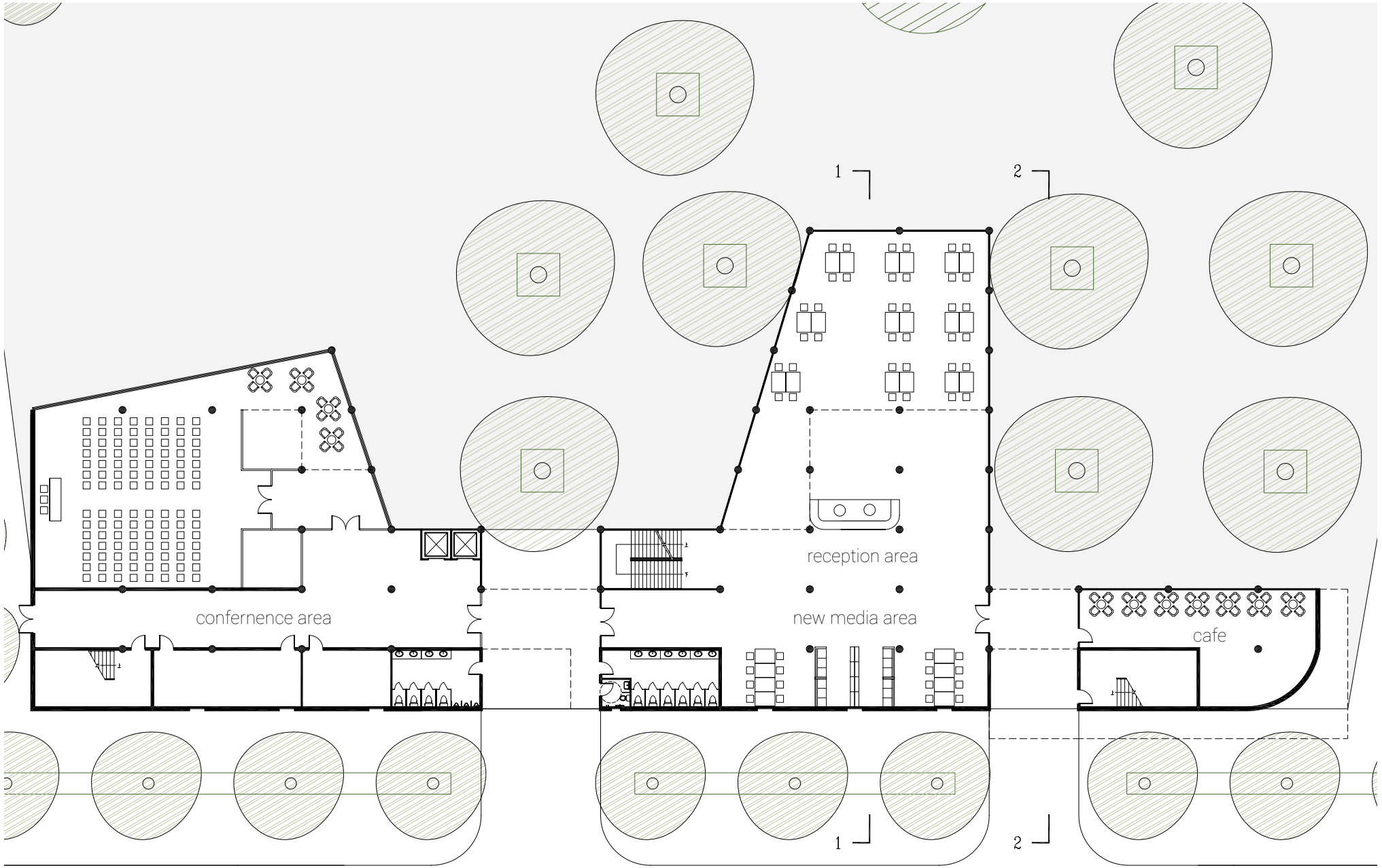
Interior expression

During the study trip to Portugal, I got the chance to visit Siza's library in Aries and Porto Municipal Library (see in fig.). The latter is inspired by the former, with more uses of different material and decorations in its interior expression, but rare to consider nature light by putting the building underground. While in the library of Aveiro University and the reading room in Porto School of Architecture, Siza expressed architecture through the complex mixture of light and physical material, creating a sense of time and curiosity. As also Utzon's approach in his Paradigm, nature light treated as metaphysical level of material contributing in his poetic architecture (Carter, A; Mullins, M. 2007).

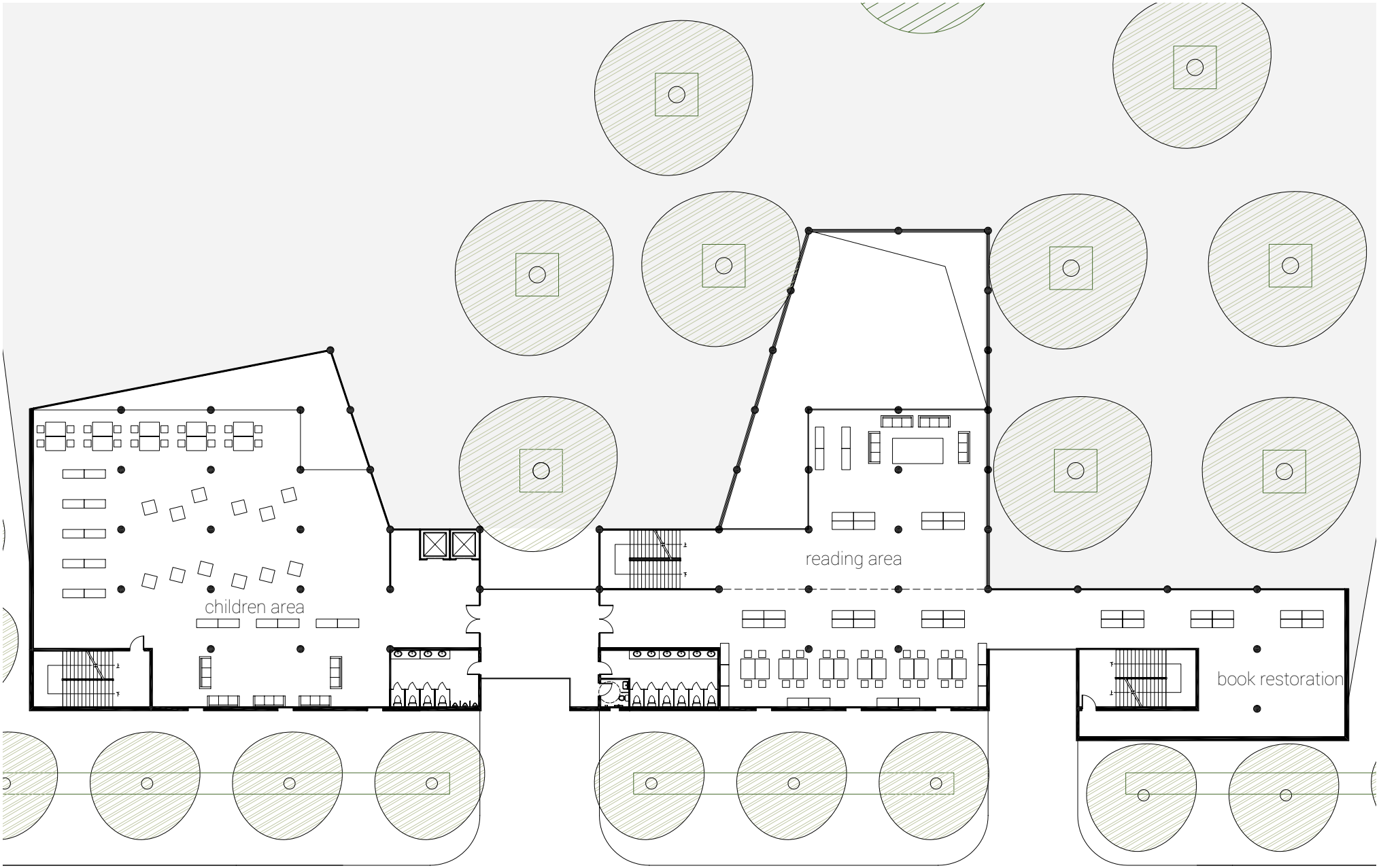
Presentation



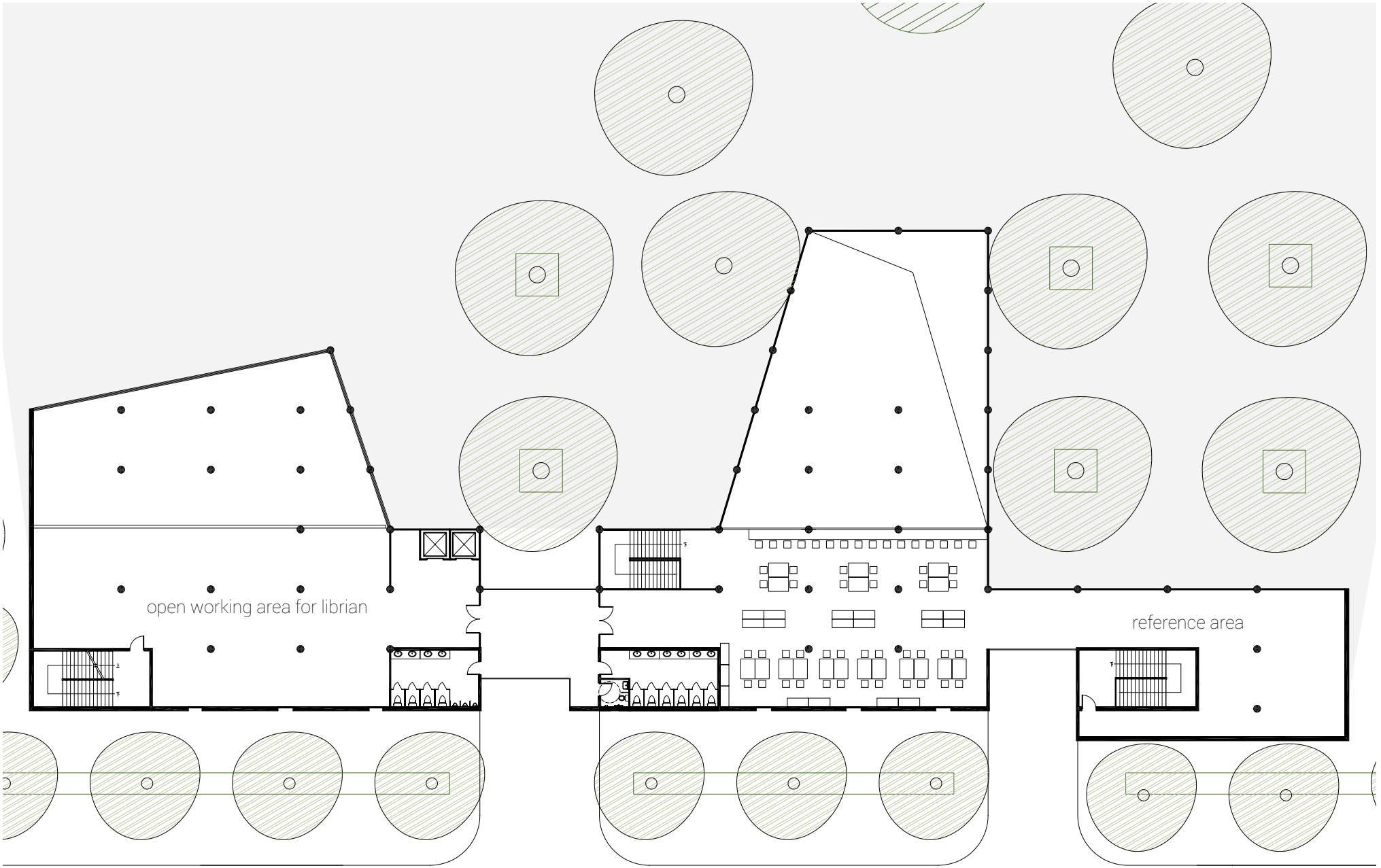
Master plan



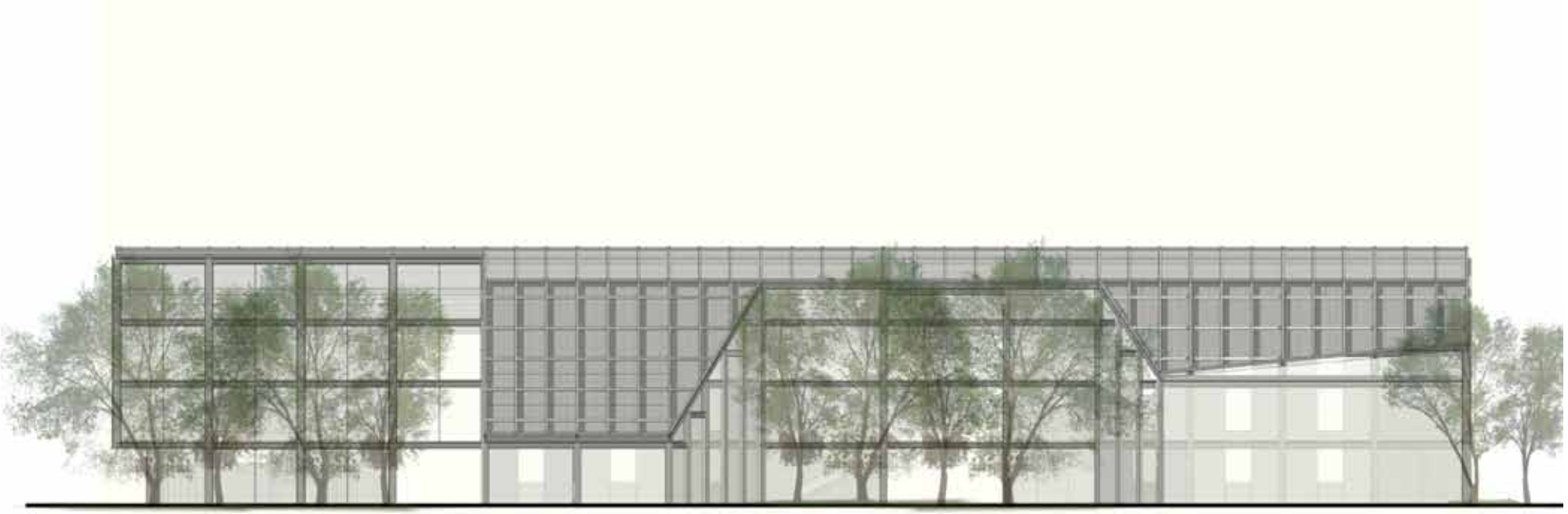
Ground floor plan



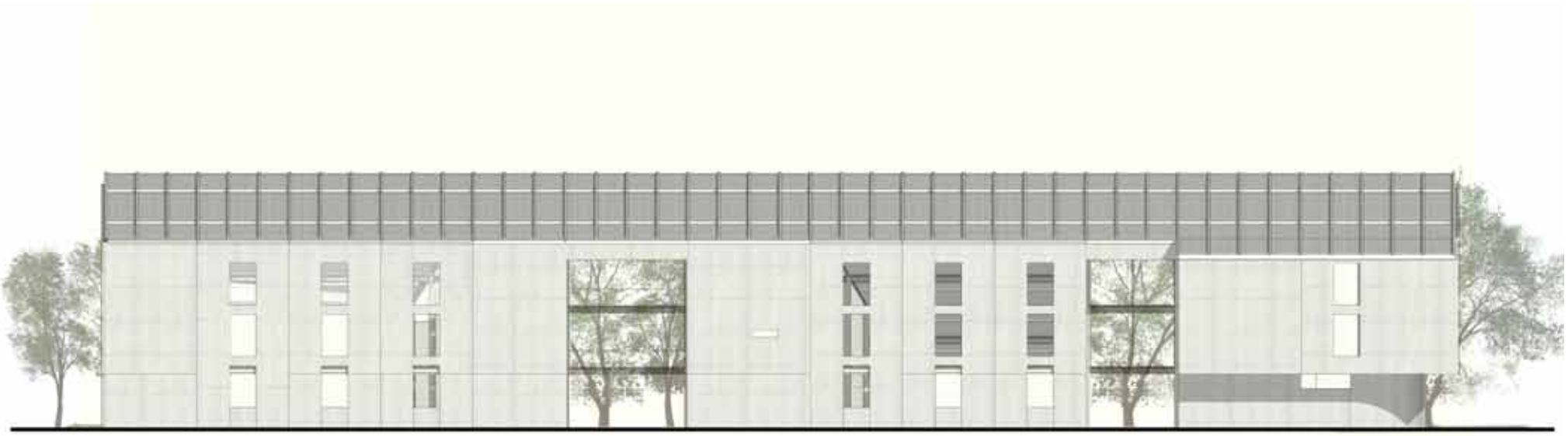
Frist floor plan



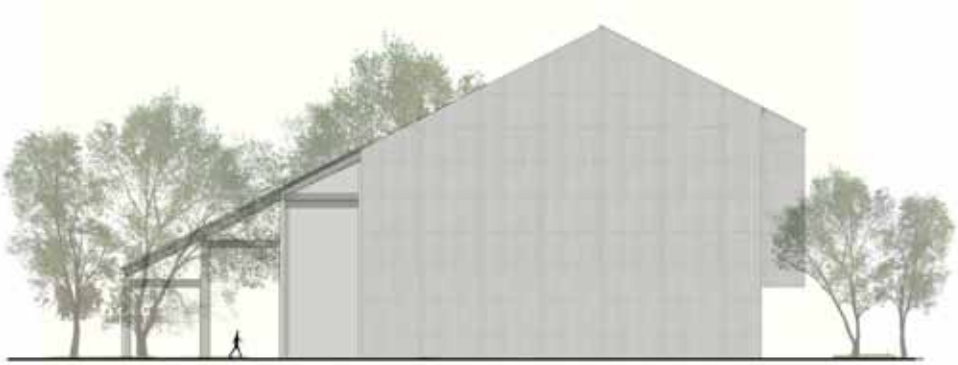
Second floor plan



North Façade



South Façade

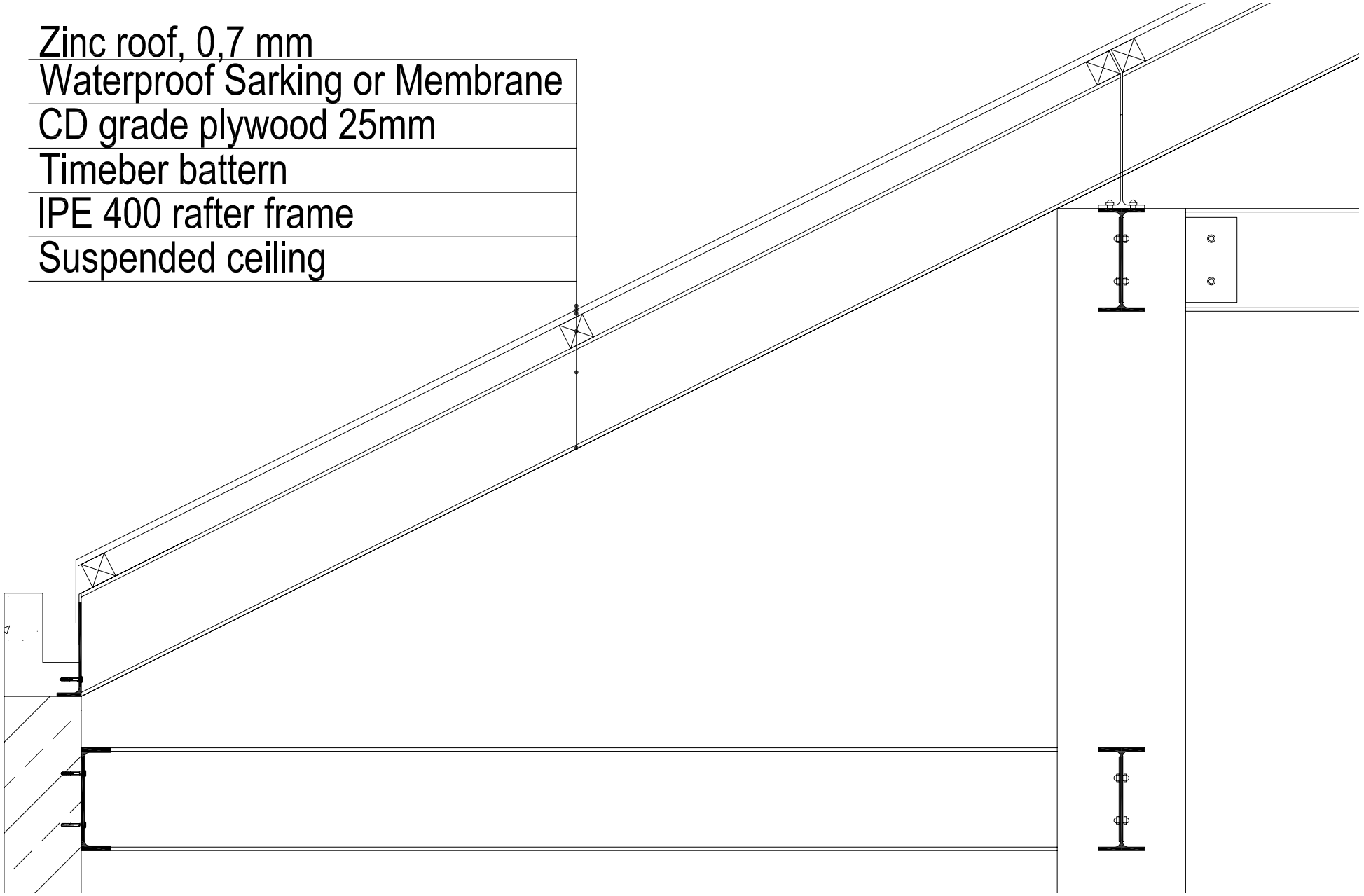


West Façade

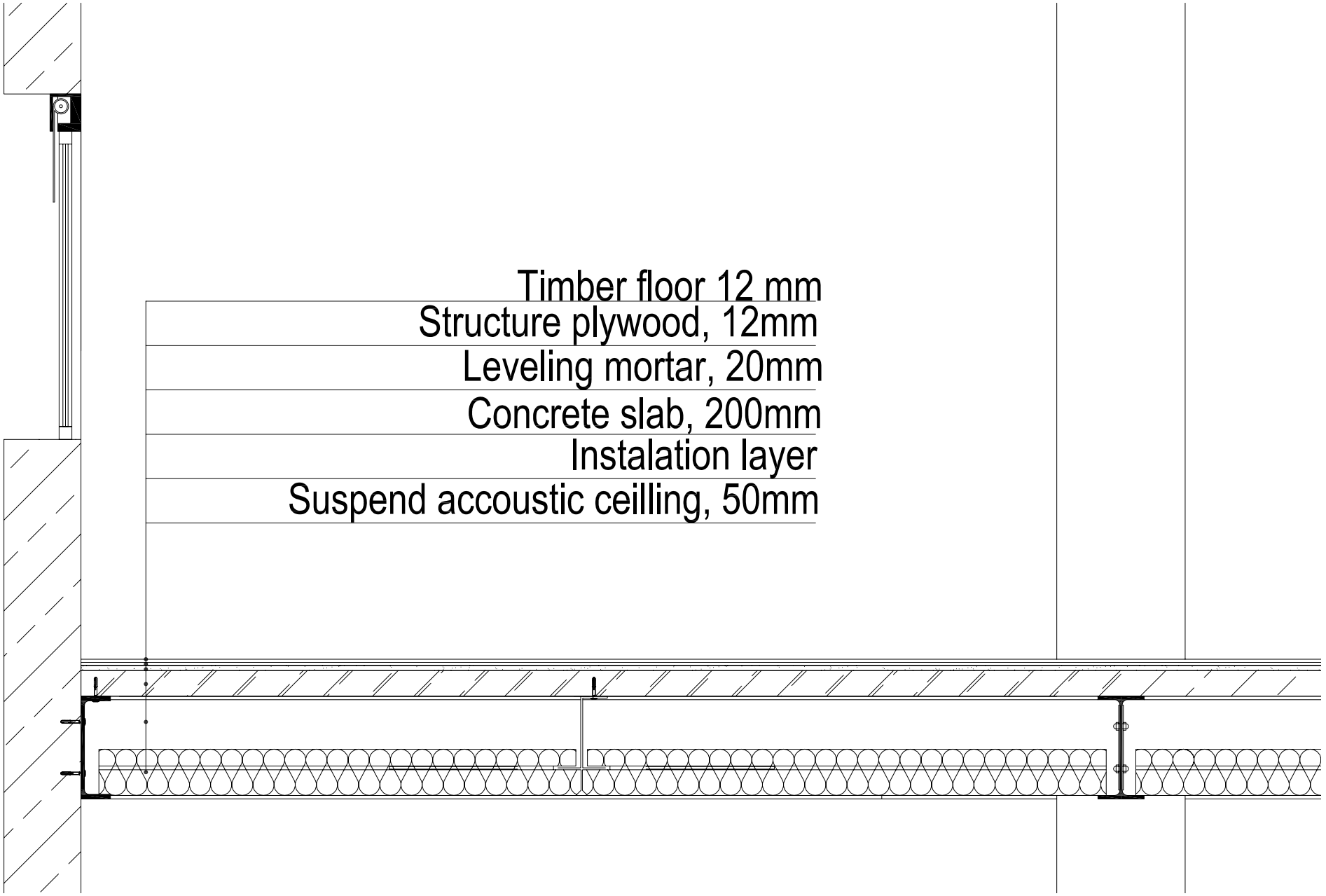
1-1 section

East Façade

2-2 section



Roof detail 1: 20



Wall detail 1: 20

Upper floor reading area

In retrospect

Reflection

This chapter will have in retrospect upon how the Utzon Paradigm has an influence on the design of the project and its element.

Once again, two components of the Utzon Paradigm: Archɛ and Techɛ, are extended and considered respectively as: Nature, Landscape and Place, The Primitive, Transcultural Influence, Ethics Humanity and Community; Nature and Form, Making, Form and Structure, Material and Light, Geometry, Additive Architecture and Prototyping.

Inspired by the great Landscape Arrabida Mountain in the city Setubal, and experiencing from the Place, a Genius loci is unconcealed: the Primitive human experience on a tree, which is deeply engaged with Nature. Following an interview with the Setubal Municipal government, I had the idea of the site containing precious memories of the citizens. Also, since the public square Largo José Afonso holds summer parties and performances every year, which helps support a thriving tourism. Based on that, two design criteria are defined, 1) building coexisting with trees and 2) preserving much of the natural site as possible, which is based on the principle of Ethics humanity and Community.

Through the process of Making, sketching, physical modeling, computer modeling and larger scale Prototyping carry out to the study of Material and Light, yet Form and Structure. As Juhani Pallasmaa suggests the association of hands, eyes and mind evocates architectural ideas and helps to find the best design solution (Pallasmaa, J. 2009). In the main open reading room, the load-bearing element of column, and load borne element of beam symbolizes a trunk and branches in response to surrounding trees. This relationship is as clear as that we can find in Nature and Form. The solution of Geometry, is shown in the volume study: derived from ambient buildings with double pitched roof, evading existing trees to shape the building Form. These irregular cut-outs generate the significance and concentration of this project. With Transcultural Influence from Chinese traditional architecture, the principle has been interpreted and applied into a poetic way of in-situ concrete column and steel beam skeleton structure. In addition to this, an Additive Architecture system and construction process is also developed.

During the midway critique, one of the supervisors commented that my conceptual design could also be explained as another theme of 'Sustainable Architecture' based on the MSc4 study guide, since it has been under the consideration of the ambient environment, the specific culture and local material strategy. Due to the limited time of developing this thesis with all theoretical background, analysis and tectonic design included, it is a shame that I could not have time to experiment and document all the energy analysis tools taught in Aalborg University within the report. But actually during the thesis, some environmental issues and passive building strategies have informed and been integrated into the final design. Therefore it is my personal statement that this project would also meet most of requirements in terms of energy performance.

However, the approach of this project is not grounded in the parametric analysis of physical comfort, but from a phenomenological perspective i.e. the Utzon Paradigm, as Adrian Carter suggested (Carter, A; Mullins, M. 2007), which is an indeed poetic yet sustainable design approach towards culture, place and human existence.

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Illustration

The figure for Arrabida Mountain:
http://www.visitsetubal.com.pt/en/

The panorama of the site:
From the competition program of Setubal Municipal Library

The figure for Jorn Utzon's sketch on Chinese architecture impression
www.utzonphotos.com

Computer illustration on Chinese traditional architecture
From the PowerPoint slide of the course: Chinese architecture history, by School of Architecture and Urban Planning, Guangdong University of Technology

Other photos, illustrations, sketches, model pictures, computer drawings and renderings belonged to the author

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