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CHADI ROBIN CHARLES

SUSTAINABLE SOLUTION USING BIOMIMICRY AND ARCHITECTURAL LIGHTWEIGHT MEMBRANES

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Master Dissertation in Sustainable Built Environment

Developed work under the supervision of
Professor Doutor Raul Manuel Esteves Sousa Fangueiro

and co-supervision of
Professor Doutor José Luís F. da Silva Ramos

November 2017

‘‘When we look at what is truly sustainable,
The only real model that has worked over long periods of time
Is the natural world.’’

Janine Benyus

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ABSTRACT

Sustainability is attracting additional importance in daily life through of all the propaganda surrounding global warning issue and how the quality of life on earth is the wickedest that have ever been. The impact of construction and architectural industry contributes in that matter, where solving and arguing that issue is more significant for the building professionals more than ever specially because perhaps time is running out and facing that problem nowadays will result greatly on the future life on earth. In this context, it is possible to say that it is extremely necessary to combine innovative materials and techniques so that alternative solutions can be created in order to make a further step in solving or reducing the negative effect on the planet.

This research project intends to study the new technologies and techniques manifested in sustainability where it will tackle the Biomimicry concept and it relation with sustainable questions through the possibility to learn from the environs in order to find a solution.

In order to apply the project as a solution to a real situation, this dissertation proposes to design an architectural structure, inspired by the spider's nets approach, for an exterior space in the centre of the Azurém Campus in the University of Minho, where this space is the hub of pedestrian movements for the university.

The architectural structure composed of a grid of bending-active elements, characterizes the decoy for a new and diversified attraction space to the campus. In addition, it is intended to show that the new technologies and materials can be the transitional link between new aspects of the field which interpret a new constructive panorama surrounding the sustainable world.

Key words: Biomimicry, Architectural Membrane, Lightweight Structure, Sustainability.

RESUMO

A questão da sustentabilidade tem assumido uma importância adicional na vida diária da humanidade, através de toda a propaganda em torno do alerta global para a ecologia. O impacto da indústria da construção civil e arquitetônica não foge à regra e contribui em muito para este assunto, dado que os projectos de hoje podem decidir, no futuro, muito da sustentabilidade da vida humana na Terra. Neste contexto, é extremamente necessário combinar materiais e técnicas inovadoras para que possam ser criadas soluções alternativas, a fim de se dar mais um passo em frente na resolução ou redução do efeito negativo no nosso planeta.

Este projeto de pesquisa pretende, assim, estudar as novas tecnologias e técnicas de sustentabilidade, abordando o conceito de Biomimética e relacionando questões sustentáveis através da possibilidade de aprender com outras áreas para encontrar uma solução.

Para aplicar o projeto como uma solução para uma situação real, esta dissertação propõe a concepção de uma estrutura arquitetônica, inspirado pela abordagem das redes de aranhas, para um espaço exterior no centro do Campus de Azurém, na Universidade do Minho, onde este espaço é o centro de movimentos pedestres para a universidade.

A estrutura arquitetônica composta por uma grade de elementos flexíveis, caracteriza o chamariz para um espaço de atração novo e diversificado para o campus. Além disso, pretende mostrar que as novas tecnologias e materiais podem ser o vínculo de transição entre novos aspectos do campo, que interpretam um novo panorama construtivo em torno de um mundo mais sustentável.

Palavras-chave: Biomimética, Membrana Arquitetônica, Estruturas Leves, Sustentabilidade.

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1 INTRODUCTION

1.1 GENERAL FRAMEWORK

The current searches for sustainability in architecture stem partly from the energy and ecological demands of environmental protection, this researches respectively exposed and tackled various environmental challenges that faces our world.

The name sustainability is derived from the Latin *sustinere* that can mean 'maintain', 'support' or 'endure' (Assembly, 2009). This term has been used more as a part of the sustainable development concept since the 1980s, which can be described as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Assembly, 1987). Even, could be defined as an ability or capacity of something to be maintained or to sustain itself, so as to meet the needs of the now without compromising the potential for people in the future and its possible also say that something sustainable is something that can continue forever.

As a simple definition, sustainability is something that improves the quality of human life while living within the carrying capacity of supporting eco-systems were also representing in the same time a vague definition, once can be also a political process or domain, as can be seen in the written definition of The Earth Chapter, that says "a sustainable global society founded on respect for nature, universal human rights, economic justice and a culture of peace".

According to the United Nations Millennium Declaration, that identified principles and treaties on sustainable development, the application of sustainability in the context of construction incorporates three dimensions of integrated development: environmental, social and economic development, including more recently the political development as a sustainability domain.

The history of sustainability traces human-dominated ecological systems from the earliest civilizations to the present time (Clarke, 1977). In the beginning of the human history, the use of fire and desire for specific foods may have altered the natural composition of plant and animal communities, meanwhile the emergence of agrarian communities which depended largely on their environment and it creating of a structure of permanence (Clarke, 1977).

The Western industrial revolution of the 18th to 19th centuries tapped into the vast growth potential of the energy in fossil fuels, being the coal used to power ever more efficient engines and later to generate electricity. In this context, a gathering environmental movement pointed out, in the mid-20th century, that there were environmental costs associated with the many material benefits that were now being enjoyed. This concern is also justified, in according to (Clarke, 1977), the architecture liberation in the basic functionalities seen during the first half of the 20th century forced to resort the use of technology to generate heat, cold, light and ventilation, in order to make the spaces more livable, leading to a greater energy expenditure, representing a big scale of global environmental problems. As a consequence, human needs for comfort have become an extremely important point in architectural design, with the term sustainability being increasingly linked to new constructions, making it extremely necessary to find ways to reduce the environmental impact caused by this industry. There is increasing global awareness of the threat posed by the human greenhouse effect, making scientists continue to investigate how human interactions with natural systems can be improved and sustained.

Nowadays, due to a growing understanding of human interaction with nature, it is widely accepted by the scientific community that consuming energy from non-renewable sources has caused serious environmental damage. Facing these circumstances, the actors in the construction sector are trying to improve their activities more sustainable, adopting the principles of bioclimatic design and looking for solutions in buildings materials and techniques that are less harmful to the environment. Within the crossroads of more recent information in the scenario of sustainability applied to architecture and engineering, it have the concept and principle of Biomimicry.

Biomimicry is innovation inspired by nature, and this definition does not mean directly to take a complex form or a design for the architectural field, but is also study how the nature behaves and adapts in different situations and environments as shown in figure 1 below.

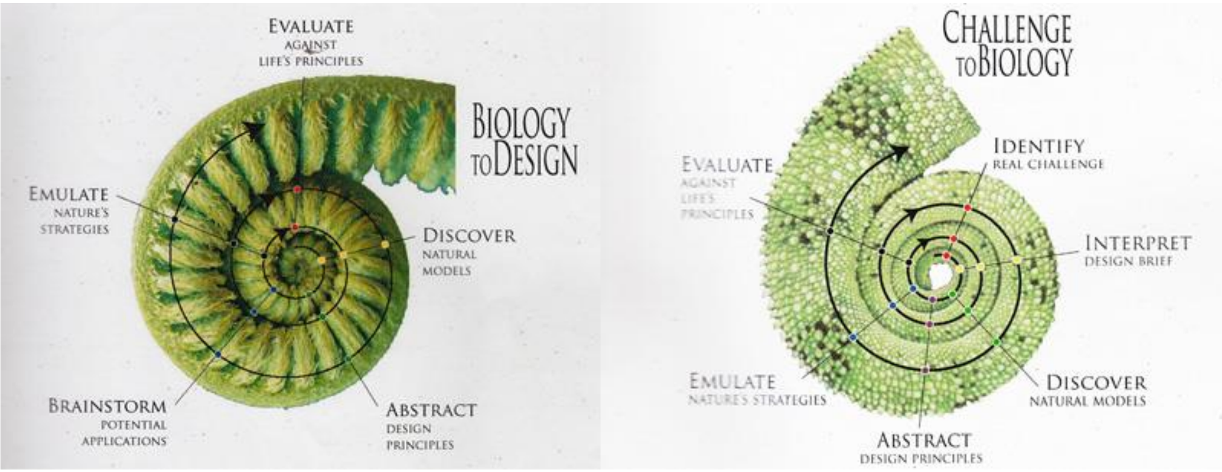

Figure 1 ,Biomimicry principles (IOUGUINA, 2011).

In addition to the new concepts and ideas of design manifested in this approach, the reduction of natural resources is mandatory and the renewal in the field of buildings is necessary, the architectural membrane are increasingly claimed as an innovative concept of a light and sustainable material for construction. Targeting the environmental efficiency, the organic shape, the minimum weight, the high flexibility, the translucency, the fast installation, and the low maintenance and cost benefits (Metropolises., Retrieved on 2016-03-13.), this justifies why designers appreciate and are using more the membrane materials. Besides, the membrane becomes a material of high potential of integration with projects starting from the Biomimicry principles, since it allows the application of innovative technologies and materials, capable of different behaviors, functions and aesthetic purposes.

Using the same direction of membrane, the use of fibre reinforced composites presents a constructive alternative of great efficiency when it is intended to have a good relation between mechanical properties and low weight. In addition, materials that present as intrinsic characteristics the durability, the reduction of the overall cost according to the life cycle, the low energy consumption for manufacturing and low weight for transportation and assembly should be prioritized. Can still represent a choice of material in architectural situations in which a good relation with flexibility and resistance is sought, in order to allow the achievement of complex shapes.

In this way, this dissertation focuses on the study and design of an architectural structure solution, which encompasses the concepts of Biomimicry, presenting as main base the use of architectural membrane, besides bending-active elements as support of the structure. The use of these technologies and inventions will able us to create and form a design. where the architectural structure composed of a grid of bending-active elements, shelled by a fabric in a complete strengthen structure will characterizes the decoy for a new and diversified attraction space to the intended design location, that is situated in a focal pedestrian crossing point in the proposed site.

1.2 OBJECTIVES

The general objective of this dissertation is to study and design an architectural structure solution, using modern and innovative concepts, materials and techniques in the area of sustainability, specifically through the application of the Biomimicry concepts.

Which will be obtainable by integrating the use of architectural lightweight membrane, representing a solution capable of reinterpreting behaviors founded in nature, presenting better functional performance, lower environmental impact and a specific shape design, in order to create a new and diversified attraction for the Azurém Campus of University of Minho.

Beyond this general objective, the dissertation also intends:

- Development of physical and digital models that can be caressed and assists its performance, making it possible to understand the real behavior of the architectural solution and to make possible changes.
- Promote a framework of understanding through a review of the Biomimicry concept, especially in the context of the sustainable architecture, and the application of architectural lightweight membrane as the main building material.
- Bring new knowledge about the concepts, materials and techniques studied, serving as a basis for studies and future developments.

1.3 MOTIVATION

Humans are clever, but without intending to, we have created massive sustainability problems for future generations. Fortunately, solutions to these global challenges are all around us. Life has been on earth for 3.8 billion years and in that time life has learned what works and what’s appropriate here and what lasts here and the idea is that how we should be looking at these mentors these biological elders they have figure out how to create a sustainable world. Rather than inventing it from scratch why we don’t take our cues from them, these are earth adaptations. With the casements life is this organisms are the ultimate engineers and they are ultimate chemist and technologist they learned how to do it in context so that’s the core idea behind Biomimicry. Is that the best idea might not be ours it might already be invented.

As a deduction the problem facing our generation and the generations of our kids and the following cohorts will face bigger and harder environmental problems than us. And in our time now we started to perceive and sense the environmental problems from the increasingly hotter temperature recorded on earth, by the phenomenon of global warming. To the rise in water on earth. All problems that will have an immense effect on our daily life sooner than we taught it will occur. And challenging these problems is a great dilemma and compulsory now more than ever.

"I think the biggest innovations of the 21st century will be at the intersection of biology and technology. A new era is beginning."
-Steve Jobs

"When nature has work to be done, she creates a genius to do it."
-Ralph Waldo Emerson

"You could look at nature as being like a catalog of products, and all of those have benefited from a 3.8 billion year research and development period. And given that level of investment, it makes sense to use it."
-Michael Pawlyn

1.4 METHODOLOGY

To reach the objectives envisioned, the dissertation is divided into two components, a theoretical component and a practical one, enabling to divide the applied methodology into five main steps:

- Carry out the study of sustainability and it applications in buildings, including the historical context and diverse approaches, highlighting the in-depth study of the use of Biomimicry concepts in new constructions as a technique to increase functional performance and the level of sustainability.
- Highlight the use of architectural lightweight membrane as a sustainable material with great potential to incorporate different technologies capable of reproducing behaviors founded in nature, and deciphering the application of the Biomimicry concepts, besides the study of fiber reinforced materials in order to understand and integrate it with the structural solution developed;
- Develop the design of an architectural structure solution through the application of the Biomimicry concept integrated to the use of architectural lightweight membrane, for the center of pedestrian paths between the buildings in the Azurém Campus of University of Minho representing a solution capable of reinterpreting behaviors founded in nature, presenting better functional performance, lower environmental impact and a specific shape design that is a consequence of the biomimcry research.
- Reproduce physical and computational models in small scale of the structure, based on previously analyzed concepts, seeking to demonstrate more clearly the behavior and the global three-dimensional shape of the solution.

- Detailing the final structural solution, specifying all the elements, materials and functions it offers, and performing a final analysis, which will sweep the way for innovative researches and applications for upcoming studies and researches in this field of applications.

1.5 DISSERTATION STRUCTURE

This dissertation is organized in seven chapters.

Chapter 1 contains the introduction to research, highlighting the importance of the theme in the current context of sustainability, the objectives to be achieved and the methodology applied to work and the description of the dissertation structure.

Chapter 2 presents the state of the art of Biomimicry concept, in which review the knowledge available in the literature, the current contexts of applications and case studies, and its characterization in the architecture scenario.

Chapter 3 presents the state of the art of the architectural lightweight membranes, in which review the knowledge available in the literature, the current contexts of applications and its characterization in the architecture scenario, and also the review of fiber reinforced materials characteristics and the application for bending-active elements to compose complex shapes.

Chapter 4 characterizes the analysis of the implantation location of the architectural structure solution, where functional and bioclimatic analyses were performed, raising the points of the reason for the choice of this location.

Chapter 5 presents the detailing of the final structural solution, from the analysis of physical models to the specifying all the elements, materials and functions it offers, and performing a final analysis comparing the result obtained with conventional constructive solutions.

Chapter 6 indicates the materials used in the project. Emphasising on the chief material used and which composes the core of the structure the FRP rods.

To finalise, chapter 7 presents the design application, presenting the design setting as a start, and then clarifying the concept and its inspiration on the design. As detailing the structure and techniques used for modelling the design, as elaborating the functions the pavilion will acclimate. And finally the future development and future view relevant for the design.

In addition, the references of literatures and figures used to illustrate this work, and the annexes are presented.

2 BIOMIMICRY

2.1 DEFINITION AND ORIGIN

Biomimicry or biomimetic is the examination of nature, its models, systems, processes and elements to emulate or take inspiration from in order to solve human problems, and also can present other terms offer used as a bionics or bio-inspiration. This term come from the Greek words *bios*, meaning life, and *mimesis*, meaning to imitate. There are a lot of definitions, but Biomimicry can be defined as the study of the structure and function of biological systems as models for the design and engineering of materials and machines. In addition, can be the attempt to learn from nature, which deals with the development of innovations on the basis of investigation of natural, evolutionarily optimized biological structures, functions, processes and systems (M.Benyus, 1997) . It is not now that technological inventions have been inspired by nature and solve problems. One of the most important examples of Biomimicry was the study of birds to enable human flight. According to (M.Benyus, 1997), although never successful in creating a “flying machine”, Leonardo da Vinci (1452-1519) was a keen observer of the anatomy and flight of birds, madding numerous notes and sketches on his observations as well as sketches of various possible flying machines. Despite these analysis carried out long time ago, the first airplane was developed in 1903 by the Wright Brothers, and was also derived of inspiration and observations of pigeons in flight (M.Benyus, 1997).

This concept encompasses three ways of being applied

- Nature as a model: Is the imitation of models, systems and elements of nature for the purpose of solving complex human problems.
- Nature as measure: After billions of years of evolution, nature has learned what works, what is appropriate and what endures, using an ecological standard to judge the correctness of the innovations.
- Nature as mentor: It’s a new way to watch and assess nature, understanding not on what we can extract from the natural world, but what it can.

The term is also a new discipline for the professionals such as architects, chemists, product designers, etc. where they asks themselves what in the natural world has been already solved and what it is trying to solve in a natural sustainable way, which results in imitations, designs and strategies, that moves towards to be better adapted to life on earth over the long hole. Giving them a guidance and vision for them in their own labor. One of the most famous researchers on Biomimicry, Janine Benyus, describes that life does chemistry in water as the universal solvent and we can use very toxic solvent as sulfuric acid, life depends on local expertise, organisms have to understand their places they have to know the limits and the opportunities of their places and life banks on diversity and rewards collaboration life waste nothing, life recycle everything. “The most of all does not foul its nest does not foul its home” (M.Benyus, 1997). As Benyus explains that animals in the nature world don’t exploit their home as much as humans shouldn’t exploit their home which effects the environment.

In the context of architecture and engineering, Biomimicry or biomimetic is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature’s time-tested patterns and strategies, where the principal goal is to create processes, products and policies, new ways of living that are well-adapted to life on earth over the long haul for the new constructions. In conclusion, the core goal is that nature has already solved many of the problems that the world is grappling with, and the living beings are the consummate engineers.

2.2 Concept Objectives

As a way of guiding and justifying the use of the concept of Biomimicry, some guidelines or objectives can be highlighted. Biomimicry can be used to increase effectiveness of the resources; to increase effectiveness of the energy; to protect from pollution; for the compatibility with the environment, and the maximum benefit from the new technology. However, correspondingly biomimetic architecture is seeking to the perfect quality, thinking of all the sustainability dimensions like social, environmental and economical, by the best tools, using of the natural resources by good way aid to rescue the important resources and decrease the energy consuming. The improvement of the build environment by following these principles:

- Depending on the sun rays and the wind;
- Interaction with the surrounding environmental whether natural or constructed;
- Energy conservation using renewable energy sources;
- Reduce consumption of non-renewable resources and prevent the use of toxic materials;
- Exploit all the resources of nature, including energy, water, land and minerals.

These objectives seek to direct the biomimetic architecture to main axes that depend basically on the nature conservation; interaction with the surrounded environmental; energy conservation and using the new technology for that. For reach the biomimetic design, these axes follow some elements through interdependence with each other, which are the study of site, design, building material, available resources and building technology. Moreover, as a Biomimicry corroboration through the big concept of sustainability, the sustainable architecture along with biomimetic architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy and development building space. For that, it's necessary to adapt several ideas:

- Low-impact materials - choose non-toxic, sustainably-produced or recycled materials which require little energy to process;
- Energy efficiency: use manufacturing processes and produce products which require less energy
- Quality and durability - longer-lasting and better-functioning products will have to be replaced less frequently, reducing the impacts of producing replacements;
- Design for reuse and recycling - Products, processes, and systems should be designed for a commercial performance;
- Bio-mimicry - redesigning industrial systems on biological lines, enabling the constant reuse of materials in continuous closed cycles;
- Service substitution - shifting the mode of consumption from personal ownership of products to provision of services which provide similar functions, such a system promotes minimal resource use per unit of consumption;
- Renewability - materials should come from nearby (local or bioregional), sustainably-managed renewable sources that can be composted when their usefulness has been exhausted;
- Healthy Buildings: sustainable building design aims to create buildings that are not harmful to their occupants nor to the larger environment. An important emphasis is on indoor environmental quality, especially indoor air quality.

2.3 LEVELS OF BIOMIMICRY

According to Benyus (M.Benyus, 1997), Biomimicry is divided into three levels of description. The first one is the organism level. This level characterizes the process of mimicking a specific organism. The second is the behavior level that mimics how an organism behaves or relates to its larger situation or context. And the final one is the ecosystem level which is the way of mimicking an entire ecosystem, as illustrated in figure2 below.

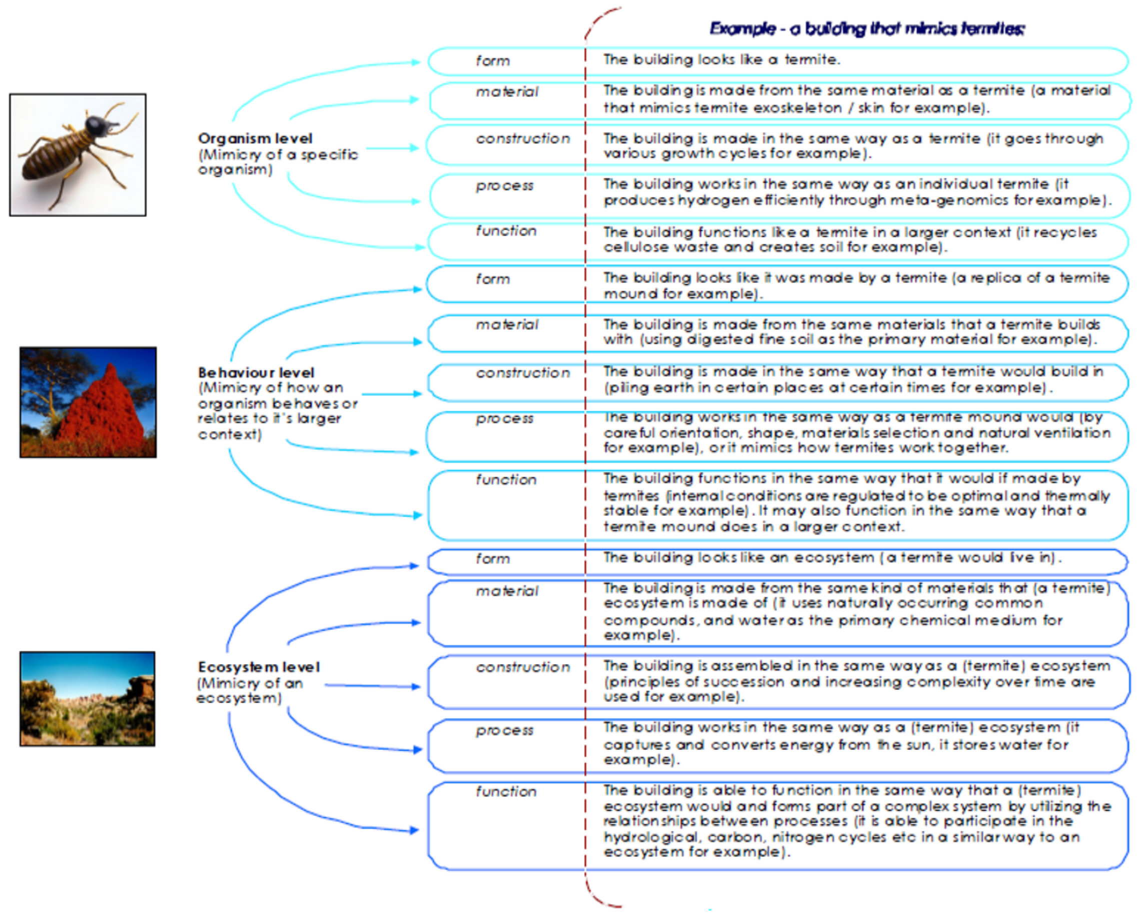

Figure 2, the three levels of Biomimicry: Organism, Behavior and Ecosystem Levels (krishnakuman, 2011)

In order to better understand each of the levels with emphasis on the application of the concept to the reality of the constructions, it is possible to specify each level in relation to form, material, construction, process and function, using a termite as an example of inspiration.

- **Organism Level (Mimicry of a specific organism):**

  The form of building looks like a termite. The building is made in the same material as a termite, a material that mimics termite exoskeleton / skin. The construction of building is made in the same way as a termite going through various growth cycles. The building works in the same way as an individual termite it produces hydrogen efficiently through meta-genomics. And the building functions like a termite in a larger context that can recycle cellulose waste and creates soil.

- **Behavior Level (Mimicry of a behavior and relates with the context):**

  The form of building looks like it was made by a termite, a replica of a termite mound. The material of building is made from the same materials that a termite builds with, using digested fine soil as the primary material; the construction of building is made in the same way as a termite would build in. piling earth in certain places at certain times. The building works in the same way as a termite mound would, by careful orientation, shape, materials selection and natural ventilation, or it mimic how termites work together. And the building functions in the same way that it would if made by termites, internal conditions are regulated to be optimal and thermally stable it may also function in the same way that a termite mound does in a larger context.

- **Ecosystem Level (Mimicry of an ecosystem):**
  The form of building has the same appearance that a termite ecosystem would live in. the material of building is made from the same kind of materials that a termite ecosystem, using principles of succession and increasing complexity over time. The building works in the same way as a termite ecosystem, it captures and converts energy from the sun and stores water. the buildings functions is able to function similar to a termite ecosystem would and forms part of a complex system by utilizing the relationships between processes it is able to participate in the hydrological, carbon and nitrogen cycles in the same way to an ecosystem.

2.4 IMPORTANT EXAMPLES OF APPLICATION

Working organisms adapt their materials or ingredients in order to adjust to different situations alike heating body effects or toxin and high pressure. For example, a spider takes what comes into its web, such a fly and it takes that it does chemistries reactions at room temperature and very low pressure, it making that great fibers which is five times stronger than steel for an ounce for ounce, awakening to the field of fibers for studies related thereto. Biomimicry is the conscious impersonation of the forms, processes and the systems in nature to solve worthy problems, and that means as long as the search it will find, so the number of examples in Biomimicry is not defined where it depends on the innovation and its limit.

Some of possible examples that could be mentioned is the camel nose and the system inside it where it filters water from inhaled air, the muscles tenders and it influence in designing bridges or the alligator skin and it influence in fabricating fibers, the locusts insect and its electrical sensors, the owl and its technique of silent flying which affected the airplane design and the entire concept of the immune system and its collaboration in designing antiviruses, or the Slime mold bacteria and it involvement in making and forming and designing the Tokyo metro map and so on. Thus the next step is making those intervention meaning something for life on earth make them active discoveries and play a role in our life and the way we see and perceive things and in the design course, the examples of discovering or developing materials while being inspired by nature are numerous, and in figure 3 below we can explore some of those illustrations.

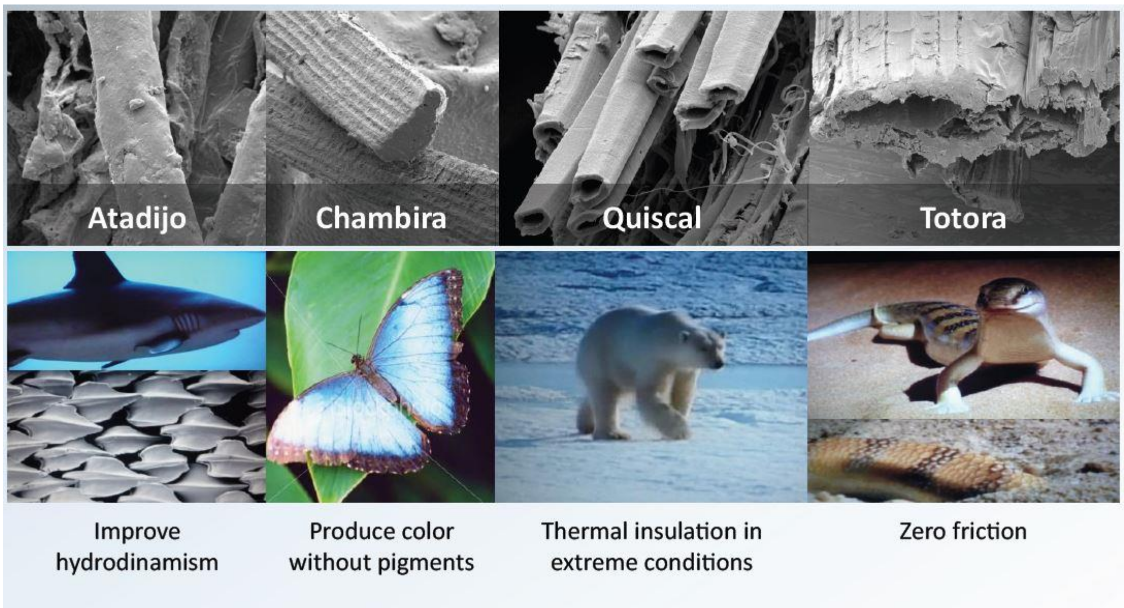

Figure 3, Different materials inspired by natural inhabitants of the earth (Prof. Fangueiro Fibernamics Biomimicry presentation).

As in this case considered, many other studies and products have been studied and discovered through analysis and inspiration in living things or organisms that exists in the natural world. Of which some will be set forth below.

2.4.1 The Invention of Velcro

The most famous example of the biomimetic concept approach is the invention of Velcro, as shown in figure 4 below.

Figure 4, the inspiration to Velcro and its technological imitation. From left to right: The hooks of the burdock seed and the artificial loops. The wool from a sheep and the artificial loops. (Wilhelm Barthlott and Neinhuis, 1997).

In the late 1940s a Swiss engineer, George de Mestral, was taking his dog for a walk, when he noticed cockleburs sticking to both his clothes and the dog's fur. Upon returning home he examined the burs and discovered the small hooks that enables the seed-bearing bur to be transported to new areas. By trial and error experiments he could, in 1955, patent Velcro, an artificial design based on the cockleburs, being the Velcro a unique two-sided fastener, one side with stiff hooks like the burs and the other side with soft loops like the fabric of his pants (Wilhelm Barthlott and Neinhuis, 1997). As illustrated in figure 5 below.

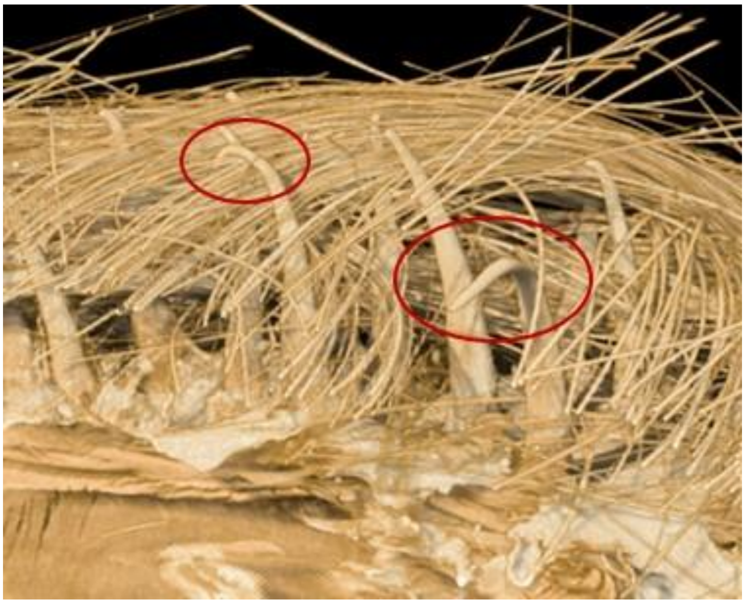

Figure 5, Close-up of hook-shaped spikes e entrapped dog hair on a burr (Wilhelm Barthlott and Neinhuis, 1997).

2.4.2 Lotus Leaves Effect

Another important example, a recent and promising case of Biomimicry concept approach is the Lotus Effect. Illustrated in figure 6 below. This effect was discovered by the botanist Wilhelm Barthlott during a systematic scanning electron microscopy study of the leaf surface of some 10.000 plant species (Wilhelm Barthlott and Neinhuis, 1997).

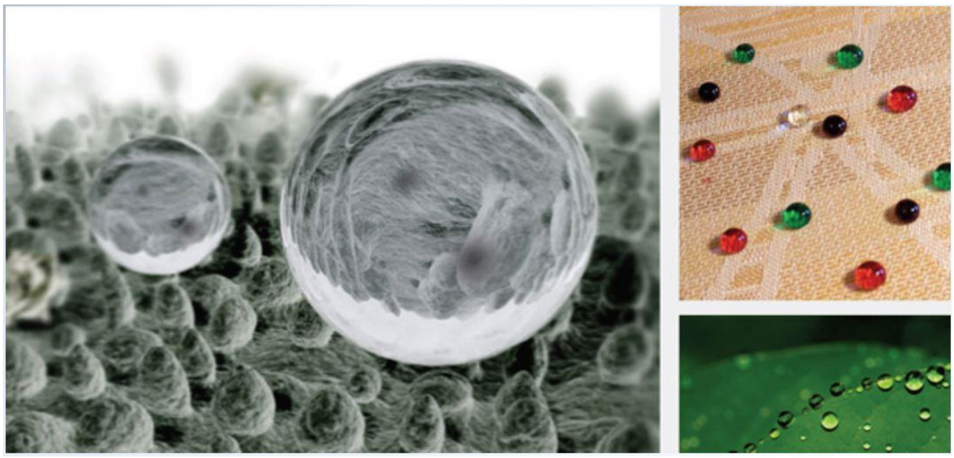

Figure 6, learning from Lotus Plant how to make self-cleaning materials. (Institute, 2017)

Barthlott and one of his students observed that species with smooth leaf surfaces always had to be cleaned before examination, while those with a rougher and more irregular surface were almost completely free of contamination. From further studies and experiment they discovered that small wax crystals covered the surface of the rough leaves. Water droplets are balancing on the top of these crystals with only little surface contact to the leaf and will therefore roll off easily. The adhesion between dirt particles and crystals is similarly minimized, so the particle is attracted to the larger surface of the passing water droplet and with that removed from the leaf surface. They called this the Lotus-Effect, after the leaves of the sacred lotus or sacred water lily, which give a particular impressive demonstration of this effect. The Lotus-Effect has great potential for commercialization and currently a house paint is distributed under the name Lotusan. A further potentially lucrative application is to manufacture a self-cleaning paint for cars.

2.4.3 Spider Silk

Biomaterials and structures are main areas where the biomimetic approach is expected to be profitable. One of the best examples is that of producing artificial spider silk for the context of structures. Silk is a biopolymer consisting of a keratin like protein called fibroin and is an interesting material from a commercial perspective due to its high tensile strength (1100 MPa for radial threads of the cross spider compared with around 500 MPa for steel) and with strong viscoelastic effects (Wilhelm Barthlott and Neinhuis, 1997). However, despite the huge research effort into spider silk, large problems still exist before any products are ready for the market. The main problem is that not only is the exact structure of the silk important for its physical properties, but these in turn also depend on the complex weaving pathway through the ducts and spinnerets of the spider, where the silk is changed from a liquid soup of proteins to solid threads.

So far the most promising candidate is BioSteel® developed by Nexia Biotechnologies that took some genes from the spider and incorporated them into the milk glands of goats (Wilhelm Barthlott and Neinhuis, 1997). Milk from the resulting transgenic goats then contained water-soluble silk proteins, which by spinning can be turned into silk fibers, although with inferior mechanical properties compared to the original spider silk. The company aims to employ BioSteel in the manufacture of fishing lines and bullet-proof vests. However, major obstacles still lay ahead, not least the question of durability. In nature the spider continuously produce new silk since it is affected by changes in temperature and moisture, as shown in figure 7 below. Inspiration from biological materials is also thought to be useful in development of new composite materials, such as artificial wood and ceramics based on nacre, a natural composite found in the hard shell of molluscs.

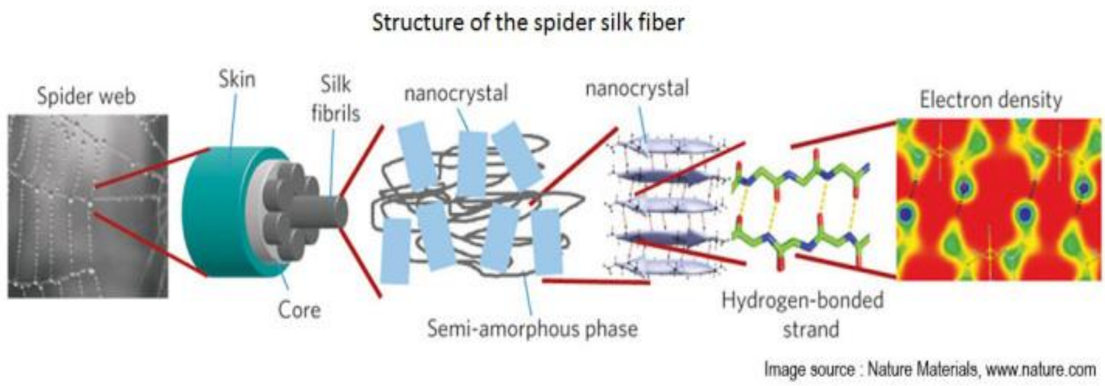

Figure 7, the process of transforming the spider silk into an electron density (MATERIALS, 2010).

2.5 BIOMIMICRY ARCHITECTURAL - CASE STUDY

2.5.1 CH2 Melbourne City Council House 2 by DesignInc

A work of the DesignInc architects, located in Melbourne, Australia, the Council House 2 (CH2) is an office building with a total area of 12500 m^2. As shown below in the figure 8. Located in Melbourne, Australia, the CH2's design purpose was to be a holistic system with its occupants as participants.

Figure 8, CH2 Melbourne City Council House 2 / DesignInc above is the biomimetic concept of the design (DesignInc, 2006).

Biomimicry plays a huge part in the design process of the building, where some influence came from the principles of a termite mound (or ants house hold), by using similar strategies from it. The aim of the city of Melbourne is to achieve zero emissions by 2020. To help achieve this goal, the consumption of energy in commercial buildings should be reduced to 50%, as one of the first contributions. Therefore, the CH2 was set in an effort to be the “lighthouse” for other projects, where it promotes an interactive relationship between the city and the nature. The brief required to build a premium grade office building that gives a working example for the local development markets, where it relies as far as possible on passive energy systems.

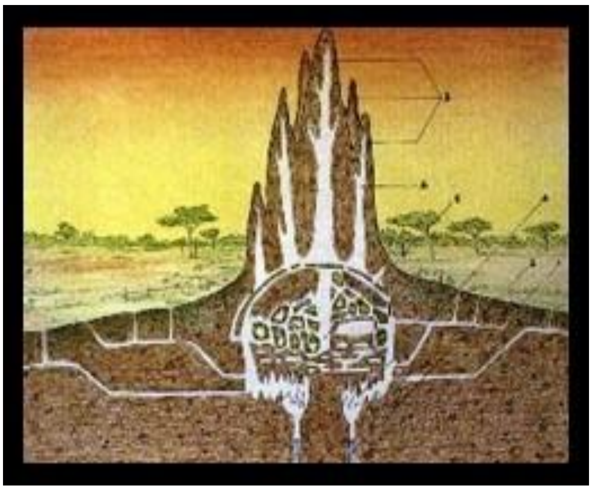

Figure 9, Graphic section for a Termite mound (DesignInc, 2006)

The architectural composition of the building engages both literal and metaphorical expressions of environmental intentions. Where the main biomimcry concept adopted was the imitation or mimicking of the termite mound, and the approach of its survival underground and the techniques adopted in order to obtain good ventilation as shown in the figure 9 above. Another nature inspired system was the façades design where the integration of moderate climate and tapered ventilation duct with natural day lighting strategies and concrete floor structure plays a central role in the building's heating and cooling system, as shown in the figures 10 and 11 below. According to the Green Building Council of Australia, the CH2 was the first new commercial office building in Australia to achieve the six stars rating system. Equally important to its environmental features is that it provides 100% fresh air to all occupants with one complete air change every half hour. The benefits of superior indoor air quality and conservative estimates on energy costs will see the building pay for all its innovation within five to ten years.

In addition to the sustainable interpretation, the building also has an approach to the environmental waste, its consequence and its effect on the surrounding and on the environment as a whole. The building use waste as facilities. That's why the elevation of the building is constructed by recycled untreated platforms from old housing frames. Another concept, that uses energy efficiently, is installing micro-turbine where lift will generate power in breaking mode, and fitting solar hot water produced by 48 square meters of solar hot water panels on roof supplemented by gas boiler.

Moreover, the CH2 don't draw down resources, where water 72% reduction in mains water consumption compared to the existing Council House of similar size, Multi-Water Reuse (MWR) sewer mining plant, Sprinkler water reclaim and rainwater collection, and from the waste approach, the building waste during construction was recycled (87%), recycling carried through within building after operations or waste separation (DesignInc, 2006).

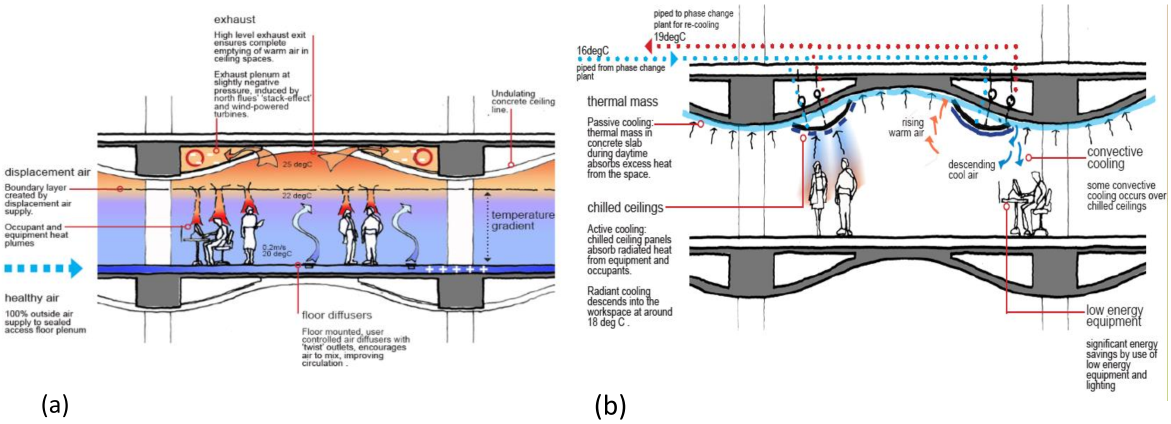

Figure 10, (a) and (b) are info-graphic sections representing the different sustainable concepts of the building inspired by the biomimetic of the termite mound (DesignInc, 2006)

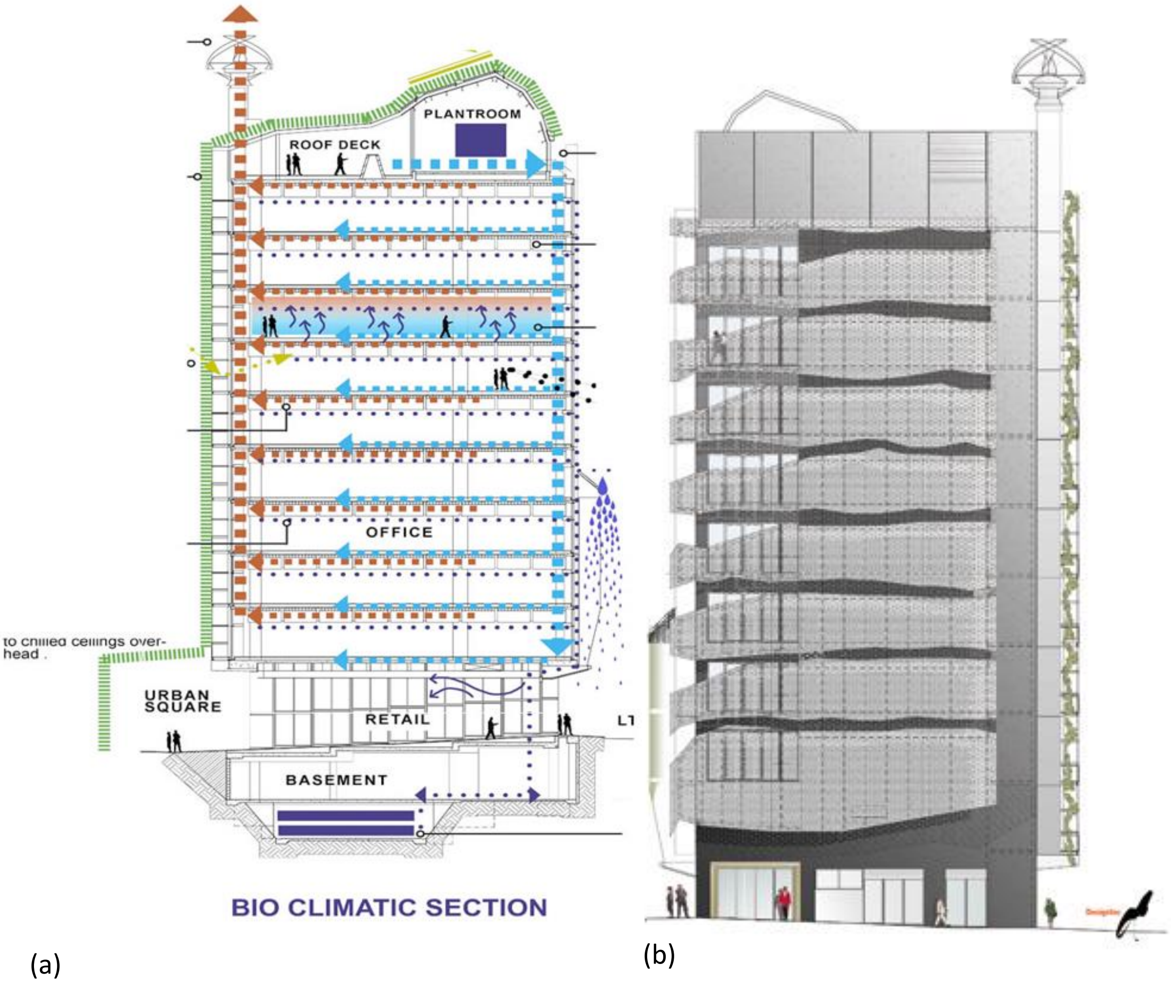

Figure 11, (a) shows a section of the building, while (b) represents an elevation of the building. Both illustrating the different sustainable concepts of the building inspired by the biomimetic of the termite Mound (DesignInc, 2006)

2.5.2 Case Study conclusion

As a conclusion, it was possible to find the use of biomimetic and mimicry nature in this case, where the designer was able to interpret those concepts on an actual construction materials and in an environmental friendly and sustainable concepts, which resulted in an overall more greener and more environmental and sustainable design. Therefore, the issue here is not originating new concepts of sustainability but rather the art of employing already existing sustainable concepts in nature in a real world structure or design for the end result perform in the equivalent way as the studied physique or entity.

3 LIGHTWEIGHT STRUCTURES, MATERIALS AND MEMBRANES.

3.1 INSPIRATION

Engineers are often inspired by nature, science and everyday life when developing new ideas and innovations for the construction industry. Alike the Karlsruhe Institute of Technology researchers, develop lightweight materials and structures after being inspired by bones and bees. Human bones have a framework structure and bees' honeycombs have a shell structure that is durable, yet lightweight enough to facilitate movement. In this context, an industry movement that's changing the way some structures are designed and built which results in lightweight construction materials. Lightweight materials that are composed of sand, cement, and even the fiber of waste from young coconut and durian for strength and bulk density, and are good for the construction of walls and roofs, thereby saving energy and reducing waste from the fruit industry (Buncio, 2016).

Afterward developments in this field resulted in finding of a new mixture with better outcomes, and it's the composites where material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure.

3.2 LIGHTWEIGHT STRUCTURES

3.2.1 Definition

A structure with low/light weight, also called "Lightweight Structures", are widely used in buildings designed with long span roofs such as stadiums, exhibition centers, and etc. These Lightweight structures can help achieve a very low mass/span ratio, incorporate curvature in the design, withstand in hurricanes, extreme climate conditions, and many more, some of those examples are the Japanese pavilion expo that is made of recyclable paper tubes resulting in a building with honeycomb. And the golden-bronze roof of Pulkovo airport where shimmering golden metal panels clad the monumental folded ceilings, as illustrated in figure 12 below. Designing Lightweight structures is not with new materials rather than the use of technological and advanced materials that keeps it a possible option for designers and developers.

(a) (b)

Figure 12, (a) represents Japanese Pavilion Expo 2000. And (b) represents the golden-bronze roof structure of Pulkovo Airport. (Carone, 2000)

A major characteristic of this system is their light weight according to their long span, which helps to enclose roofs for big spaces. To achieve these large spans light/weight structures, the load should be deducted as tension and compression instead of being converted into bending stresses. The FE-analysis of light shell structures is amongst the most difficult tasks for engineers. The typical Lightweight structure is composed of cables, membranes, shell and folded structures. It can also include space grids, braced vaults, domes, and arch stayed truss system (Carone, 2000).

The structures self-weight is usually a small portion of the applied load and the generated forces. These Lightweight structures consist of lightweight materials yet high in strength, as well as the advanced technologies that help in the design and construction. For many forms, the surface is pre-stressed, resulting in double curved shapes that require specialized cutting patterns and care during erection. They are recognized for their aesthetic appearance and their innovative character.

3.2.2 Lightweight Structure. Case Study: Foster and Partners Roof the Great Court

With the need of a new role for the reading room and courtyard that were relieved of it storage duties in the new British Library place, that opened in Kings Cross in North London in 1998, Foster e Partners British architects have elegantly blended it unique brand of contemporary architecture with Sir Robert Smirke's 19th century neo-Grecian building (Barker, 2001). As shown in the figure 13 below.

Figure 13, the great court by foster and partners panoramic photo (Barker, 2001).

The Great Court, the largest covered courtyard in Europe, fundamentally transforms the nature of the entire British Museum building. However, the eyes of any visitor soon transcend the Reading Room to the magnificent steel-lattice roof that covers the quadrangle. The idea was to produce a canopy that was delicate and unobtrusive, avoiding the need for columns within the courtyard. The result is a stunningly unique geometrical form. Although it looks simple and delicate, it represents a feat of modern engineering. The fine steel lattice is constructed from custom-made steel box beams joined at six-way nodes.

The geometry of the roof's toroidal framing was defined using a customized form-generating computer program. The roof shape is curved to a tight radius of approximately 165 feet (50 meters) (Barker, 2001), which means it can act much like a dome, while imposing minimal loads onto the existing surrounding structures. The junction of the roof and the Reading Room uses a ring of 20 composite steel-and-concrete columns, which align with the room's original cast-iron frame. These columns are concealed by the new limestone cladding surrounding the entire drum of the Reading Room. The room's domed roof remains external and is used as the hub for the courtyard's roof. The roof's connection to the original load-bearing walls of the courtyard is through a slide bearing carried by a concrete ring beam on top of the existing wall. The outer edge of the roof rests on a new concrete ring beam at the cornice level of the original Great Court walls. The roof seems to float effortlessly above the space providing an ethereal presence, which is a tribute to modern design innovation and technology (Barker, 2001)

3.2.3 Case study Conclusion

In this case study it is noticeable the interpretation of the concept used in covering the roof and the light structure and a simple structure that occurs in the nature, where it is a great example of not only mimicking the nature as it is, but then again just to emphasize an idea or a concept prevailing in the nature. And it is obvious wherever the designer got the idea of light weight structure from a simple spider net that exists in nature and they didn't mimic it exactly but they grabbed the concept of how it functions and how it works and then apply the similar idea on a real project that needed a cover or a structure that it is strong as it is light to cover the space. So here the biomimcry wasn't implemented directly but was a brief or a door into the complete image or the final solution. Where the nature was the source of inspiration in order to solve a real life problem.

3.3 LIGHTWEIGHT MATERIALS

3.3.1 Definition

During the Industrial Revolution of the 18th and 19th centuries, the basic materials of construction were sparse. There was wood, stone, brick/mortar, iron and steel. However, iron and steel of that day were vastly inferior to the ones used today. In 1709, Abraham Darby established a coke-fired blast furnace to produce cast iron, and by the end of the 18th century (Carlucci, 2000), cast iron began to replace wrought iron, because it was cheaper. The ensuing availability of inexpensive iron was one of the factors leading to the Industrial Revolution. In the late 1850s, Henry Bessemer invented a new steelmaking process, involving blowing air through molten pig iron, to produce mild steel. This made steel much more economical. With the advent of the 20th century, improved lightweight materials such as aluminum, magnesium, beryllium, titanium, titanium aluminizes, engineering plastics, structural ceramics, and composites with polymer, metal, and ceramic matrices began to appear. In short, the Lightweight materials may generally be considered to fall into three categories:

- Metals: advanced steels and magnesium;
- Composites: typically using polymers and fibers for the reinforcement;
- Novel Materials: represented for the ceramics, carbon nanotubes, others.

3.3.2 Lightweight Materials case study: Pohl Architekten

Part of a worldwide research network conducted by PlanktonTech Institute and developed by Pohl Architekten, the COCOON_FS is a structure that integrates architectural sculpture, new technologies and biomimetic principles as shown in the figure 14 below. It focus on basic research of marine plankton organisms such as diatoms, the intention of the project is to develop as a material efficient construction by learning from natural lightweight composite structures. Pohl Architekten created a technical solution by translating natural lightweight constructions into technical prototypes using highly efficient technical fibers. It is a floating system that embodies the activities of PlanktonTech (GROZDANIC, 2012).

Figure 14, a night photo of COCOON_FS. (GROZDANIC, 2012)

COCOON_FS visualizes both natural lightweight construction as well as highly efficient technical design solutions. With its weight of only 750 kg, the pavilion can easily be transported to any location. In the sense of stability the floating construction is able to withstand thunderstorms. The self-supporting shell of the structure is made of FRP (fiber reinforced polymers) that forms the skin and the supporting structure in one. The FRP composite design is optimized by all design parameters including broad iterative research of parametric design, production needs. Compared to biological solutions in nature, the structure is to be seen as morphogenetic design.

3.3.3 Case study conclusion

In this case study, the objective of the design it's not only mimicking the nature in structures or forms, but mimicking it in the composition and use of materials in the project, where the design time have solved a technical solution by translating natural lightweight constructions into technical prototypes using highly efficient technical fibers. Therefore, it's possible to see that this structure implements a new version of mimicking combining the form with the materials in a fully integrated project.

3.4 LIGHTWEIGHT MEMBRANES

3.4.1 Definition

The Latin word "membrana", from which the modern "membrane" is derived, means a "parchment" or "skin", the main characteristic of which is its thinness. The Lightweight membrane represents a light material used to form lightweight constructions. That is, the architectural membrane represents both a material and a structural principle.

Modern membranes used in building construction as load-transmitting surfaces have to be capable of being tensioned and adopting three-dimensionally curved forms. The thin skin is able to resist only tension loads. Mechanically tensioned membranes should ideally form a doubly counter-curved surface; while pneumatically tensioned systems are usually in the form of doubly curved surfaces in a single direction. Only in this way can the membrane resist opposing forces, such as wind suction, wind pressure and snow loading, and transmit them economically and safely to the primary structure and the foundations. Since the 1950s, the development of plastics technology – especially in the form of composite materials – has led to increasing numbers of innovative membrane projects. Materials of great strength now allow the construction of large-span, translucent roof structures with slender dimensions and without intermediate columns. In the future, one may expect an ever greater use of membrane systems as permanent space-enclosing structures, even under the climatic conditions prevailing in central and northern Europe (Mauritz, 2010).

Due to their lightweight construction and their great variety of shapes, membranes are ideally suited for extensive roof constructions, facade elements, or mobile constructions.

Product Features:

- low weight due to lightweight construction
- large, complex membrane shapes are possible
- individual structural calculations

Fields of Application:

- Weather protection membranes, for example large shade sails
- mobile, temporary constructions, for example for events
- extensive membrane roofs for event locations or industrial buildings
- facade structures

3.4.2 Lightweight Membranes case study: Kazakh Hotel

Placed in the center of the domed roof, a foldable membrane with an area of 470 square meters (562 square yards) was designed and tailored to fit accurately a hemispherical shaped glass dome (Planex, 2016). The purpose of building this membrane inside the event venue in Kazakh Hotel was to cover up the venue during summer to provide shade, darken the place when needed and provide good room acoustics. Leaving the venue with a bundle of folded membrane in the center and giving an esthetically attractive look when opened, the membrane should open and get retracted with excellent folding features, as shown in figure 15 below.

(a) (b)

Figure 15, (a) and (b) illustrates the foldable structure above the arena (Planex, 2016)

In order to insure an enduring moving mechanism, the material of the connections should suit and bear the long-term stress caused by regular folding and unfolding. In search for the suitable material, Planex ordered the German Institutes for Textile and Fiber Research to perform a folding endurance test according to DIN 53359 (Planex, 2016). After performing a biaxial tension tests to analyze the strength of the material and of the seams by the Blum Laboratory, the results came in very good, and further tests (stress-strain characteristics and relaxation characteristics) were without complaints.

The manufacturing department started preparing the drawings, the cutting layouts and the detailed plans. The layout of the cuts, the seam allowance and other functional and technical aspects were defined. To guarantee a perfect fit, a CNC cutter was used to cut the membrane segments based on DWG drawings. The seams were made with a high frequency welder to achieve extremely resistant connections. Pockets were fitted to protect the radially running straps from UV radiation. Only five months passed between signing of the contract and completion of the foldable membrane.

3.4.3 Case study conclusion

In this case the subject is the way the designer manage to design and implement and build the covering while using membranes and how fast he managed to complete it in a real design issue. This aspect is very important where with the high level of technology existing in our world nowadays the impossible is becoming possible and everything can be completed and build if it was established in the right way. Which opens the world of emphasizing and mimicking the perfection which is nature or what is known as impossible concepts.

4 PROJECT SITE LOCATION

Located in the center of the Campus of Azurém of University of Minho, in Guimarães, Portugal, this project site is a place that has great impact on the campus, with a great flow of pedestrians and users, increasing the importance of a differential status where the project developed within this dissertation and for the initial site.

4.1 UNIVERSITY OF MINHO

The University of Minho, located in the region of Minho, was founded in 1973. It is one of the then named "New Universities", because at that time it deeply changed the landscape of higher education in Portugal. UM is one of the biggest Portuguese universities, with over 19,000 students (42% of which are postgraduate students) and with about 1300 professors and 600 employees. The University of Minho plays a huge role of development and growth, which makes it a representative for it in the region. This university is known for its significant economic activity and by the youth of its population. The University of Minho is one of the 100 best universities in the world, according to Times Higher Education ranking, as of 2013, for universities founded less than 50 years. It occupies the 76th position in the ranking, and the 75th in 2014. The university is widely regarded for the number of citations of its published papers. In the Times Higher Education World University Rankings of 2015, the university was ranked between 351 and 400 worldwide (Minho, 2017).

The first students ever to be enrolled in this university were in the academic year of 1975/76. After that, in February 1974, the official community took office, defending a model "University Project groups" (as opposed to an organized structure in Colleges or Departments) based on a matrix system structured in "Teaching Units", "Units Research "and" Support Units ", which justified the choice of plants" concentrated type " materialized in a configuration "University Campus", which was intended to open the community. While stemmed the debate on the location of the new campus, the school was initiated in facilities provisional in Braga and Guimarães, in the city, the University worked initially in vilaflor Palace, In 1976 the Foundation Committee of the University of Minho regards the urgent need to answer to the question "University of Minho: where". The campus in Guimarães stayed open two years later. An intervention was implemented in Urbanization General Plan Fernando Távora in 1980 (Fernandes, 2007). After the report of the Regional Development Agency referred to "Need for local authorities (Hall and Municipal Assembly) can intervene in the process of defining and organization of universities designed Guimarães". It was expected to locate the university facilities in the fertile valley of the Ribeira de Santa Luzia, in a vast area between the hill and Latito hill of S. Pedro de Azurém. This area is near the historic city center and has an excellent framework landscaped. In the city of Guimarães, in the year of 1541, King John III authorized the allocation of degrees, the bachelor and PhD in Arts, in high school located in the Monastery of Santa Marinha da Costa; even though this school was transferred to Coimbra in 1553, the public studies on grammar, philosophy and theology were set to resume in 1681. That’s why now the city of Guimarães has a university tradition.

Figure 16, The Arial view of the Campus of Azurém, University of Minho (Minho, 2017)

This campus shown in figure 16 includes many schools such as The School of Engineering with most of its courses, The School of Architecture, some of the School of Sciences and of the Institute of Social Sciences. A general library and several specialized libraries can also be found in The Azurém Campus. It also contains a canteen, a grill, three bars, a medical station, a sports complex and a copy center. The construction of the university was divided between the years. The engineering building was one of the first buildings to be constructed. It was designed by the famous Portuguese architect Fernando Távora who helped in shaping the Portuguese modernism movements in the 80s. After that, the architecture building was completed by the same architect. Later, different construction companies had their touch to the campus, by adding structures and buildings until it became what exists now. Reaching till now, works continue with the library building that is being constructed now.

4.2 FERNANDO TÁVORA

A well-known architect from Portugal, Fernando Luís Cardoso de Meneses Tavares e Távora, simply called Fernando Távora, was born on August 25, 1923. He began his architectural studies in 1945 at the School of Fine Arts of Porto, which concluded in 1950 with the project of a sea house. With this project, it showed immediately his understanding on modern architecture, positioning him among the few Portuguese representatives in the "International Congresses of Modern Architecture" in the following years where he met the best modern architects of the time. Later on, he came to join the team of "Survey on the popular Portuguese architecture" in the year 1955 (CURTIS, 2013). Joining this team is extremely influential in the future of architecture in Portugal, especially that it is the most ambitious initiative, related to this topic, to date.

Figure 17, Fernando Távora (CURTIS, 2013)

Besides and after his academic career, Távora shown in figure 17 worked as an architect on several different projects. These projects include Porto Town Council, consultant to Vila Nova de Gaia Town Council, consultant in the Commissariat on the Urban Renovation of the Ribeira/Barredo (Porto) project, consultant in the Technical Bureau of the Northern Planning Commission, and consultant in the Local Technical Bureau of Guimarães Town Council. He also worked on the General Plan of Urbanization Guimarães. This General Plan reserves a vast area of fertile valley situated between the Latito hill and the hill of San Pedro de Azurém, for the installation of a Campus. This area convers the land of Azurém Quintas, Azurém Low, the Verdelho and Veiga, north / west of axis Campo de S. Mamede / Street S. Torcato, south of the new highway and the source of Mall University. The designed plan defines and ensures the effective reserve of the whole area, which will be then partially reduced, but the deployment of patches of buildings is dedicated to the education university (CURTIS, 2013).

After his astonishing works, Távora was awarded several prizes in architecture, as well as the Golden Medal of the city of Porto and the Order of St James of the Sword. The University of Coimbra awarded him a Doctor Honoris Causa (CURTIS, 2013).

4.3 THE ARCHITECTURE OF THE CAMPUS OF AZURÉM

The School of Sciences and Social Sciences, the School of Architecture and the Educational Complex (1st and 2nd phases), in the Campus of Guimarães, deserve the attention for the prestige of its authors who wanted the quality of the solutions they present reflected in their design. The Bartolomeu Costa Cabral projects for the first two phases of Azurém Educational Complex can be now considered as a single entity, because the most recent work repeats "the architectural and construction solutions of the 1st phase, in order to give unity to the whole” (Fernandes, 2007) , as shown in figure18 below. And has the same implementation principles, two parallel bodies that longitudinally extending along the axis southwest-northeast that organizes the entire campus.

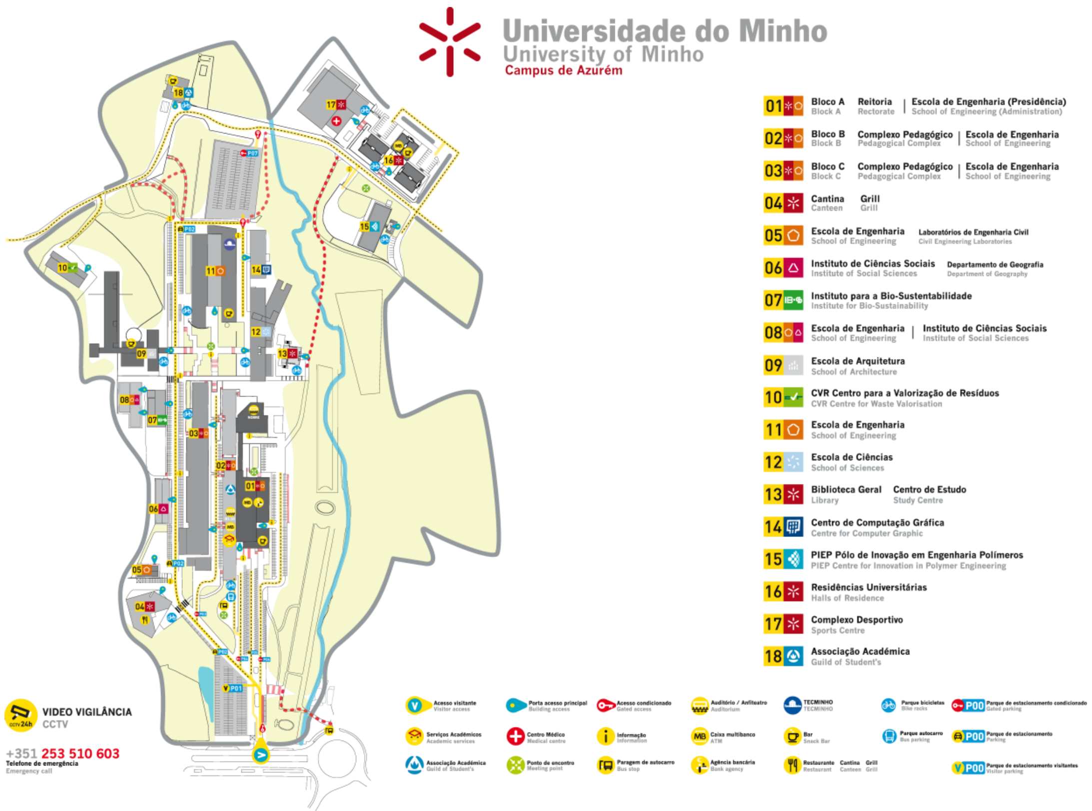

Figure 18, Graphical map of university of Minho, Azurém campus (Minho, 2017)

A large atrium, running through the main building of the educational complex, distributes access to all collective spaces. In this authentic interior street, a skylight, stretched alongside the aisle, emphasizes the longitudinally of the atrium and helps illuminate the whole space. With a terrace facing the Latito lot and the castle and the library (downstairs) of northwest side drawing there are the administrative offices and auditoriums. The upper floor has work classrooms and laboratories, initial installations of the Engineering School that relates to the central atrium through a dynamic set of galleries. The lobby axis extends outwards, like a small square overlooking the hillside Latito, which functions as an outdoor foyer for the main auditorium (built in the 2nd phase) completing this composition. Throughout the collection recognize architecture with predominantly functional concerns, without thereby neglecting the search for an image that prestige to the institution and a good adaptation to the context. Their language is obviously influenced by the modern movement, whether in the remarkable application of Le Corbusier's "five points of new architecture" (such as the use of pillars and horizontally stretched windows and their part in defining the language of this project) or in the use of formal vocabulary Aaltiano evident in the organization of the library and the design of the noble audience. The outer galleries, on the other hand, found an industrial language, emphasized by the assembly of standard metal parts (articulated with concrete slabs left to view) in a design that combines economic efficiency and simplicity and suitable for a building that originally functioned as a school of Engineering.

Following the aforementioned expansion plan Azurém Campus, the third phase of the project sought to link up with the organizing principles of the initial Educational Complex. Its implementation was organized around a square that has an effort at a higher elevation, the former organizer axis Campus: the outer longitudinal path located between the two buildings of the first phase. Interpreting this axial logic, designers of the new Engineering School took as a principle the compositional extension of this route, creating a vacuum inside the same alignment, dividing the building into two separate but interconnected bodies. This intention, however, does not immediately become clearly, since the height difference between the deployment platforms of buildings of the first two phases and the third is difficult to read this continuity, which is also disturbed by the asymmetrical varied expression (either in volumetric, or in the language) of the elevations the two bodies of the building, the tops facing the new square. In buildings Sciences Schools and Social Sciences and Architecture intended relationship with the former Costa Cabral projects is more consistent. The project Alexandre Alves Costa and Sergio Fernandez was not built in its entirety, since the planned tower to the south side was not performed. But his relationship with the buildings of the pre-existing set is evident in the alignments sought for its implementation and in the longitudinal development of its main body in the southwest-northeast direction, parallel to the dominant campus axis; the importance attached to this axis is well stated in structurally bold console the building form to west / south, seeming to contradict the rigidity of the border established by the support wall that emphasizes the difference in elevation between the platform where it implants the initial Educational Complex and the new square. In the language it is also evident a search for dialogue with the pre-existing buildings, taking a purist influence, which are visible evocations of the already mentioned "five points of new architecture" and the concept of "architectural promenade". This reference is evident at the main entrance, where the articulation of the succession of pillars with the curvature of the glass and the ramp seems to evoke the aforementioned house Savoye. However, the presence of this bend in the elevation results from an intersection of volumes, inside the building, is assumed as the main space theme. The site location where the square or space under study was developed in a large raised platform that framed the southeast facade of the building, by aligning its limits; under this great platform, passed the car access route that from the canteen, followed along the Northwest Educational Complex facade and was extended through the new buildings of Engineering and Architecture.

4.4 THE STUDY AREA

The study area consists of approximately 4900 m^2, with respectively 64.7 meters and 74.6 meters, as illustrated in figure 19 below. The current situation of the site is an open space, which is intended to be a buffer zone where it is located practically in the middle of the campus and it related all the campus resources to each other. The design of the site is an alteration of grey and green materials which are brute concrete and grass with the installment of several trees but it is noticed that the area doesn't have a sheltered space or protected space where there is no shading part in it and the trees are too small to create any shading of some sort, which respectably created an immense problem in using that space in winter.

Merging the different functions and activities areas on the initial map of the university, it is very understandable that the site is a very communal and a vital point in integrating all axis of movement and connecting the different facilities of the campus. At the site, it is necessary to walk in the study area or the periphery of the study area in order to go from a point to the other in the campus. So the focal point of the entire campus is this location. And because the shape of the site is a longitudinal one, the site which is approximately in the center works as a space to free or discontinue the longitudinal axe, working both in the shape mode and function approach, where it breaks the uninteresting longitudinal axe and free the center in order for the user to feel free from the hardening of forms in the surrounding.

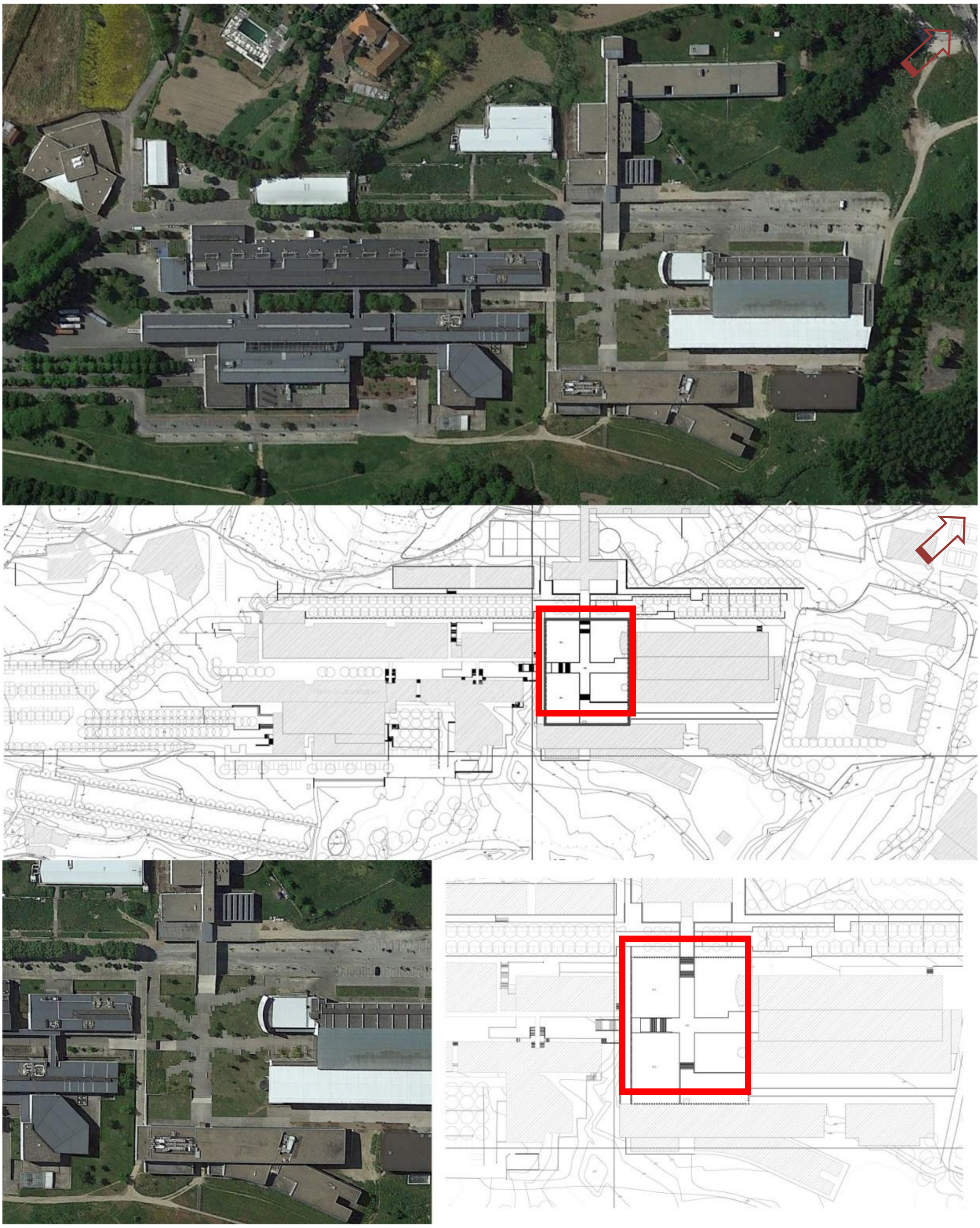

Figure 19, Different maps that displays the location and shape of the site, adapted by the author (Minho, 2017).

In Figure 20 shown below, it's possible to identify all the sectors and functionalities of the Campus of Azurém of the University of Minho in Guimarães, in order to better understand the relationships between campus buildings and spaces, and the importance of the circulatory space that represents the site of implantation of the project to be proposed.

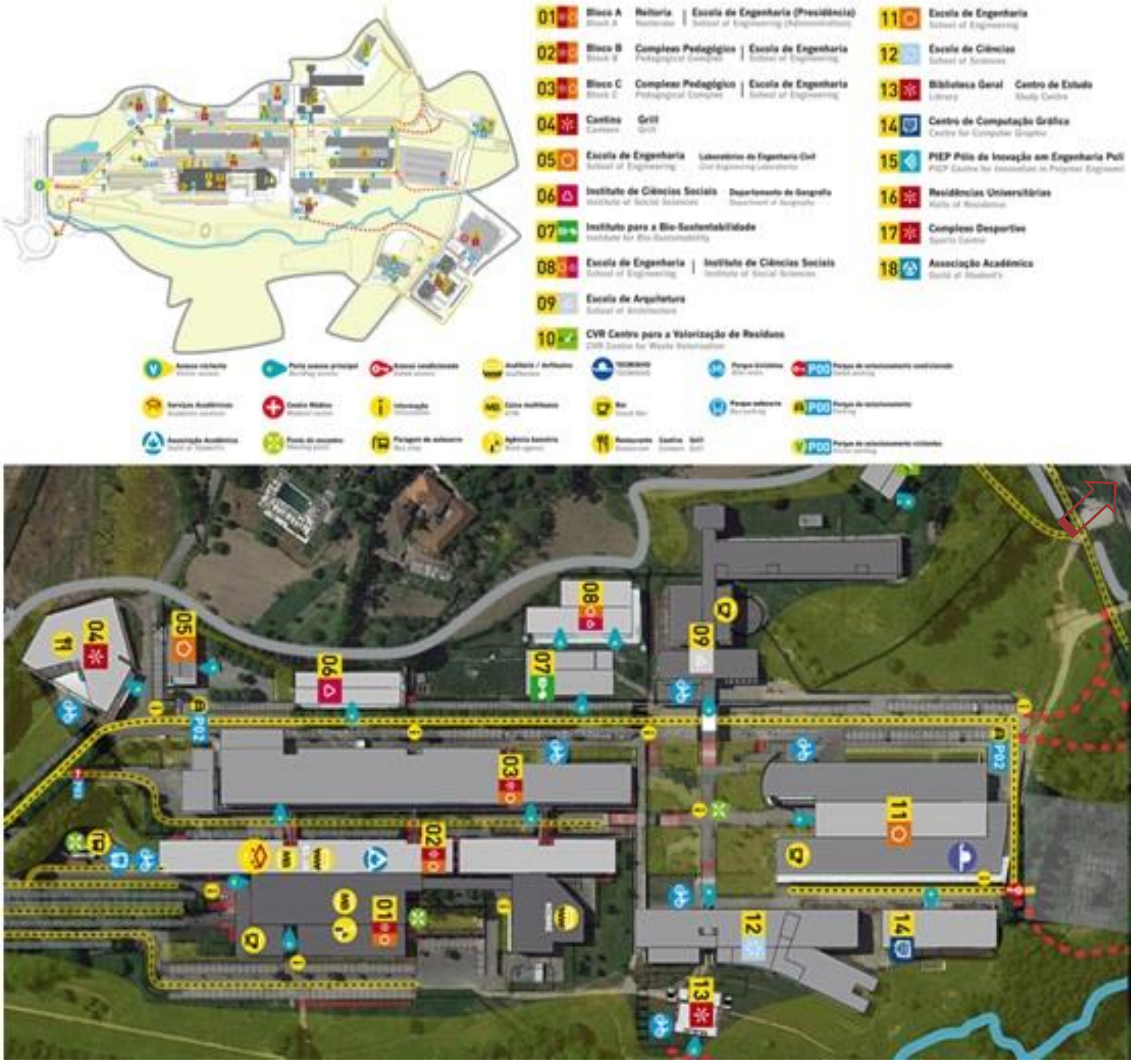

Figure 20, the integration of a functional map and the initial site in one displaying map (Minho, 2017)Adapted by the author.

4.4.1 Bioclimatic Analysis

Making the analysis in relation to the environmental conditions in the site, it's possible to conclude that the site is very environmental accessible from the sun rays hits the square through the large distance between the buildings and the center of the site, as illustrated in figure 21 below. This is an important characteristic of the place, working as an advantage and a disadvantage for the design propose that depends on the state of the environmental and the time in the year. The open space also presents the wind incidence in different ways, which means that the area has good incidence of sun and wind, both being considered as conditioning factors and potentialities for the project.

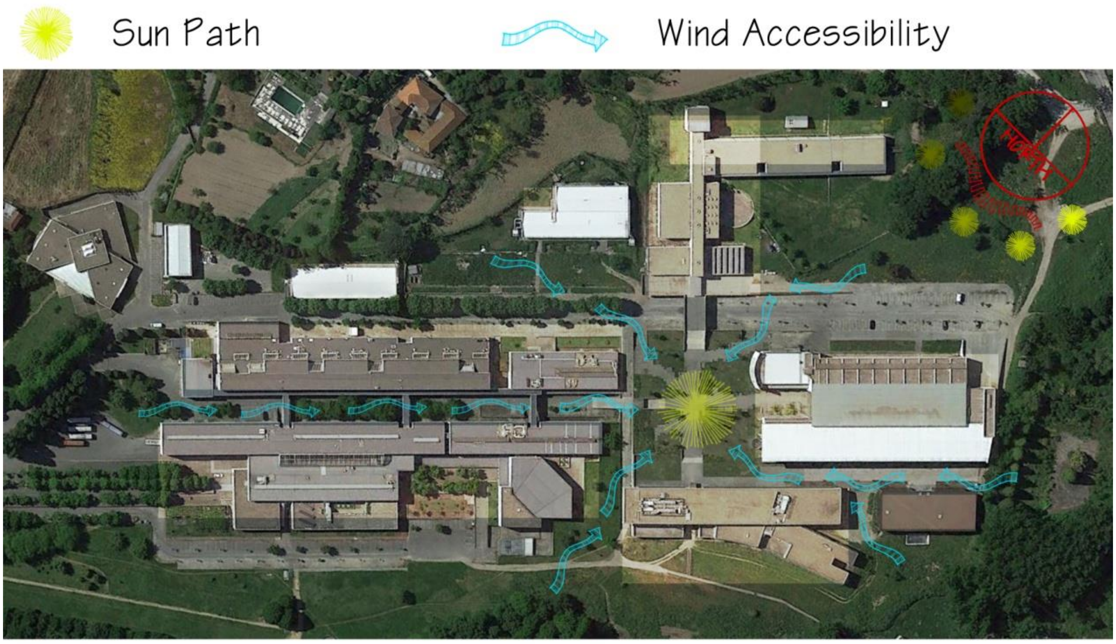

Figure 21, the campus of Minho site modified by the author in order to reflect the environmental facets on the site (Minho, 2017). Adapted by the author.

4.4.2 Area Accessibility

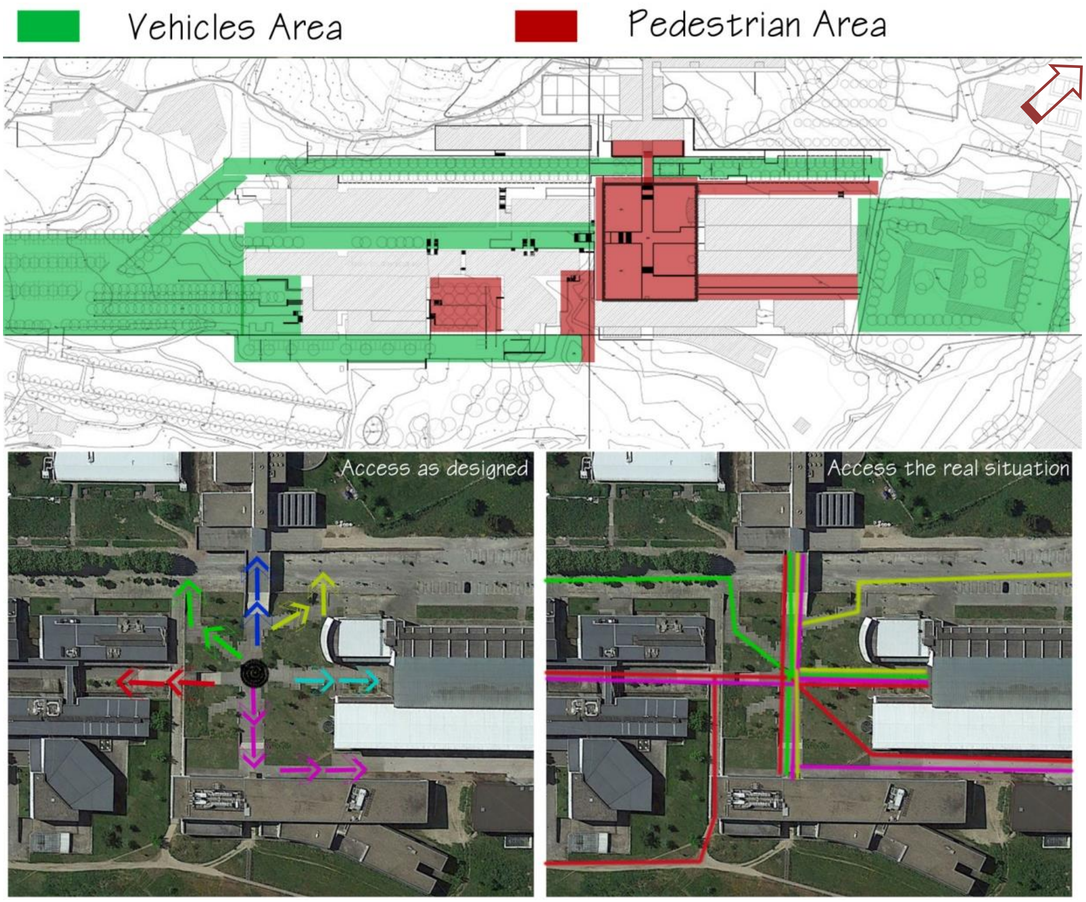

Figure 22, three maps representing respectively the accessibility of the site and access as designed and access of the real situation (Minho, 2017). Adapted by the author.

Figure 22 above discuss the surrounding common spaces of the site where the assimilation of the vehicles areas and pedestrian areas which contribute in the access of the proposed site. The university campus is designed in a way that each faculty has vehicle access near its entrance and focal points and a pedestrian area that connects directly to the facility. It´s noticeable that accessibility for the entire campus is very respectable in both pedestrian and vehicles aspects, and the site plays a big role in connecting and relating the vehicle area with the entrances if the different facilities of the campus. Also in figure 22, analyzing the movement of the users and examining the initial vision of movement for the site as designed by the initial architects, it is very clear that there is a big problem in the way the users are relating to the space and the way they are using the open space of the site. The initial design the site or the open space was designed and intended to obtain and play the role of the buffer zone of the campus were students should connect to the campus from the center of the site. But after studying the movement of the users in a real situation and connecting each movement path from the entrance of a facility to its respective access, it`s possible deduce that there are a lot of empty spaces in the site and the center of the site is no longer playing the role that was designed to ensure.

4.4.3 Site assessment

In every project the ambitions of the designer and the imagination is always much bigger than the real world and the limits and glitches that manifested on the way to sort out the design. The imagination is considerably bigger that the real world where besides the studies started from a big scale and started to be narrowed down into details and more minor scale and minor facets. And In this case at the beginning it started as a study for the entire site where it started as a serious studies for the entire site as shown in the figures presented down, tackling the connection between diverse paths in the site and the levels and the assembly of the site and the relation between grey and green spaces in the location and the placement of different buildings and architecture elements and also the movement of the users and the pedestrian walkways that are demonstrated in the location. As illustrated in the series of maps represented respectively in figures 23, 24, 25, 26, 27 and figure 28 below.

Figure 23, modified site plan for the location, adapted by the author.

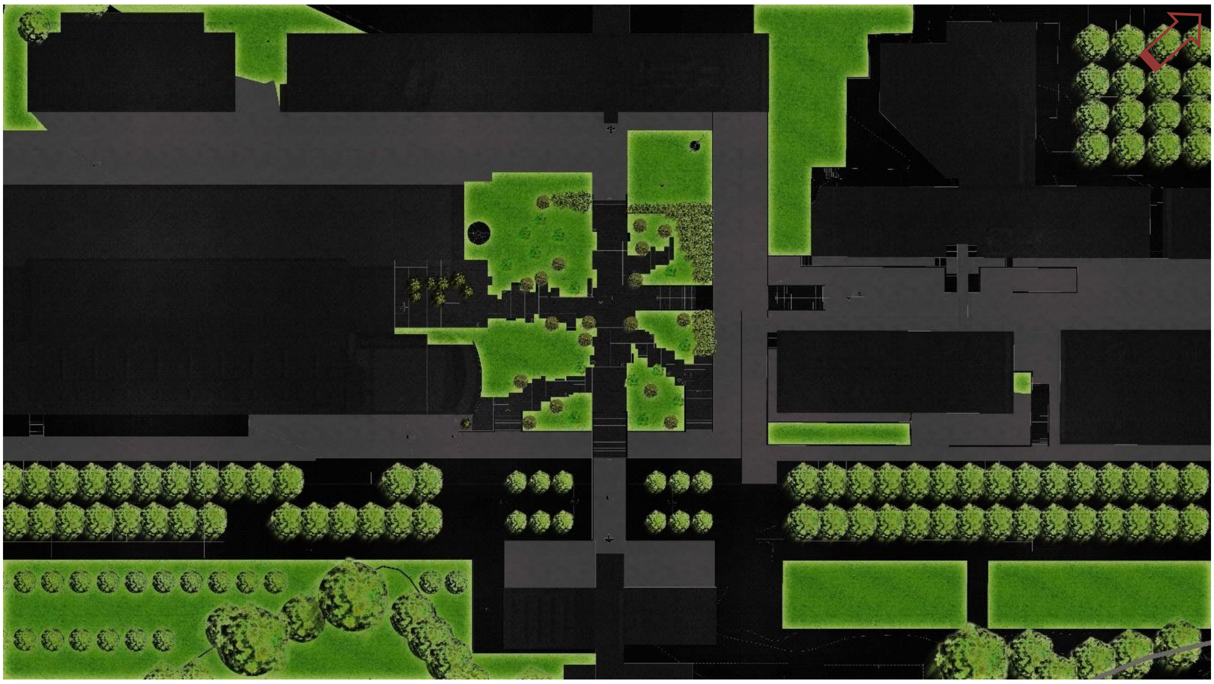

Figure 24, illustrating the green areas surrounding and existing in the site, adapted by the author.

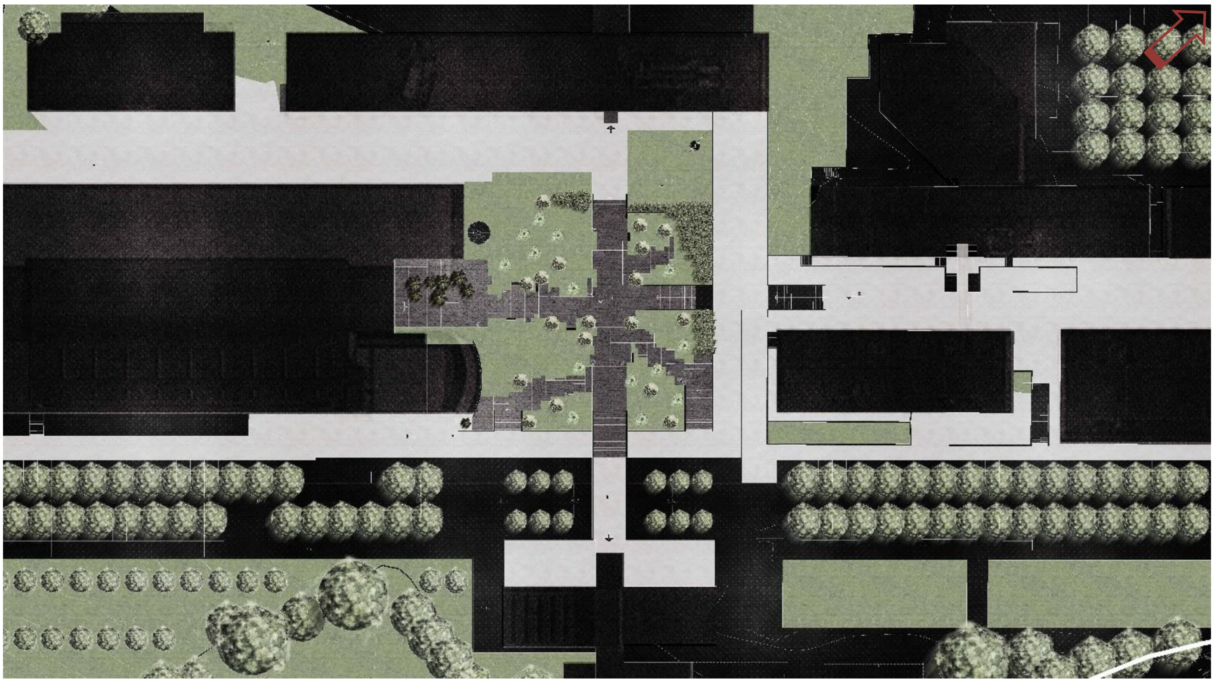

Figure 25, illustrating the grey scale area of the site, adapted by the author.

Figure 26, illustrating the different elevation levels of the site, adapted by the author.

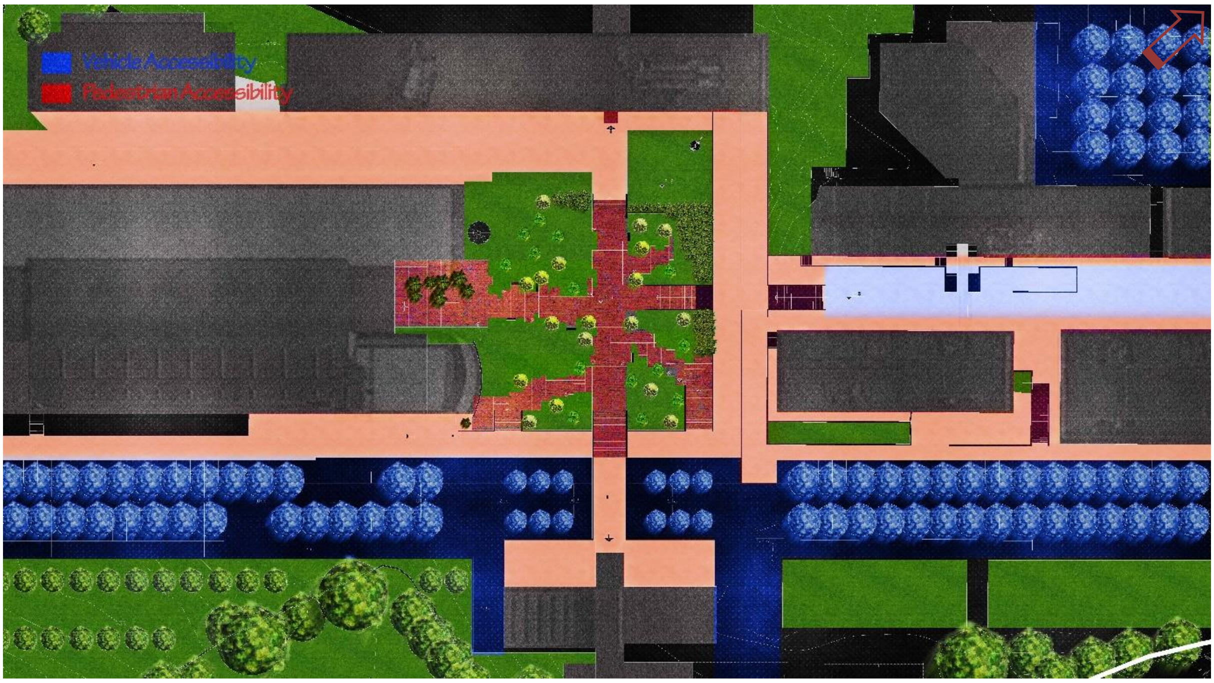

Figure 27, illustrating the vehicles and pedestrian accessibility of the site, adapted by the author.

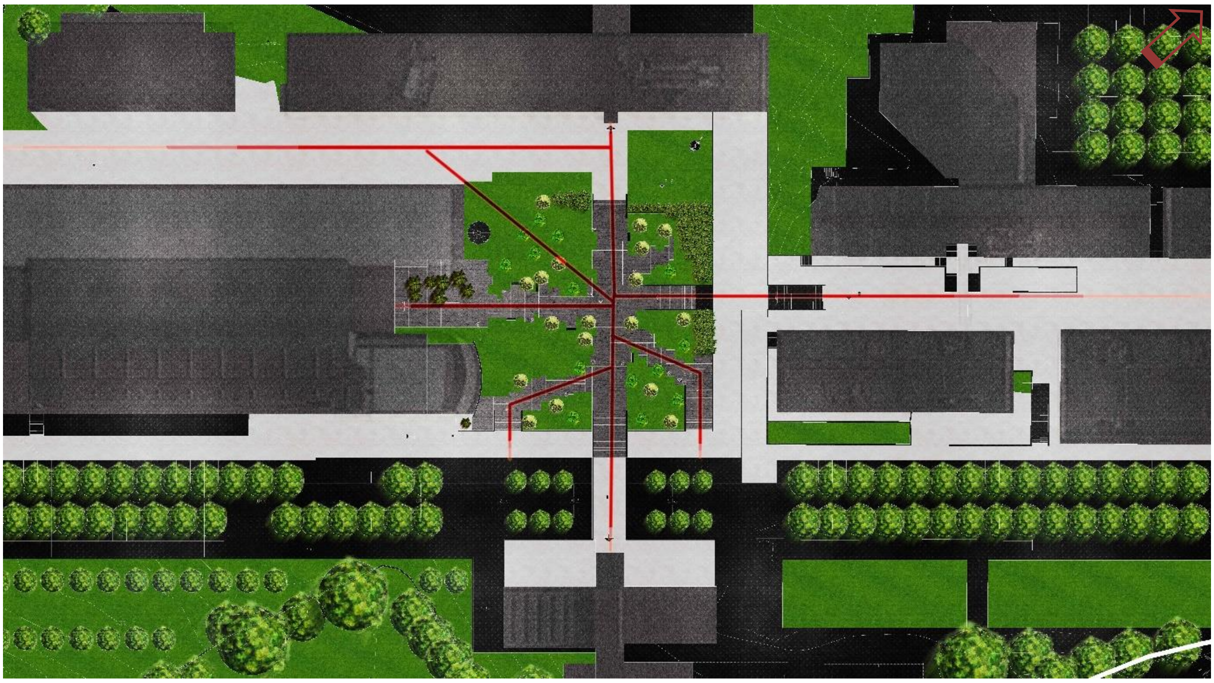

Figure 28, illustrating the connection between the diverse accesses of the site, adapted by the author.

4.5 SITE ANALYSIS CONCLUSION

In conclusion, the site main problem consists of a number of issues, one of the core difficulties is that the location is being used as a buffer zone for users it is not a chief attraction spot in the campus but rather a connection between the different facilities of the campus without adding or directly affecting or engaging the users in one way or another. Besides the main problem is the campus don't have this focal point that connects the different users to each other or don't engage the users in some sort of an activity, but it is used as a route only. Where all the users of the campus either students or staff or etc… can't relate to the site and be associated with it. Accordingly, the main objectives for the design is to be this attraction that grabs the users and affect them or relate them to the site and to each other, where a design in this area of high accessibility will affect a big number of users of the campus if not all users. Therefore the design have to effect and target everyone and not only specific facet of the users. Hence the end product should contemplate that the site has its main objective as a buffer zone it is there to attach the facilities of the campus in one pivotal point but the matter here is that somewhere in this setting a product should exist in order to appeal and intersect more users into the campus and relay them to it and that's the key idea.

5 THE STRUCTURE DESIGN

5.1 CONCEPT: SPIDERS WEB

When one thinks about spiders, the first thing that comes to mind is their webs and their complex design. A spider's web contains its own architectural blueprint, and the engineering calculations to accompany it. In order to succeed, the spider first needs to draw up a blueprint, just like an architect. That is because an architectural structure of such size and strength is impossible without a blueprint. After the blueprint has been readied, the spider needs to calculate what loads will be placed on what areas of the web, just like a construction engineer. Otherwise, the web will just collapse. The material produced by the spider is five times stronger than steel, yet it possesses neither furnaces nor technology. When one considers how the spider weaves its web, a real wonder emerges. A tiny creature with no intellectual ability can produce a thread tougher than steel and erect structures with it. It is a great phenomenon how it can do all that in the same way architects and engineers do. The webs are built by dew spiders are both aesthetic and amazing in terms of engineering. These spiders build their webs on a horizontal plane to appear like a sheet lying on grass. They use vertical grasses as girders and ensure that the weight on the grass is evenly distributed on this grass. This method was reproduced by people, in order to cover large sites.

Moreover, the remarkable mechanical properties of these natural fibers have attracted the attention of materials scientists. Researchers are looking to arachnids and other silk makers for ideas about how to make new structural materials for bridges and vehicles, dirt-resistant adhesives for climbing robots and sturdy polymers for biomedical devices. Many silks bring together properties that are not readily present in man-made materials, the extreme toughness and elasticity seen in spider threads is one example. When the orb web has deteriorated and is no longer useful, many spider species will destroy it, eating up all the threads so it can recycle the raw silk material. Spiders may leave the heavy bridge thread so that they can easily rebuild the web at a later point.

Consequently, a structure design's main purpose is covering large areas, and doing so, nature had the answers for this implementation. One marvelous answer was the spiders' nets where the design, shape and materials of these nets, if implemented and emphasized on a bigger scale, can and will satisfy the need. In this case, designing a shading part or a shelter in a sustainable Biomimicry way is inspired and highlighted from the spider's web.

5.1.1 How spiders make webs?

Spiders have several spinnerets at the base of their abdomen. Every gland produces a thread for a special purpose. There are seven different known glands. Each spider possesses only some of these glands and not all seven together. Normally a spider has three pairs of spinnerets, but there are spiders with just one pair or as many as four pairs of spinnerets, with each spinneret having its own function, as illustrated in an internal anatomy of a spider in figure 29 below.

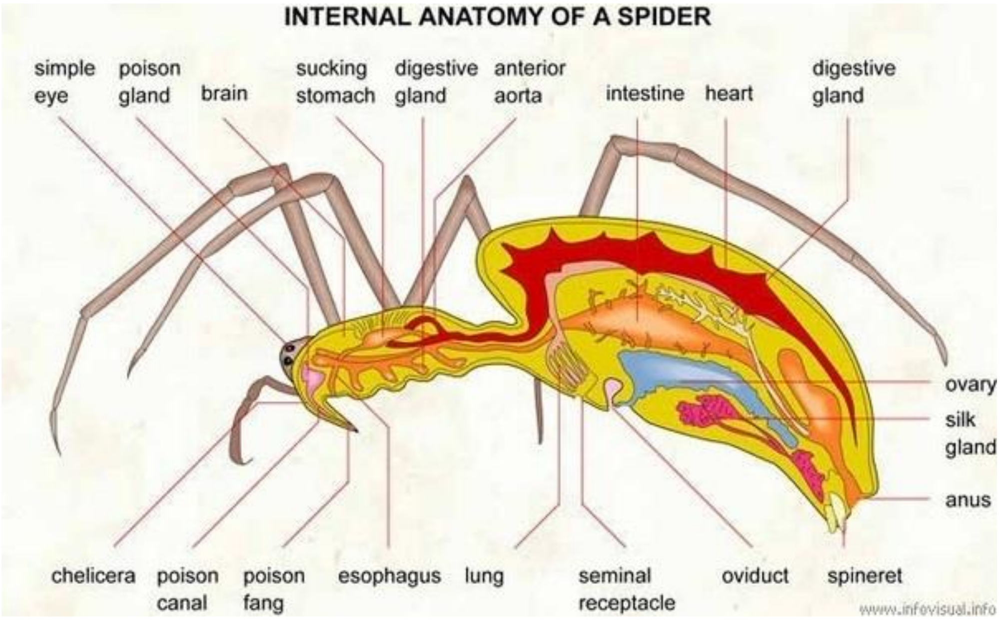

Figure 29, illustrates an internal anatomy of a spider. (Dery, 2005-2016)

The average diameter of a thread in an orb web is around 0.15 mm, and the smallest measured thread was only 0.02 mm thick (Szalay, 2014). The web can be seen only because of the sunlight's reflection on its threads. Even though the wires are very thin, but they are capable of stopping a bee flying at full speed clashing into them. This thread is not only strong but also very elastic. A thread of the orb web spider Araneus diadematus can be stretched 30 - 40% before it breaks, but steel can only be stretched 8% and nylon around 20% (Szalay, 2014).

5.1.2 Types of webs

There are several different sorts of web that can be found: the sheet web, the orb web, the tangle web, the funnel web, the tubular web and the dome or tent web, where some of those webs are represented in figure 30 below. Furthermore the most common type of web is the orb web and is usually found around households. Referred to as the orb web, the name came because of its circular shape and its resemblance to a giant wheel. Also, this web is an immensely strong web.

Different types of silk may be used in web construction, including a sticky capture silk, or with fluffy capture silk, depending on the type of spider. Webs may be in a vertical plane (most orb webs), a horizontal plane (sheet webs), or at any angle in between. Most commonly found in the sheet-web spider families, some webs will have loose, irregular tangles of silk above them. These tangled obstacle courses serve to disorient and knock down flying insects, making them more vulnerable to being trapped on the web below. They may also help to protect the spider from predators such as birds and wasps.

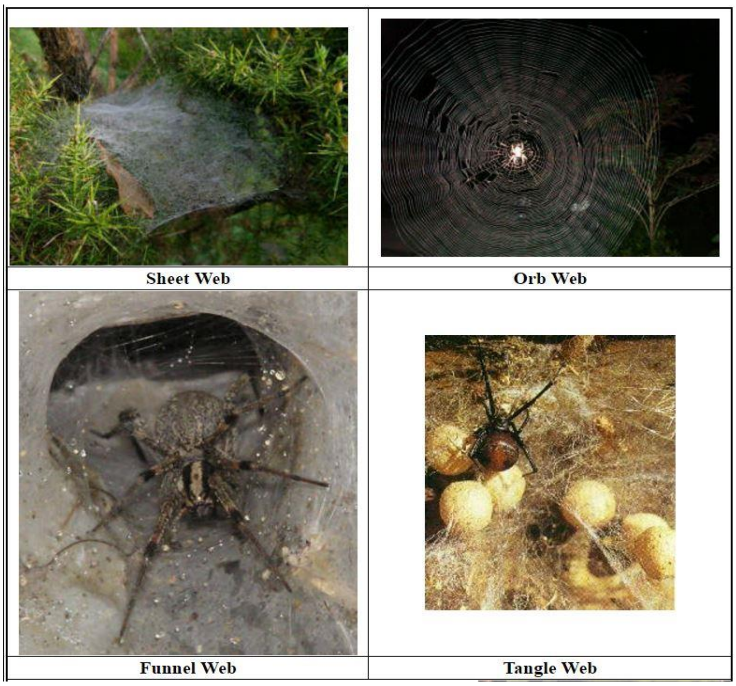

Figure 30, the different types of spider webs (Szalay, 2014)

Besides the orb webs, other web designs are used by different species. The net-casting spider, Deinopsis, constructs a web between her forelegs and hangs head down waiting for an insect to pass. The web is thrown over the victim and entangles it. The Bolas spider also has a special catching technique. As the name may suspects she throws the thread with an adhesive bubble at the end to her prey. The prey is decoyed by chemical substances (pheromones). The trapdoor spider hides in a tunnel that can be closed with a door. If the prey walks over a signal thread the door is opened and the spider grabs it. Funnel weaver spiders spin a horizontal mat and wait in a funnel at the end for their prey to come along. The Linyphiidae and Theridiidae to which the red backs and black widow belongs use three-dimensional tangled web (Szalay, 2014). Linyphiidae makes a horizontal dense sheet web with a lot of non-adhesive threads above it. If an insect flies against a thread it tumbles onto the mat and is grabbed. The Theridiidae construct a messy space web in which the prey is entangled.

5.1.3 Uses for Spider silk

Spider silk was and still used for several applications. Some of those applications can be considered under the implementation or influence of nature which put it in the case of Biomimicry, even though some of those application where completed in old times where nature was the only reference and the ultimate guide for Biomimicry concepts to the people. In olden times, it was used to treat wounds and control the bleeding when someone is injured. Polynesian fishermen use the thread of the golden orb web weaver Nephila as fishing line. In the New-Hebrides spider web was used to make nets for the transportation of arrow points, tobacco and dried poison for the arrow points. Some tribes in New-Guinea used webs as hat to protect their head from the rain.

During World War II the threads of Araneus diadematus, Zilla atrica, Argiope aurantia and other orb weavers were used as hairs in measuring equipment. The Americans used the threads of the black widow (Latrodectus) in their telescopic gun sights.

In 1709 a Frenchman, Bon de Saint-Hilaire (About, 2009), demonstrated the possibility of making fabric from silk. Many cocoons were boiled, washed and dried and the thread was collected with fine combs. Some socks and gloves were produced. A study to the economic yield of this method revealed that this would never be profitable. It was calculated that 1.3 million spider cocoons were needed to produce one kilogram of silk.

In Madagascar there were some attempts to milk Nephila's for the production of silk. A thread was pulled out of the spinner of the spider by hand. If the spiders silk was exhausted, she was put back in the forest and the next spider was milked. The gathered silk had a beautiful golden colour. This project was also banned because of many problems (About, 2009).

5.2 DESIGNS CASE STUDIES INSPIRED BY SPIDERS NETS

5.2.1 Human-Scale Spider Web

The fifth Tape Installation exhibited by Numen/For Use, made from 700 rolls of clear packing tape (bernik, 2010), shown in figure 31. The design team developed an incredible human-size inhabitable spider web at DMY Berlin 2010. The making of the human-sized web took place over four consecutive days inside of the Tempelhof former airport. Almost 45km of tape wrapped around constructed scaffolding posts that allowed visitors to experience the installation by crawling around inside.

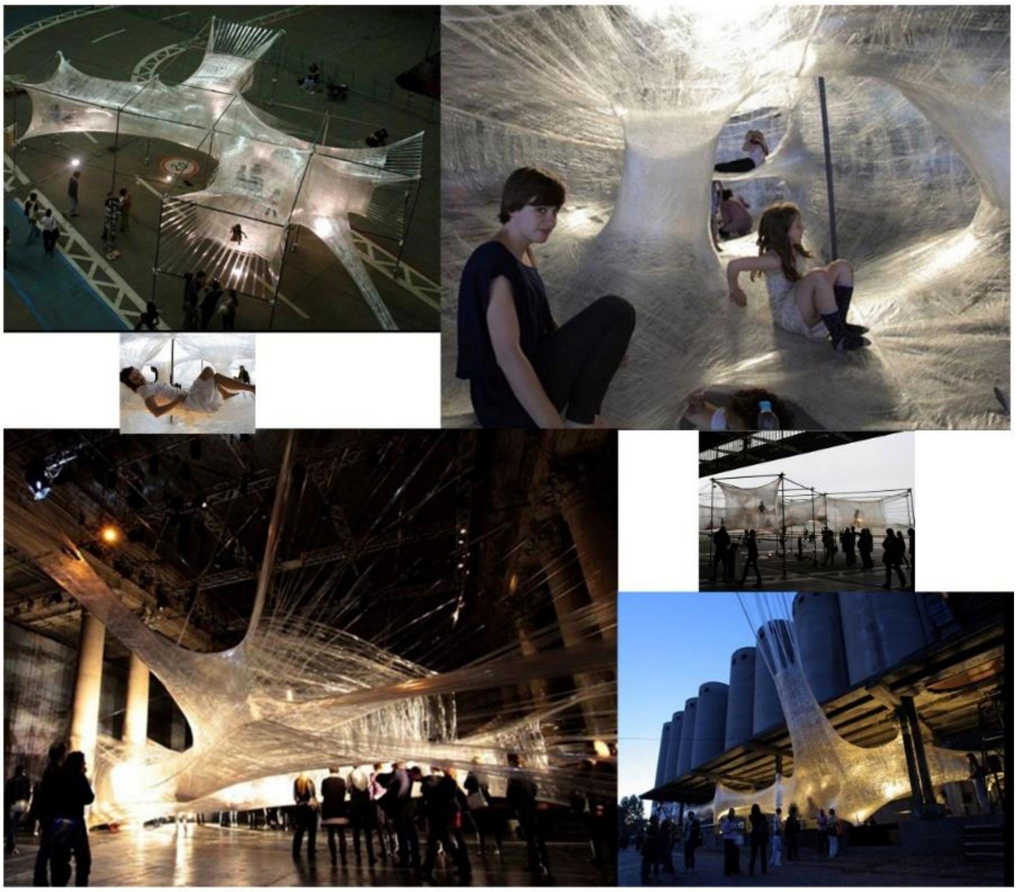

Figure 31, Human-size inhabitable spider web at DMY Berlin 2010. (bernik, 2010)

During installation, the scaffolding construction support had to construct due to the restrictions at site. After 160 hours of installation, and with the assistant of six workers, the structure was made, and the existing structural components at site were weaved around by tape. 1000 rolls of tape were used in previous installations and costs approximately 620$ US dollars (about 500 Euros) and were woven around structural components that already existed on site. The cocoon shape is realized through the design concept of dance performance (bernik, 2010). The form evolves as dancers swing in, out, and around existing pillars, stretching the tape while moving. Each step is recorded by the trail of the tape and the resulting form is the recorded choreography. A unique relationship between man-made materials and natural organisms are translated into entangled surfaces. This environment encourages visitors to engage with spatially. The mechanical and chemical construction qualities of tape combined with the amorphous nature of the organic structure unwinds a special narrative that is a beautiful showcase of bio-mimicry.

5.2.2 Case Study Conclusion

In conclusion this case study emphasize the concept of implementing a design can be both easy and affordable to build while preserving the main objectives that was designed for. Where we can notice that in a very short time of construction and very affordable budget a biomimetic design has been made and functioned as intended. So the idea that the biomimetic designs are hard and expensive is not entirely true but it depends on the designer and the concept.

5.2.3 The ICD/ITKE Pavilion

Developed and located at the University of Stuttgart, the Pavilion is based by the diving bell spider web. The ICD/ITKE research pavilion is a perfect demonstration of building an architectural potential inspired by the underwater nest construction of the water spider. As shown in figure 32 below.

This spider, an architectural mastermind since it builds its own oxygen tank, lives its entire life underwater. Called the diving bell spider, it is an adept problem-solver with an ingenious solution: a tiny air bubble that carries oxygen in it, is built by the spider and trapped in the spider’s silk. Its web is indeed shaped like a diving bell, spun among underwater vegetation (Stinson, 2015). The air bubble helps the spider to survive. To deposit air inside the beautifully designed bell, the spider makes periodic trips to the surface and pokes its abdomen out of the water, gathering the air among hydrophobic hairs to form a bubble, which gives an impressive feat for human engineers.

The pavilion resembles a glassy bubble streaked with web-like strands. It’s actually a plastic membrane essentially supported by layers of black carbon fiber composite material applied by a big robotic arm programmed to mimic the spider.

(a) (b)

Figure 32, (a) represents a night view of the ICD/ITKE at the University of Stuttgart Pavilion, while (b) represents a diving bell spider web (Stinson, 2015)

“The web construction process of water spiders was examined and the underlying behavioral patterns and design rules were analyzed, abstracted and transferred into a technological fabrication process,” says Achim Menges (Stinson, 2015), the head of the Institute of Computational Design. In other words, the robotic arm performs like the spider. In spots where the membrane is most vulnerable, it senses it and deposits fibers accordingly, using just enough pressure to do the job without penetrating it. Wet carbon fiber is essentially glued to the inflated membrane, which, like a balloon in the wind, is constantly in flux. The robot adapts its approach to the membrane as needed since it changes in shape. “The rules are determined, but the final shape is not,” says Menges (Stinson, 2015). Once the carbon fiber scaffolding was in place, the membrane (which was inflated by air pressure) was deflated to become a “skin” stretched over the composite framework.

5.2.4 Case Study Conclusion

In this case the issue is different where the design is not easily constructed and the budget is respectively high. In this project it was intended to mimic a specific thing or objective and in order to do that a big process had to be achieved. So respectively the objective of the project should have been achieve regardless the time and money used in the project and at the end of the project both was achieved and the complete design was a great manifestation of biomimetic approach where it was mimicked both in the formation of the materials and formation of the structure and the extra issue in this case is the way the design was constructed was the main issue where it wasn't built by normal human workers like any other project but it was built by robots that mimicked the spider construction technique. Therefore, in this case, we have a new mimic technology presented which is not only mimicking the concept or the form or the materials but also the way of building of constructing.

5.3 THE STRUCTURE

For the project to be developed in this dissertation, the design of the structure, as a pavilion, will be based on the funnel spider web.

5.3.1 Why funnel web nets design?

The choice of funnel web nets formation to emphasize in the design was based on different criteria's which was made by the selection of this type of web and gave it a more philosophical approach to the design by collaborating with the technical approach. The type of the site and its size made it impossible to choose the others webs, which requires big supports at the end in order to maintain the structure. In this case (project) the buildings that will consist the supports of that structure. Implementing this technique will raise a lot of concern of the structure of the buildings and will make a lot of problem with the size and space of the structure, especially with the vibrancy that will be generated from the wind and the turbulences that will correspond affect the structure of the supports which in the case is the university buildings. As shown in figure 33 below. And because the university was built in different years and different techniques were used in each part of the university all made it clearer that the support of our design should be made from the design itself on the floor and any further interpretation from the building structure should play a supporting role but not a main supporting pole.

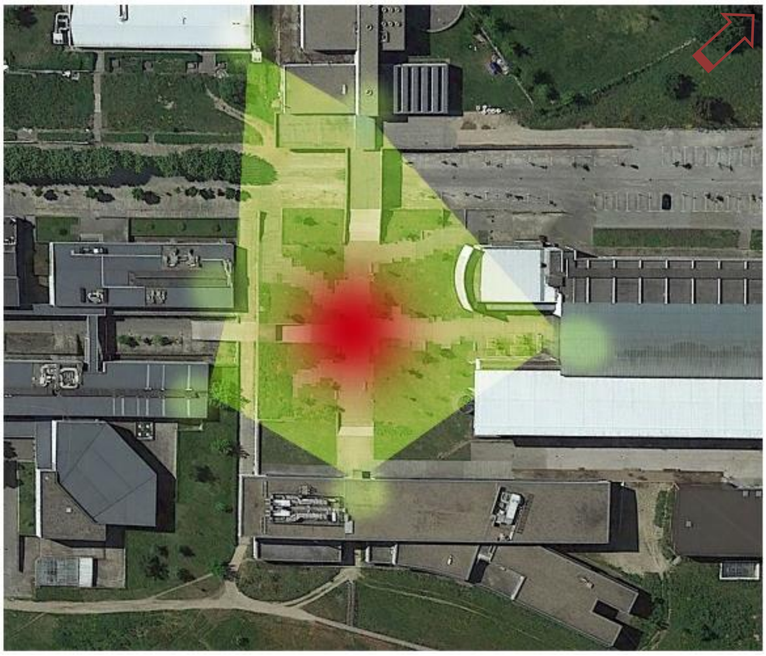

Figure 33, Simulation of the design supported by the buildings structures (Minho, 2017)Adapted by the author.

Therefore between all the types of existing webs, the most appropriate web shape of that can support itself and don't need extra and additional support, is the funnel web net which contains both a cover and a structure web exclusive in its net. And a central big design is no longer an option because the support needed will erase the role the open space is playing and will give it an altered role. Therefore the structure of the design should affect and be implemented on the ground but in a controlled way where the attraction for this structure can be extended to the entire site but with keeping the site its identity and its main purpose. So the design should be place not in the center but rather it should revenue and control a side of the site with some assembly with the entire location and adjacent features.

5.3.2 Funnel web spiders

Funnel web Spiders, spiders that make funnel-shaped webs, which they use to trap insects, are among the most abundant and conspicuous spiders in temperate grassland areas. Illustrated in figure 34 below. They are also known as grass spiders. Worldwide there are about 700 known species of funnel web spiders. Unlike most other spiders, they are most abundant and diverse outside of the tropics, with more than 400 species in North America.

Figure 34, a funnel web spider in its net (About, 2009)

Most funnel web spiders are retiring and rarely stray from their webs, unlike their free-roaming relatives, the wolf spiders. The funnel-shaped web is composed entirely of dry silk, without sticky threads. It has one or more horizontal sheets of finely-meshed webbing. The top is called the sheet web where tangle of lines, extended upwards, is attached to the surrounding vegetation. At the back of the web, there is a small funnel-shaped opening that forms a retreat for the spider to rest in. Spiders can move easily on its web, but other insects have difficulties moving across it. Flying or jumping insects view at first the sheet web as a suitable surface to land on, or they may accidentally bump into the vertical lines and drop onto the sheet. The insects then will be trapped in the web's slippery entangling lines. While sitting in its retreat, the spider detects the vibrations in its web caused by the trapped insect and runs rapidly to the struggling prey, biting it repeatedly. After wrapping it with silk, the spider typically drags its prey into the funnel retreat for feeding.

5.3.3 Funnel web spiders nets

There are three distinct spider families that are known popularly as funnel-web spiders. Even though each type is different, but they are all referred to as Funnel-web spiders because of their funnel-shaped webs. Some species are among the deadliest spiders in the world, yet others are considered undamaging to humans. Funnel-webs make their burrows in moist, cool, sheltered habitats—under rocks, in and under rotting logs, such as the Australian funnel spiders, and some in rough-barked trees (occasionally meters above ground). That's why funnel-webs burrows are usually found in suburban rockeries and shrubberies, but rarely in lawns or other open terrain. A funnel-web's burrow characteristically has irregular silk trip-lines radiating from the entrance. Unlike some related trapdoor spiders, funnel-webs also use their burrows as trap prey without building any lids to them.

These spiders get their name because, generally, their webs have a flat surface for capturing prey and a small funnel-like tube leading to a silken burrow in which the spider hides, according to the University of California's Integrated Pest Management Program (IPM). The spider waits in the funnel for prey to fall onto the horizontal web, and then it rushes out, grabs the prey, and takes it back to the funnel to consume. Australian funnel spiders pick moist and sheltered places to build their burrows, like under rocks or logs or in shrubbery. According to the Museum Victoria, the entrance to the burrow is surrounded by irregular strands of silk, which act as trip wires, alerting the spider hiding in the burrow that prey is present. The spider then goes out and attacks. Residents of grassy areas will recognize the funnel webs scattered in the grass during the summer and early fall. These spiders can also build there webs anywhere there is a crevice, that's why funnel webs are also found in cracks of shingles. Also, they are often seen in the corners of porches.

Spider's funnel webs are rather messy and are composed of flattened, often branching, tunnels that are used for hiding when danger approaches. Some species prefer to hide their webs under rocks, while others live exclusively under mats of moss, rotting logs and other organic debris.

5.3.4 The web

This family of spiders is named based on the funnel in the webs. The web is a horizontal, sheet-like web with a small funnel-like tube off to a side (or for some species, the middle of the web), and it is used by the spider for hunting and protection. Illustrated in figure 35 below. The spider lays attentive in the funnel, waiting for an insect to fly into, or land on the web. When an insect crashes on the web, the spider will rush out quickly checking to see if it is a prey to bite it. The venom is fast-acting on the prey, so once the prey is subdued (within a second or two), the spider will drag the prey back into the funnel (for safety while eating, and to prevent other insects from recognizing the danger that lurks on the web) depending on the species, the web may or may not be sticky. If the web is not sticky, the web will actually become tangled around the prey's feet, ensnaring it in the web. Sometimes, this may cause hardship for the spider later, because if the spider wanders across a web that is sticky, the spider may walk clumsily and become prey for another funnel weaver.

Figure 35, the entrance of the funnel web spider net (About, 2009)

Many species have multiple entrances to their webs, which are tube-like openings of silk. These openings are usually connected with some distinct silk strands (trip lines). These lines alert the spider of the presence of prey to hunt it. The prey is simply ambushed and overpowered by the spider. After attacking the prey, the spider bites and drags it back inside the retreat, the funnel-web, to consume it. These preys can be insects, spiders and small vertebrates such as lizards and frogs.

5.3.5 Early Warning System

Funnel-web burrows are distinguished from other holes in the ground by the appearance of their entrances. A series of irregular silk 'trip-lines' radiates out from the entrance. If silk trip-lines are obviously around the rim of a spider burrow, it can be certainly recognizable that it belongs to a funnel-web spider.

The silk entrance to the burrow of a Funnel-web Spider has a more or less well-defined funnel-like silk entrance 'vestibule' within which is a collapsed, tunnel-like structure with one or two slit-like openings. The tunnel leads back into a short surface chamber from which the burrow descends. The burrow is often weakly silk-lined and rarely more than 30 cm deep. The spider hunts mostly at night. It sits just inside the entrance of the burrow with its front legs on the trip-lines, ready for the prey. When a beetle, cockroach, or small skink, typically any insect considered as a funnel-web food, walks across the lines, it causes vibrations on the web. The spider senses these vibrations and races out to grab its meal. The prey is quickly subdued by an injection of venom from the spider's large fangs. Funnel-web spiders may also forage on the surface in the vicinity of the burrow. Holes are normally found in moist, shaded areas like rockeries, dense shrubs, logs and leaf litter. A small, neat hole lined with a collar of silk which does not extend more than a centimeter from the rim could belong to a trapdoor spider (the common Brown Trapdoor Spider does not build a 'door' for its burrow). As shown in figure 36 below. Other possible whole owners include mouse spiders, wolf spiders or insects (most commonly cicadas or ants).

Figure 36, the early warning system implemented by the funnel web spider ((About, 2009)).

5.3.6 Design as a pavilion

In architecture, a pavilion (from French pavillon, from Latin papilio) has several meanings. In architectural terminology it refers to a subsidiary building that is either positioned separately or as an attachment to a main building. Often its function makes it an object of pleasure. Historically, pavilions have served as places of prayer, sport, entertainment, art and of course, romantic liaisons. Yet this ability to accommodate many different purposes does not mean that pavilions are neutral, non-descript zones or blank sheets of paper. The opposite is the case. Around the world pavilions rank amongst the most revered forms of architectural expression.

In this way, the suggestion of the design is to be like some sort of a structure with a pavilion face like entity which will be a Multi-functional Pavilion, where it will create public spaces with social functions like culture, recreation, sports. And it would be built with temporary pavilions of minor scale that can be easily fitted in the existing site inside the university campus, it would also have light components and could be movable. They could be places where people could take some fitness exercises, take part in workshops or expositions or just rest. Some of the suggested functions that can be placed inside this pavilion are a social bar where drinks can be offered to users in a socially integrated place so users can have a social space outside but yet inside their campus. Another function can be a small stage or a small music room or space where users can share their expertise in the musical field. It can also have small library or reading space with an access to nature. And it can correspondingly have a rest space where users can come and take a nap or rest in a smooth home like space.

The function can be different especially from the acoustic point of view but because the site is big and is divided into different parts this uniqueness in function can be made under a joint structure that will from the final pavilion.

The pavilion final design will require to achieve several objectives in order to be efficacious and worthy:

i. Achieving the envisioned objectives while still attaining sustainability outcomes
ii. Generate a shading or a covered protected space
iii. Appeal passing by entities
iv. Creating innovative functions inside the design
v. Associates the diverse levels of spaces in the campus
vi. Generate a focal tough but grasped point of interest while reserving the inventive impression of the location
vii. craft utilities to the altered planes of the design especially in the bottom level

6 MATERIALS

Our concepts of sustainable architecture often implicitly draw from images of the vernacular. An earth sheltered home with passive systems is considered the pinnacle of sustainability whereas a speculative office building with a glazed façade would be its base. Lower energy is commonly related with buildings whose forms are directly resolute from local climatic conditions while those buildings with sophisticated and multifaceted systems are routinely seen as energy hogs or corners. Sustainable lightweight or fabric materials, as a class of advanced technologies, occupy a shadowy middle ground between the low tech and the high tech approaches. While clearly very sophisticated, these materials are presumed to be direct and discrete substitutes for much larger systems. As such, there has been much hope placed on those materials as delivering the elusive solution to the intractable problem of ever increasing energy use by building traditional systems.

The faith in lightweight materials as sustainable substitutes for conventional materials and systems may be misplaced, however, and may instead cause the field of architecture to miss out on the unprecedented opportunities possible if the characteristics of these materials were to be fully exploited. As per the argument that the true potential of lightweight materials lays in their instrumentality for manipulating physical phenomena and not in their application within the confines of building performance.

The nature of the design envisioned in this project necessitates the factor that the materials used should require certain characteristics. One of those vital feature is to be light. Lightweight materials are an immense outlay in temporary structure, and are not exploited considerable in huge and long term structures or entities. Nevertheless in this design the lightweight materials used would be able to assemble a project that is both resilient and effective as considerably light and sustainable. Wherever the use of a strong firm material such as the FRP rods for the main skeleton of the design structure and respectively using the polyester fabric as the mesh cover for that structure will form together the light weighted and functioning design.

6.1 GFRP GLASS FIBER REINFORCED POLYMER

A composite material consists of two or more elements whose attributes, when combined, can offer incredible properties. The most common category of composites, and the type which we manufacture, are polymer matrix composites or as more commonly referred to ‘Fiber Re-enforced Plastics’ (FRP). They consist of a resin matrix or ‘bulk material’ which in the case of all our tubing is Epoxy and also a fiber re-enforcement which could be one or more of Carbon, Aramid, Glass, etc. These materials are referred to as ‘Carbon Fiber Reinforced Plastics’ (CFRP), ‘Glass Fiber Reinforced Plastics’ (GFRP), and so on (AslanFRP, 2017).

In this design one of the main materials used and the main structure is composed of GFRP or Glass fiber reinforced polymer bars, which they consist the main core and the skeleton of the design. And in the following paragraph we discuss and present some features and properties of this material and its influence on sustainability trait.

6.1.1 What is GFRP?

Glass Fiber Reinforced Polymers are a proven and successful alternative that have numerous advantages over traditional reinforcement methods giving structures a longer service life. An examples of GFRP rods can be seen in figure 36 below.

Figure 37, illustrates diverse GFRP rods (Juli, 2017)

The GFRP rebar is a structural ribbed reinforcing bar made of high strength and corrosion resistant glass fibers that are impregnated and bound by an extremely durable polymeric epoxy resin. This combination equals an engineered material system resulting in unique attributes that replace and supersede typical materials such as galvanized, epoxy coated and stainless steel rebar. Its characteristic properties are ideal for any harsh and corrosive environments. GFRP is permanently resistant to chemical acids and alkaline bases, therefore extra concrete cover, anti-shrink additives, and even cathodic protection are not required. GFRP significantly improves the longevity of engineering structures where corrosion is a major factor.

6.1.2 Why it was introduced in construction?

Corrosion of steel is a major cause of infrastructure degradation. Solving this problem is a major challenge for the engineering community. Porous, concrete will allow water and corrosive agents such as salt to penetrate and reach reinforcing steel. Once exposed to those corrosive agents, steel will begin corroding. When rusting, steel expands and thereby cracks the concrete surrounding it. And the effect of such corrosion is tremendous like High rehabilitation cost, Health and Safety-hazard, Shutdown due to corrosion failure, Contamination, Loss of efficiency, and structural glitches. Therefore the technology of reinforced concrete is facing a serious degradation problem in structures due to the corrosion of steel rebar. Traditional Steel reinforcement can cause expensive problems both in terms of logistics and in length of service life. Several options have been explored, most notably the use of galvanized steel rebar, epoxy coated or stainless steel. The results, however, have been disappointing, as these solutions have turned out to be less than effective or cost prohibitive. Glass Fiber Reinforced Polymer (GFRP) has proven to be the solution, a major evolution in reinforced concrete technology. Lightweight, non-existent corrosion, that offers excellent tensile strength and high mechanical performance. GFRP rebar is installed much like steel rebar, but with fewer handling, transportation and storage problems.

Fiber Reinforced Polymers (FRP's) are a proven and successful alternative reinforcing that will give structures a longer service life. A complete spectrum of authoritative consensus design guides, test methods, material and construction standards, product procurement specifications and qualification procedures are available to the designer and owner to safely and commercially implement FRP's in many different types of structures like Concrete Exposed to High Voltages & Electromagnetic Fields, Concrete Susceptible to Corrosion, Concrete Exposed to De-Icing Chlorides, Concrete Exposed to Marine Chlorides, Tunneling & Mining, Masonry Strengthening & Historic Preservation, Weight Sensitive Structures (AslanFRP, 2017).

6.1.3 Advantages of using GFRP

The GFRP has many advantages over other materials that perform in the same approach or can be applied in the design or aspects. But the GFRP have several features that give it an upper hand when compared to others materials, where it have Corrosion Resistance. GFRP will not rust, even in the harshest environments. It does not react to salt ions, chemicals or the alkaline present in concrete. Superior Tensile Strength. GFRP rebar offers a tensile strength up to 3 times that of steel. GFRP is highly efficient to resisting heat transfer applications and does not create a thermal bridge within structures. Electrical and Magnetic Neutrality. GFRP rebar does not contain any metal; it will not cause any interference in contact with strong magnetic fields or when operating sensitive electronic instruments such as MRI units and rooms, Communications, Airports, Transformers, Aluminum and Copper Smelting Plants, Tele-Communications towers, Airport control towers, Hospitals and Rail roads. Lightweight. GFRP rebar is 9 times lighter in weight than the equivalent strength of Steel rebar. It is much easier to handle, and in most cases, only one truck load will be sufficient to supply the rebar even for an entire project (AslanFRP, 2017). And there is much more advantages that the GFRP maintain and some can argue that it is the future of construction materials in our nearby future.

Some of the various advantages of using GFRP:

- 80+ years of lifespan and corrosion resistance
- 9 x lighter in weight than the equivalent strength of Steel rebar
- 3 x tensile strength of steel
- Non-conductive to heat and electricity
- Non-magnetic (transparent to electrical fields)
- High Fatigue endurance and Impact Resistance
- Non-existent corrosion, rust free
- Transparent to radio frequencies
- Cost effective vs. epoxy coated, galvanized and stainless steel rebar
- Impervious to chloride ion, low pH chemical attack and bacteriological growth
- Reduced whole of life project costs
- Low carbon footprint
- Maintenance free
- Standard/custom lengths, shapes and bends
- Non Toxic
- Easily cut and machined
- Easy and Rapid Installation

6.2 FABRICS

Fabric is viewed as a material which is flat and two-dimensional and thus, until recent times, it has been used in architecture as a surface sheet. However the material has not been fully exploited. Fabric structures have been used in architecture since humankind first began to build. Their constructional advantages in terms of economic use of materials, light weight, speedy assembly and flexibility and adaptability in operation were recognized and adopted by traditional cultures across the world. Contemporary fabric structure systems make use of these same characteristics to create dynamic and evocative architectural forms that are simultaneously symbolic of this long history and modern innovation.

At first, building with textiles seems riddled with problems fabrics are usually perceived as flammable, vulnerable to water, impermanent and weak. Architecture is equated with density and mass, while textiles have often been limited to lightweight decorative expressions. Few practitioners would guess that textiles have a long history as an architectural material, giving rise to a tradition of portable habitations and porous buildings several thousand years ago. In the context of buildings, fabrics disappeared as wood, stone, metal and glass became the materials of choice, but recent developments in textile technology have revealed their relevance to architecture today. Even though robust architecture and tactile fabrics may seem irreconcilably diverse, there are threads that bind. Visionaries know that the cutting edge in architecture is not sharp, but sensuous and soft. At a time when architects are pioneering new structural networks, immersive webs, mobile buildings and fluid exchanges, textiles have revealed a surprising history of modularity and multifunctionality, and an essential narrative function. While early textile structures afforded protection from the elements, they also featured symbols and inscriptions that represented a mode of belonging. The ciphers woven into dwellings were also stitched into clothing, identifying whole groups and forging indissoluble links between architecture, individuals and communities. Today, textiles continue to be loaded with signifiers, and their role in apparel makes fabric a familiar second skin. Textiles are more tactile than conventional construction materials, and their colors, textures and finishes imbue them with stylistic references uncharacteristic of building supplies.

In architecture, fabric structures are forms of constructed fibers that provide end users a variety of aesthetic free-form building designs. Custom-made fabric structures are engineered and fabricated to meet worldwide structural, flame retardant, weather-resistant, and natural force requirements. Fabric structures are considered a sub-category of tensile structure. A fabric structure's material selection, proper design, engineering, fabrication, and installation are integral components to ensuring a sound structure. Correspondingly fabric structures are forms of constructed fibers that provide end users a variety of aesthetic free-form building designs. Custom-made fabric structures are engineered and fabricated to meet worldwide structural, flame retardant, weather-resistant, and natural force requirements. Fabric structures are considered a sub-category of tensile structure. A fabric structure's material selection, proper design, engineering, fabrication, and installation are integral components to ensuring a sound structure. Most fabric structures are composed of actual fabric rather than meshes or films. Typically, the fabric is coated and laminated with synthetic materials for increased strength, durability, and environmental resistance. Among the most widely used materials are polyesters laminated or coated with polyvinyl chloride (PVC), and woven fiberglass coated with polytetrafluoroethylene (PTFE) (Swicofil, 2015).

6.2.1 Polyesters

Strength, durability, cost, and stretch make polyester material the most widely used in fabric structures. Polyesters that are laminated or coated with PVC films are usually the least expensive option for longer-term fabrications. Laminates generally consist of vinyl films over woven or knitted polyester meshes (called scrims or substrates), while vinyl-coated polyesters usually have a high-count, high-tensile base fabric coated with a bondable substance that provides extra strength. (Swicofil, 2015). Precontriving fabric is made by placing the polyester fabric under tension both before and during the coating process. This results in a weave that has increased dimensional stability as shown in figure 37 below the range of design forms potentials.

Figure 38, illustrates the capabilities and extents of using polyester in architecture. (Architecture, 2010)

Polyester was once regarded as a cheap fiber due to its easy fabrication and modification but it was also referred to as an uncomfortable fabric but this image is starting to change with the emergence of polyester luxury fibers such as high density polyester and such as polyester micro fiber. Some of the most common properties of the polyester fabric are such as being strong material and resistant to stretching and shrinking as being also resistant to most chemicals and have the characteristics of quick drying and being crisp and resilient when wet or dry, being resistant to wrinkle or mildew or abrasion, and it's able to manage environmental conditions and resisting them and it is easy washed and took care off.

Because of their many desirable qualities, polyester fibers and fabrics have many diverse uses. And usually it is mainly used in the outdoor due to its vast and high tenacity and durability. It is a strong fiber and consequently can withstand strong and repetitive movements. Polyester can be molded into almost any shape. As much the polyester has diverse characteristics as much as the way it is fabricated is diverse and full of possibilities and each can give a dissimilar outcome and effects.

Most polyesters are extracted from petroleum from which the constituent acids and alcohols are derived. The types of processes that manufacturers use vary. Where in a general idea the polyester is synthesized by first polymerization and then followed by spinning and then drawing this tree steps form the synthesis phase of the materials and the after a various of polyester can be made by doing one of the following steps, where adding a diluent or by changing the shape of the holes in the spinneret or by drawing it out more or by adding dye nutrients or by also crimping the materials. Where each one of those steps can produce different fibers. After this steps we have the phase of fabricating the yarns where there are two types of polyester yarns: filament and spun. After we have the phase of blend as the polyester can also be combined with other fibers to produce a variety of effects such as blending it with cotton, or wool, rayon, nylon and etc…, then there is the weaving phase as after the yarn are made, they are shipped out to textile mills to be woven into fabric. Polyester can be made into both woven and knitted fabrics. And at the end there is the finishing processes as after the fabric is made there is the finishing processes such as hear setting or singeing or anti-static are examples of finishing that can be applied on the polyester fabric. In our case the yarn used is the high density polyester (HDPES) with 550 dtex. And in the following figure represents the characteristics and the test report for the high density polyester that will be used in the design where it is fabricated by the A.ferreira and filhos, SA AFERFI Company in Portugal and tested by the durafiber technologies (DFT) werk bad hersfeld company in Germany as demonstrated in the technical document below.

durafiber TECHNOLOGIES
Werk Bad Hersfeld

Werkszeugnis / Test Report
DIN / EN 10204 - 2.2
Ausgabe-Datum / Date : 30.03.2016

A. Ferreira & Filhos, SA
AFERFI

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Portugal

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Produkt / product : 550 dtex f 96 V0 TYPE 730
Los-Nr. / lot : 873
Aufmachung / package type : ZKG93
Packliste-Nr. / delivery no. : 81418711
Auftrags-Nr./ order conf. no.: 00597762
Menge / quantity (kg netto) : 100,2
Bemerkung / remark :

Eigenschaft : Property	Maßeinheit unit	Meßmethode method	Meßergebnisse results x	s	n
Titer [effektiv] linear density	dtex	DIN EN ISO 2060	565,2	2,61	12
Höchstzugkraft breaking load	cN	DIN EN ISO 2062	3887,6	52,12	12
Feinheitsfestigkeit tenacity	cN/tex	DIN EN ISO 2062	68,8	0,95	12
Höchstzugkraftdehnung elongation at break	%	DIN EN ISO 2062	13,1	0,92	12
Bezugsdehnung 1 (cN/tex) 45 elongation at cN/tex	%	DIN EN ISO 2062	5,3	0,24	12
Heißluftschrumpf [180°C, 15 Min.] hot air shrinkage [180°C, 15 Min.]	%	DIN EN 14621:2005	13,8	0,17	12
Präparationsauftrag amount of finish	%	DIN 54278, Teil 1	0,7	0,01	4

Die DIN-Methoden wurden an die speziellen Produkteigenschaften angepaßt — The measuring methods were adapted to specific properties
Die gemessenen Werte entsprechen den vereinbarten Produktspezifikationen — The results correspond with the specification agreed
Obige Angaben entbinden nicht von der Durchführung eigener Eingangskontrollen — The above data does not release from delivery control

Qualitätssicherung / Werk Bad Hersfeld

Diese Mitteilung wird maschinell erstellt und nicht unterzeichnet — This note will not be signed

6.3 COMPONENTS AND DETAILS

The magnificence of fabric structures is in the few components required to create such a structure. These elements include the primary structure as the FRP rods and the high density polyester in our case and specific components related to the structure, the fittings and hardware used to tension the membrane and the membrane itself. And in our case these components are a group of different materials that work together in order to complete and form the final design. As illustrated in figure 39. Where else than the yarn we have the mast or compression membrane which in our case is the FRP rods compressed and supported by the yarn where most fabric structures require a compression member to form a complex shape.

Figure 39, illustrates different components in a typical FRP rods structure with a fabric cover. (Corboy, 2017)

Besides that after we have the base plate forms the connection between the tension membrane structure and the ground, wall, building or adjacent structural system. The base plate is usually fixed to the bottom of a compression member or separated from the structure and connected to the post with a pin connection as in our case the rods are fixed on the ground by a steel base case and the adjacent support the poles of the buildings by pins to the structure of the dwelling. After we have the connection of the membrane plates, where Membrane plates are the most time consuming components to design and the key to successful tension membrane structures. Membrane plates provide a “link” from the membrane to the structural masts. These plates are installed to accept membrane catenary cables and pin connection hardware. And in our case the membrane plates are formed by the fabric cables that links and support the yarn and the adjacent support FRP rods. As where the catenary cables or Catenaries" are formed along the fabric perimeter stretching from one extent to the other and they will play the role of strengthen the model and complete the tension scenario and in our case they are formed by steel cables connecting the outer rods to their extent in order to support the structure and the tensions. And in the end there is the tie downs of the cables where each perimeter mast requires either a large moment connection or a series of cable tie downs to withstand the loads. Tie down cables are generally attached to cleats on the top of a mast and connected to anchors installed in the ground with turnbuckles. Specialized Hardware Fabric Structure hardware consists mostly of parts made for yacht racing, bridge building, and rigging and mountain climbing industries. Shackles, turnbuckles, "toggles" and carabineers are just a few of the hardware choices available. These components are the link between the membrane and the primary structural support.

7 DESIGN APPLICATION

7.1 DESIGN SETTING

In order to indicate where the proposal should be placed, it was grasped by some factors that are not unswervingly associated with the concept of the design or for the aesthetics of the design. But it was related to the site and the importance of not placing any outlandish structure in the location that will disturb or implant sentiment that will lessen the tranquility and unrestricted space that the site offer to the user. Where the space obtainable in this location serves as a relief for the users, where they connect to this site as an intermediate space where they can rest in harmony with the view and the nature. And likewise an immense important role this situate play is the circulation, where a big number of university users pass by this location frequently either by day or by night. From all this conditions the decision was made to place the structure in the corner of the site. Ash shown in figure40 below. As it will serve as a place to attract the users and also to influence and sway them directly. But maintaining the main tenacities of the site and the main purposes that it was initially designed to endure.

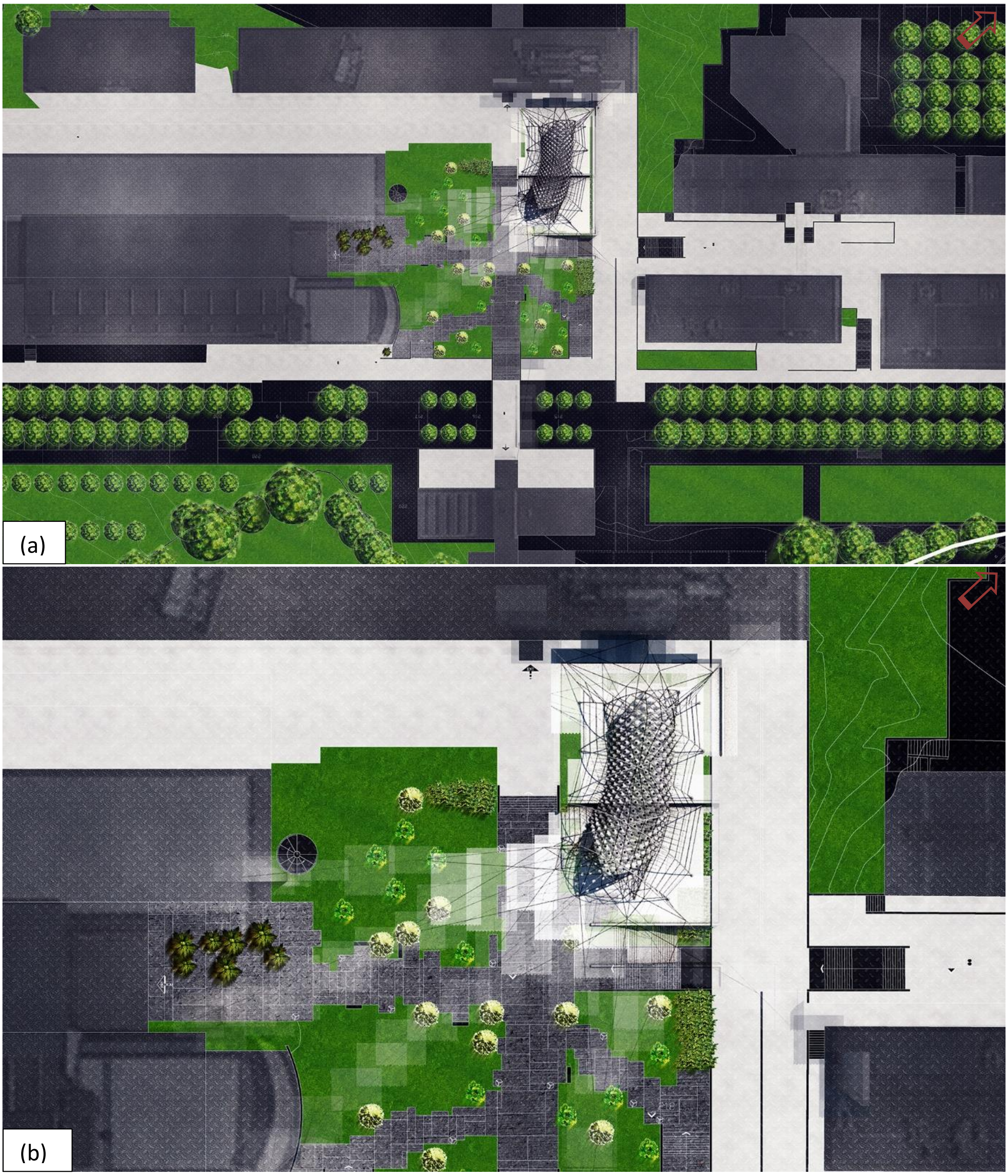


Figure 40, (a) and (b) represents a top views of the design implemented in the site. Illustrated by the author.

The structure is positioned in this manner in order to benefit from particular aspects where underneath that location exists an immense space in the underground that can be profited from as a full undercover space that can be used in diverse functions. Besides that part of the setting is not very lively or used by the users of the site therefore placing the structure there will not be an obstacle for any circulation but it will create new routes and new utilities. And it will play a role in concluding the entire functions of the site. But also with the concept of the design and the cables that directly connect some features of the structure with the adjacent entities bounces a complete picture of the design as a part of the site and not as an alien structure that is implanted in this location. Likewise in the way the structure is located and formed it will perform a part in executing sentimentalities on the users from all the different sides of the site where the angle of implementation is very widespread where wherever the user is approaching the site from, he will be unswervingly and circuitously touched by some facets of the design which serves the entire picture of Biomimicry concept that was applied here. Correspondingly this part of the site is the lone one that don't have a trail or don't end up on an culmination, wherever all the others paths associates different vital dwellings in the campus with each other, approximating the main buildings with the others faculties for example, besides it's a buffer zone for users accessing the parking or the residence and especially since the forthcoming enlargements of the campus, where the focal entrance of the university will be from the other side of the campus which makes the main admission to the main buildings will be from this site which will create even further firmer circulation configurations. Nevertheless in this side of the site, the path departing there, don't lead to anything nonetheless it's a dead end. Furthermore the foliage that exists in that area is not as vigorous as somewhere else in the site, where the plantation that are perceptible there are either small shrubs skirmishes or even some minor plants. Where in the upper level of the chosen location, its impartial filled of grassland as it is waiting for some installation to be adopted there. Therefore by placing the structure in this method it will give this side significance and a purpose that didn't attain formerly. Then it will play a role as a utility, and also as a connection or as a buffer zone while visually connecting all the entities of the location to each other's. Where the users is loomed by the design and engrossed by the structure of the pavilion without any direct contact or without direct implication but simply with the visual aspect of the structure by applying the same techniques that was used by the spiders to lure preys inside their nest in order to grab them and eat them later. As illustrated in figure 41 below.

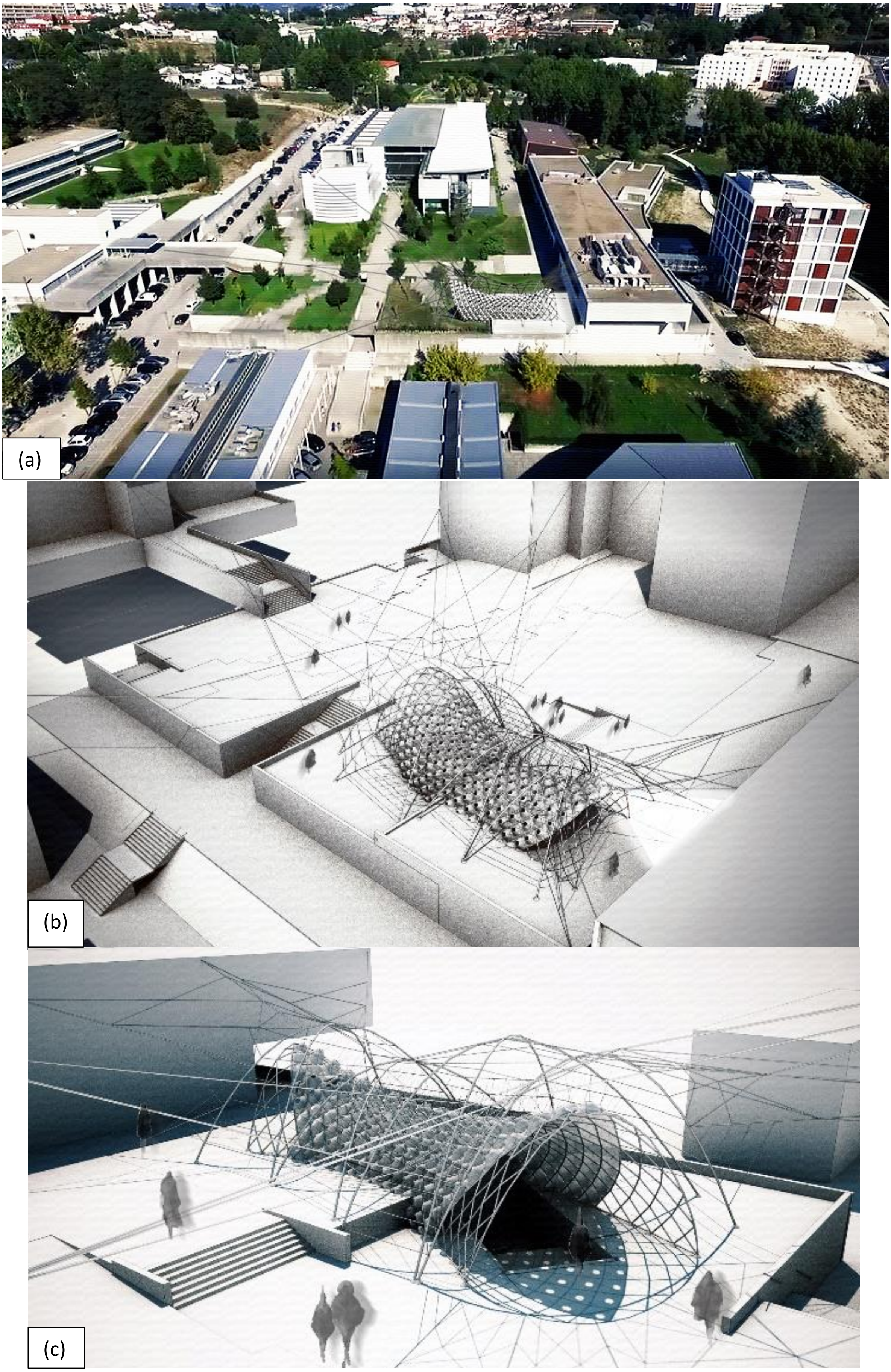


Figure 41, (a), (b) and (c) represents different bird's eye view of the structure. Illustrated by the author.

7.2 DESIGN CONCEPT

In order to comprehend what kind of design will be shaped a lot of circumstances or features should be taken into account for devouring the margins of the design. Where for example an immense restriction are the materials used for the proposal wherever the materials will compel the ideas for the design and the end result of it, another factor is the location of the design and additional big restriction is the intent of the design and the concept that the designer is trying to achieve and implement.

In this project the materials where previously carefully chosen for diverse and important reasons, alike the obtainability and the acknowledgement of those materials in the current environment, where a preceding pavilion was made with the equivalent resources, and the familiarity with the FRP rods and the fabric yarn both can be pooled to result in a pavilion that is both sustainable and nature friendly. Besides also being a light weighted design, without having a negative impact on the surroundings. Another factor was the pavilion location where in the commencement of the conceptual design, the concept of spider nets implemented in the location had a vast theory as shown in the figure 42 below. Wherever in the beginning the idea was to implement the concept of spider net on all the paths in the location in order to benefit from the largest amount of users imaginable and affect them in an immense and direct way. We can see in the figure below the main idea was placing several private spaces in the green areas of the site while placing the intermediate phase of the design which resembles the supporting cables on the paths, in this way the user passing by in the location will be contacted directly by the attitudes of the design and of the different pavilions and it will be communicated directly with the shaded intermediate way.

The lone problem of this proposal was that in this way the site will lose its foremost characteristics and the purpose it was made for which is being this outlet for students and users of the university to be unrestricted and connected to the nature, besides to get that infinite look for the nature that the site benefit them. That’s why a decision was made to stabilize the design of the pavilion to a certain area of the site for altered motives stated in the subsection design location overhead. Where in this manner the design will attend its influence and will correspondingly respect the site and its welfares for the users.

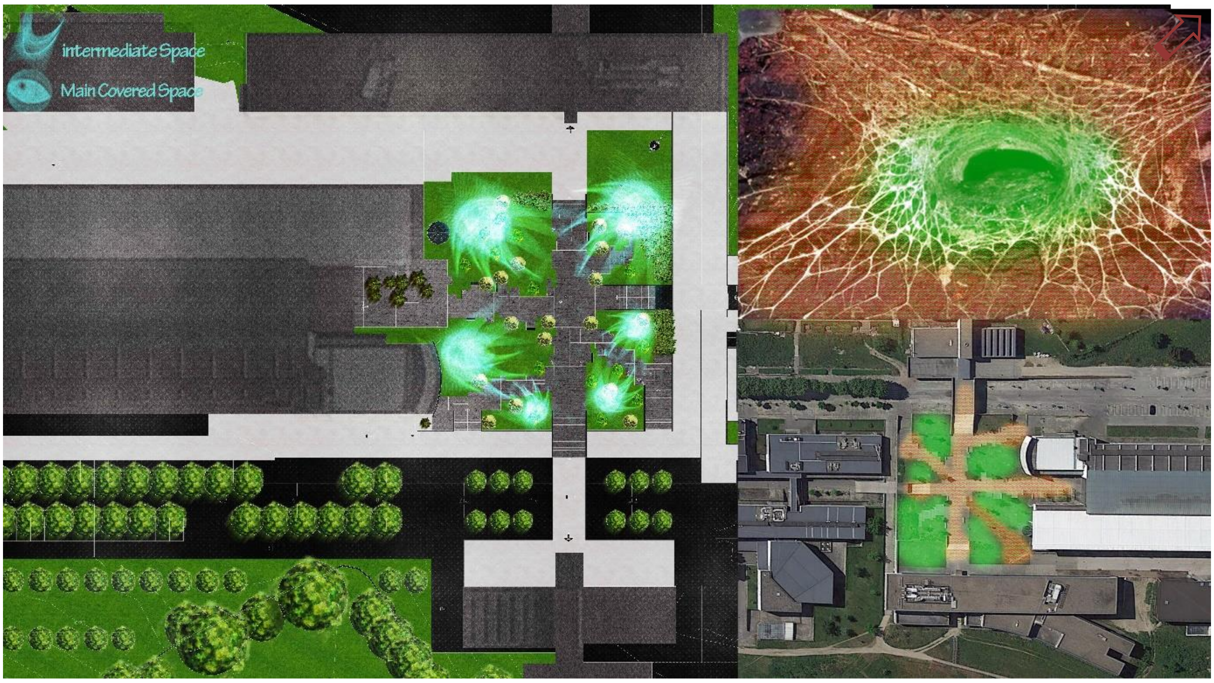


Figure 42, illustrating the initial concept of the design. Illustrated by the author

Afterwards when the location of the pavilion was restricted to the top right corner of the site. A more detailed design concepts started to manifest and occur in the vast image of the spider net ether. At first the initial idea was to create particular sort of a shading pavilion reinforced mainly by the FRP rods and then by the involvement of the CNC fabric, and it role as a supporting factor in the design. Consequently the foremost idea was to create a flat pavilion supported by the rods and covered by the fabric in order to comprehend the tensions of the pavilion and concluding it, as shown below in the figures. Formerly the next step was to employ and transfigure the corner of the pavilion by altering the heights of the corners, where the entrance of the pavilion had the prime height as well as the adjacent corner had the lowermost altitude. In this way the user will visually distinguish the entrance of the pavilion and be engrossed visually to it. Nonetheless the thing was that the pavilion was too feeble visually to contribute immensely in attracting the users besides the large bulk design jammed the site unambiguousness and tranquility. Therefore at the end the decision was made to make the pavilion as a partial tube more or less where both corners of the pavilion where the lowest and the center point was the heights.

Then in the two initial design the fabric was supported inside the pavilion, where they were stressed and tensioned by textile fabric directly to the ground. But in the final designs the case was unlike where the fabric was tensioned from the external supporting rods, where in this way the fabric played a role in the complete tensioning and strengthening of the pavilion. These attempts were presented in figure 43 below.

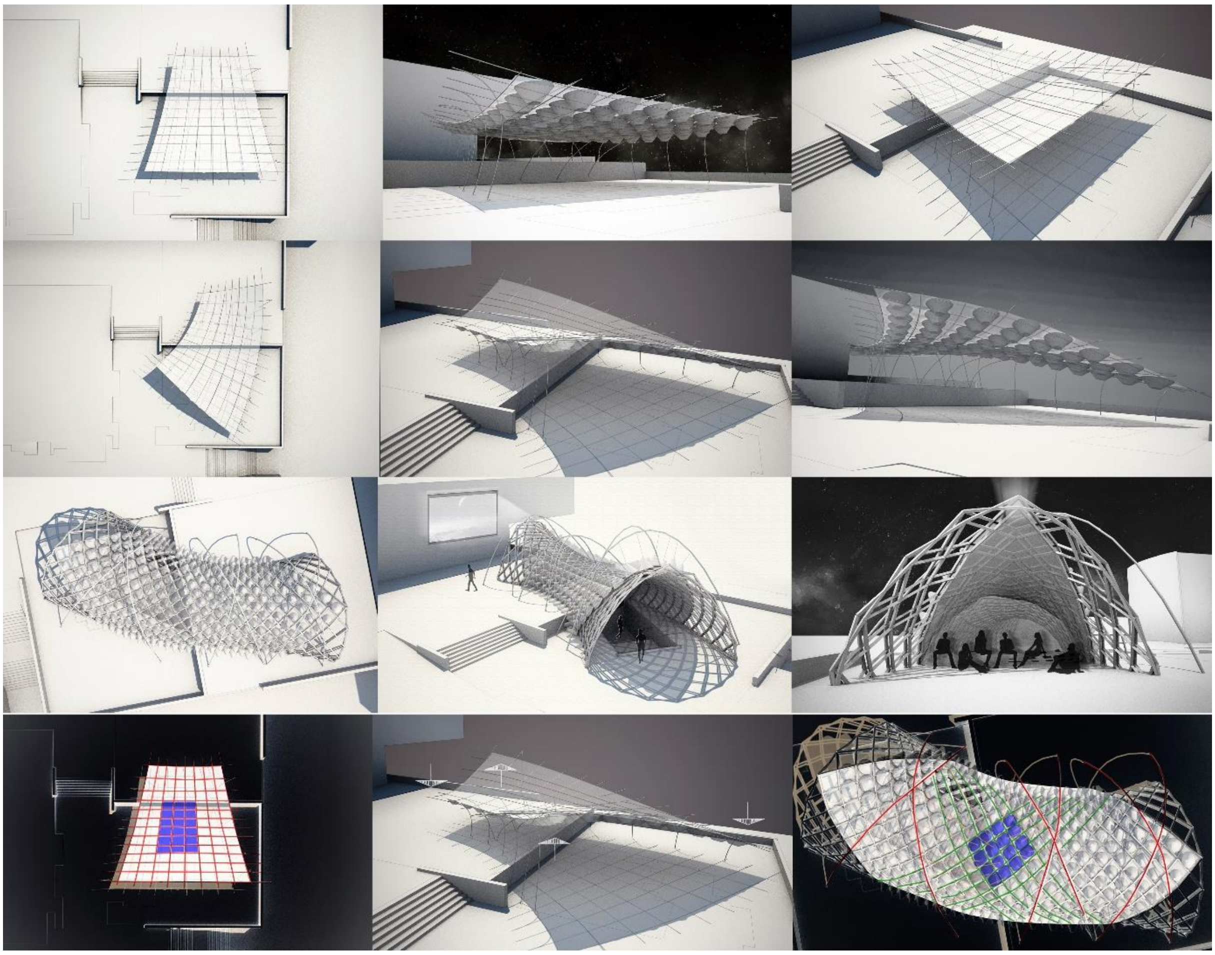


Figure 43, illustrating different initial design of the pavilion. Illustrated by the author.

In the end the final design was an outcome of all the measures premeditated previously, where the biomimcry concept of the funnel-spider net in collaboration with the site restrictions and the influence of the pavilion core objective for the final understanding of the project, all contributed in producing a design that attests all those factors into one model. As shown in figure 44 below. The final project is a pavilion that manifests the concept of the early warning system established in the funnel-spider web, where the design of the project resembles the admission of the net. The ambiguity and the prominence of the entrance resemble the one of the net. And here is the focal manifestation or adaptation from nature which is called Biomimicry. That’s why the main resembling and inspiration is not the shape of the spider net merely, but in detail the organization that the spider practice to catch and appeal preys, and this is the biomimcry concept that was amended in this project. Whereas mentioned before the funnel-spider uses the shape and the way he brands the net to lure preys inside the net and then surprise them and attack them, then take them inside the nest for future feasting. The early warning system that the spider use when the prey touch the net and the spider sense the vibration of the net which allure him that there is something outside is the precise inspiration. Where in this project the way the pavilion is molded is acclimatizing the concept of the spider, by way of the visual ambiguity of the entrance of the pavilion will lure the users in the site to go inside the pavilion therefore the entrance is the main attraction of the pavilion where all the different elements subsidize in capitalizing on the visual impact of the entrance. And because of the human nature and its interest in discovering new things this sentiment will lure them inside the pavilion in the same technique that the spider use to lure nearby interested insects the same way the pavilion will lure the interested user.

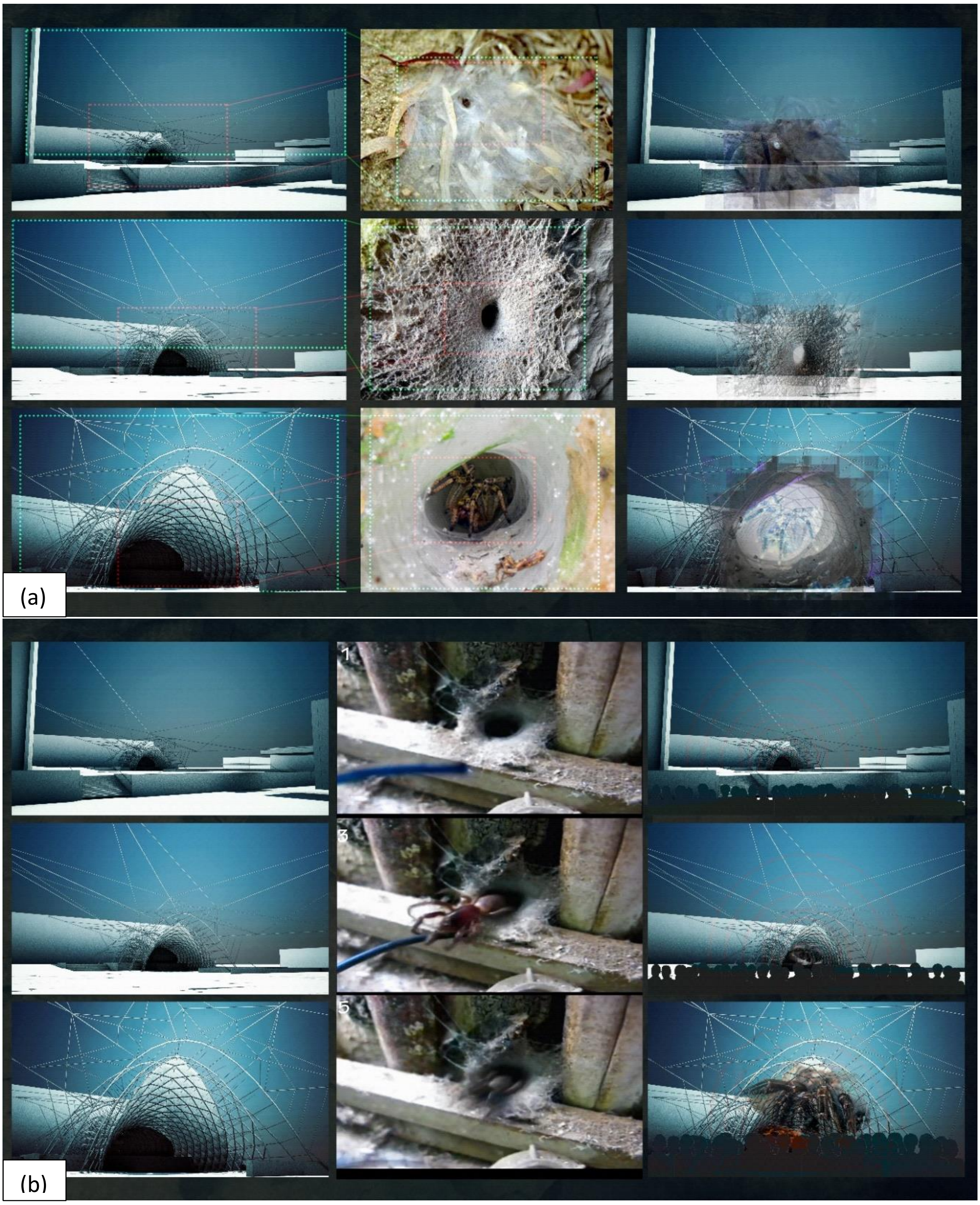
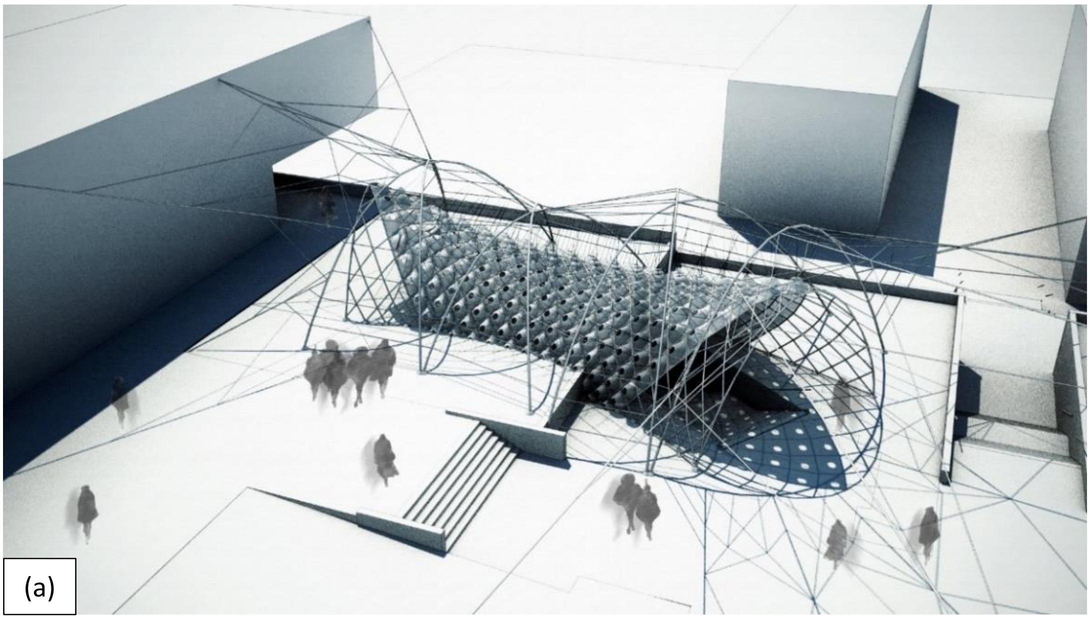


Figure 44, (a) and (b) illustrates the core Biomimicry concept adapted in the project. Illustrated by the author.

The pavilion is designed in way where all the components of the project are vigorous in a lone perspective point, which is the center of the entrance. As if you stand in the site and gaze around, you will perceive that all elements endue and arise from a unique cradle, which is the entrance of the pavilion. As shown in figures 45 and 46. The shape of the project is a semi- tube that is protracted in both ends of the design. The entries of both sides are the uppermost points of the project and respectively the broadest too. Then it narrows and shorten while fluctuating to the middle. Similarly the way the fabric will be stressed from the exterior supports will play a dual advantage role in aesthetics and in structure, as it will concludes the image of the pavilion that established in focusing all the elements on one point and also by implementing the portrait of the structure in tensioning and supporting that core structure.



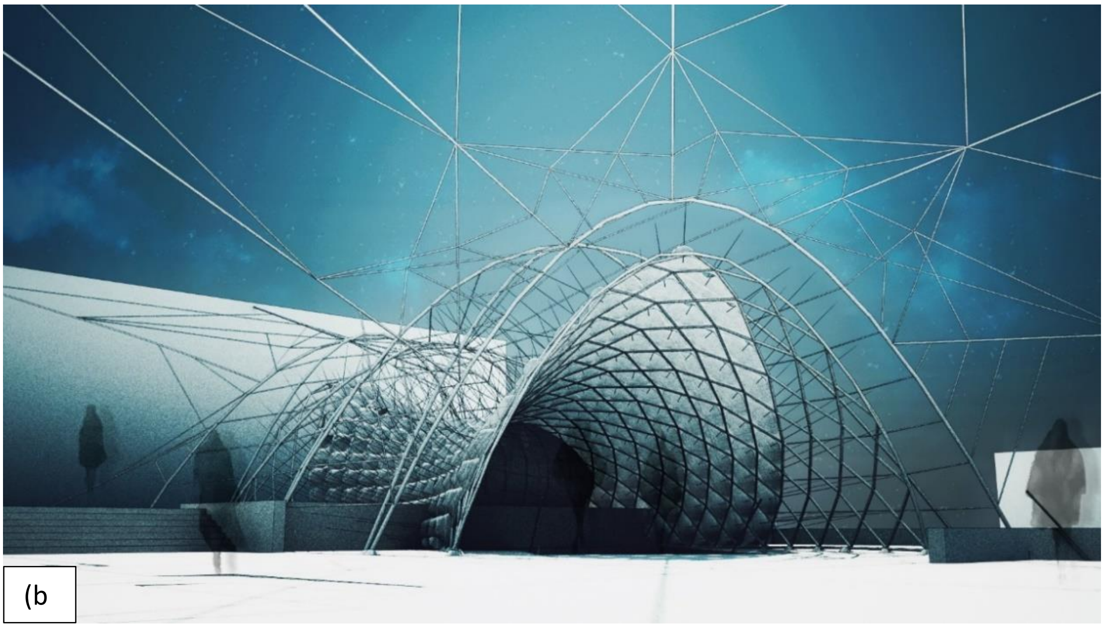


Figure 45, (a) and (b) illustrates both a human eye view and bird's eye view of the project. Illustrated by the author.

Figure 46, illustrates different human eye view integrated in real life picture of the site. Illustrated by the author.

7.3 DESIGN STRUCTURE

The structure of the design is based on the way the materials used act in tension and the end project is a complete organization that supports itself but not independently but each feature is supported by another. The main material used are the FRP rods which are the main structure then there is the CNC fabric that play a role in supporting the FRP. As shown in figure 47 below.

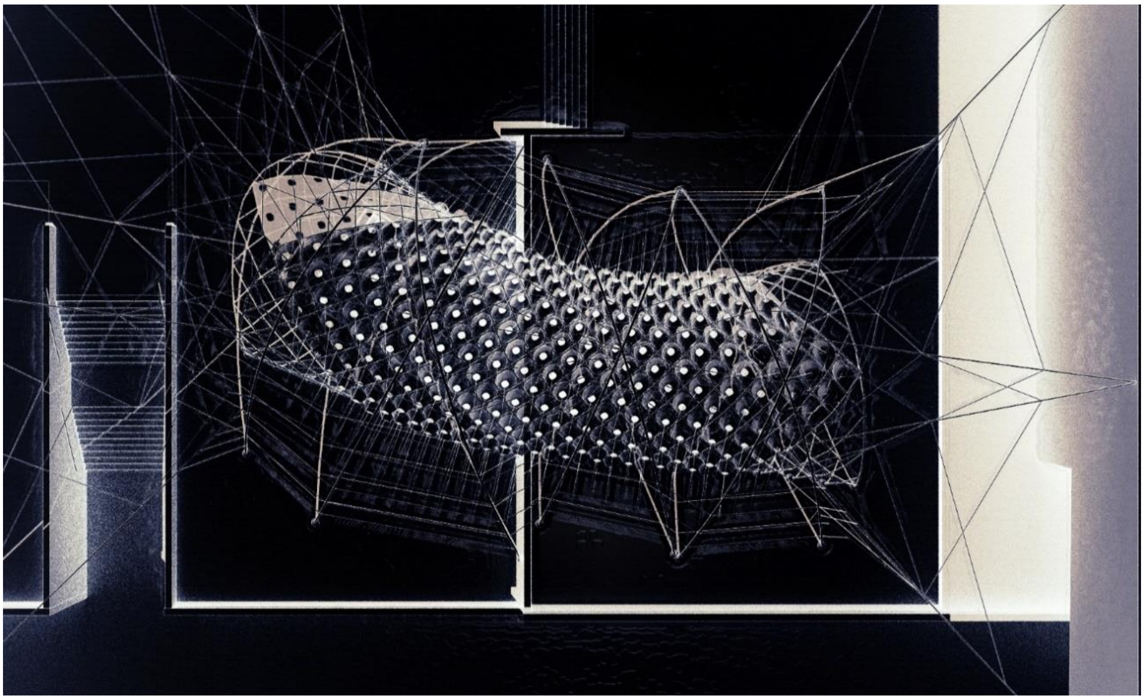


Figure 47, illustrated a top view plan of the structure representing the structure supports. Illustrated by the author.

The design is composed from 8 stages. Where the commencement is a steel base for the FRP rods that are fixed in the ground which will be the base of the rods in order to fix them and stabilize them. Then the next stage is fixing the rods in an active bending way where the rods will be fixed on both side to form at the end the main structure core of the design. Then the CNC fabric which is placed on the rods, where the fabric is in collaboration with the rods in one core as the rods will be positioned inside the fabric in a manner to be collective together in one mode, then the rods with the fabric will be placed in position. After that the CNC fabric will be stretched and tensioned by fabric cables to an upper layer of FRP rods that are stationary on both side of the ground on a higher level of the structure in order to support and tensioned the fabric, which in itself will support the rods and generate the sheltering layer of the pavilion, especially because of the design decision that the fabric should be stretched from the outside and not the inside to be in coherent with the design concept and to attain its aesthetic role. Subsequently after accomplishing the main structure of the design with the strengthening the fabric and accomplishing the core of the structure we partake the steel cables that will bond and support the double ends of the design with the neighboring buildings in order to reinforce the bending rods and make a thorough representation of the design, which those cables will execute the role of supporting the design aimed at to stabilizing the structure. Besides that since the vast distance the steel cables will partake intended for linking the structure. Additional slighter steel cables will be engaged toward supporting the chief cables, and they will be positioned in an arbitrary manner but with an arrangement where they will be more condense near the entrances.

Afterwards the decision to associate both ends of the structure with neighboring buildings and not the ground is made because of a couple diverse motives, but mainly it was since of the foremost Biomimicry concept where in this manner the final shape of the structure will play a role in enticing the curiosity of the user to the structure and especially to the center of the entrance, wherever the visual link will be sustained from far away and then be condensed nearby the entrances. Therefore the user will have a visual link from distant to the structure which will lure him to be attentive in the structure and be engrossed to go inside it. A more detailed perspective of the structure can be seen in the figure 48 and 49 below.

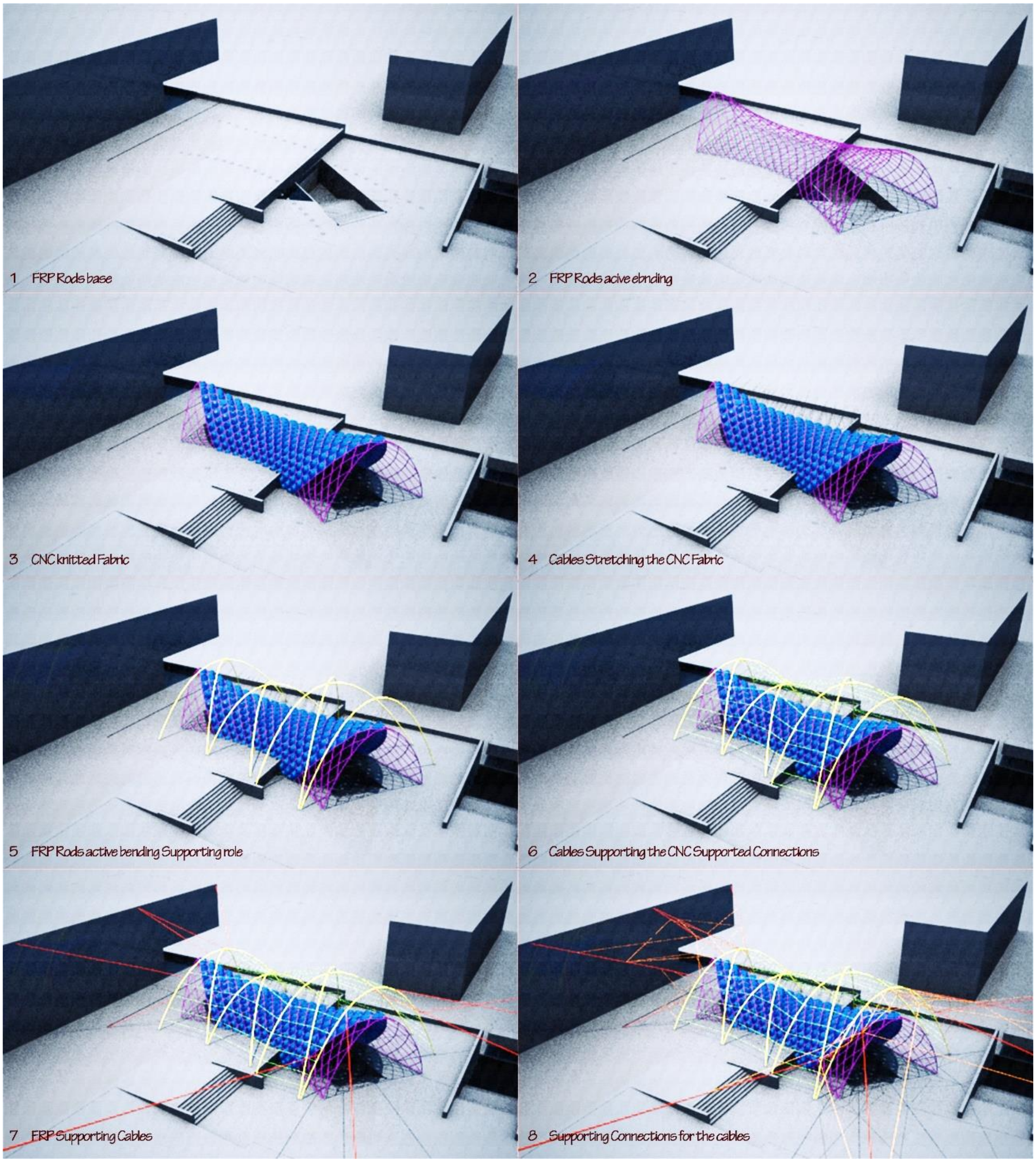
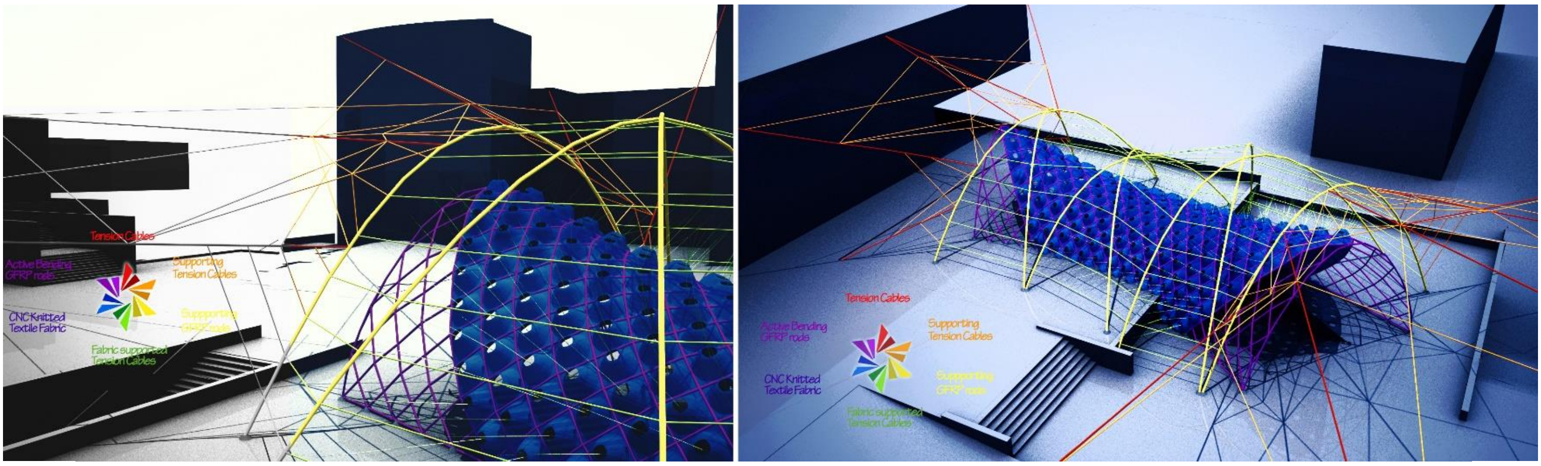


Figure 49, illustrating the different construction stages of the design. Illustrated by the author



(a) *Figure 48, (a) and (b) illustrates the different materials used in the design. Illustrated by the author.* (b)

A grouping of diverse units molds the design. Where each fabric unit is by the dimension of one meter by one meter and is stretched from the medium by a fabric cable and is supported with the FRP rods that will border each unit, and make the boundary of the unit by encompassing the fabric which is designed to endure and partake a somewhat like pouches where the rods will fit inside and perform as a whole unit with the collaborating of the fabric. In the figure underneath we can perceive altered details of the way the fabric should be prepared, and how the pouches or the pockets should be fashioned. Then where the connections should be positioned in each unit of a quota of the structure, which will be taken as a reference. Also the way the fabric will be designed and in which way the rods will fit inside is also presented where the way the structure is prepared, as its tube shape will make the fabric tougher to design. Wherever the rods should fit inside the fabric from distinct places and go out from other places. The fabric details are illustrated in figure 50.

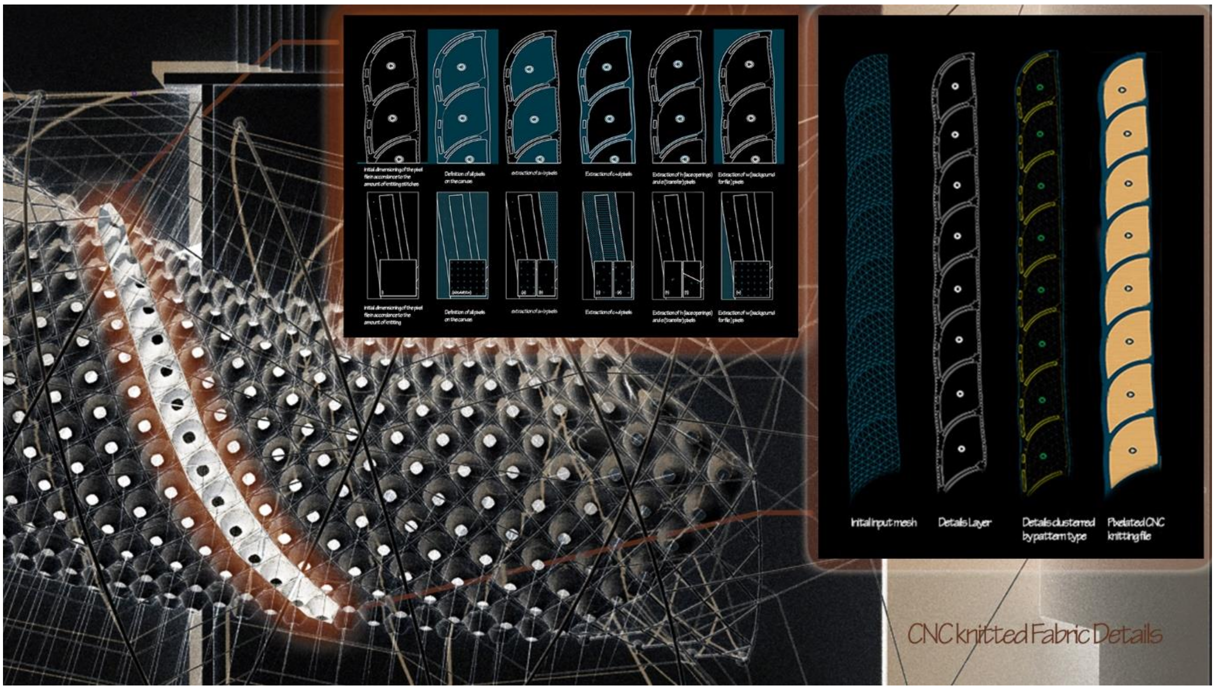


Figure 50, illustrating the details of the CNC fabric. Illustrated by the author.

The design dimensions are represented in the figure number 51 below, where the pavilion is formed in dissimilar non static way. Therefore the dimension of the structure is grander on the edges of the structure than in the medium. As much as it's higher in the boundaries than in the middle and respectively correspondingly broader from the edges and slenderer in the central part. In addition to the main edges of the structure is made by two curvatures that are represented in the figure 52 below. Also the design is placed on a double layer because of the landscape of the site, where one part is higher than the other, which makes the dimensions even more diverse.

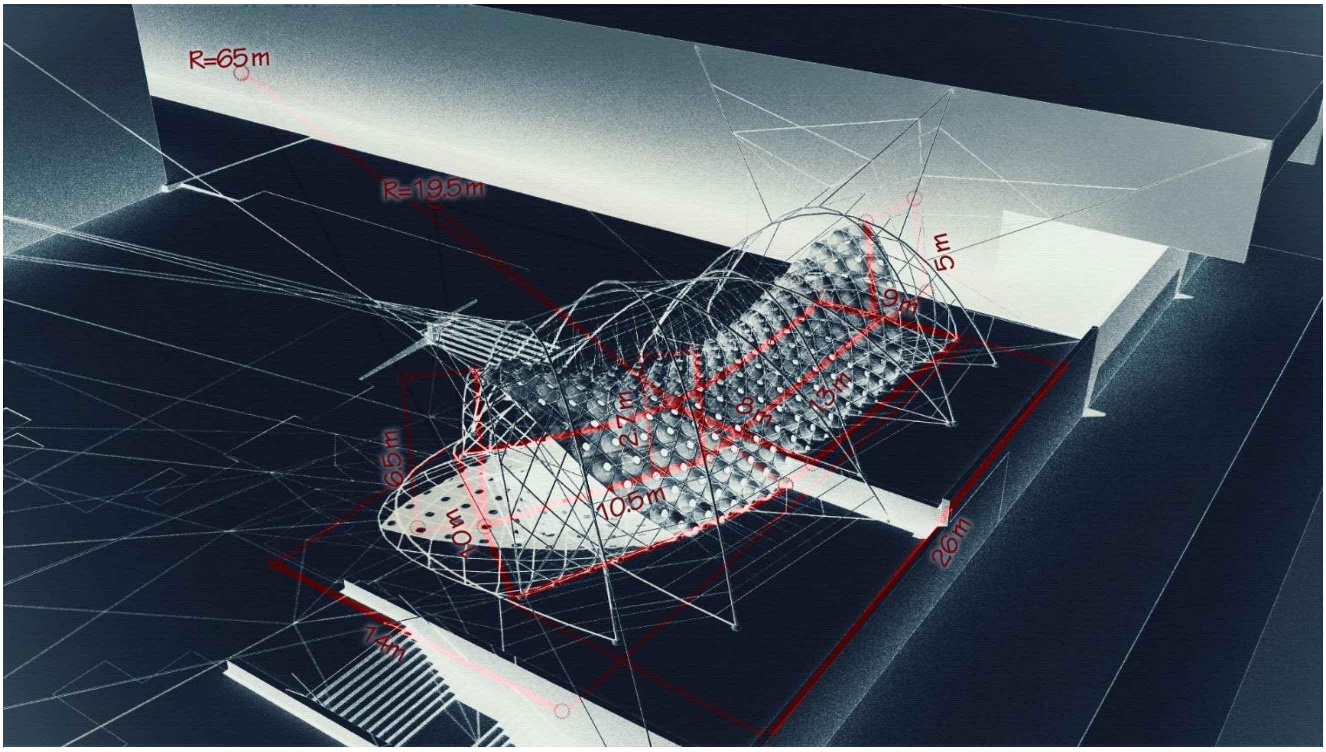


Figure 51, illustrating the diverse dimensions of the design. Illustrated by the author.

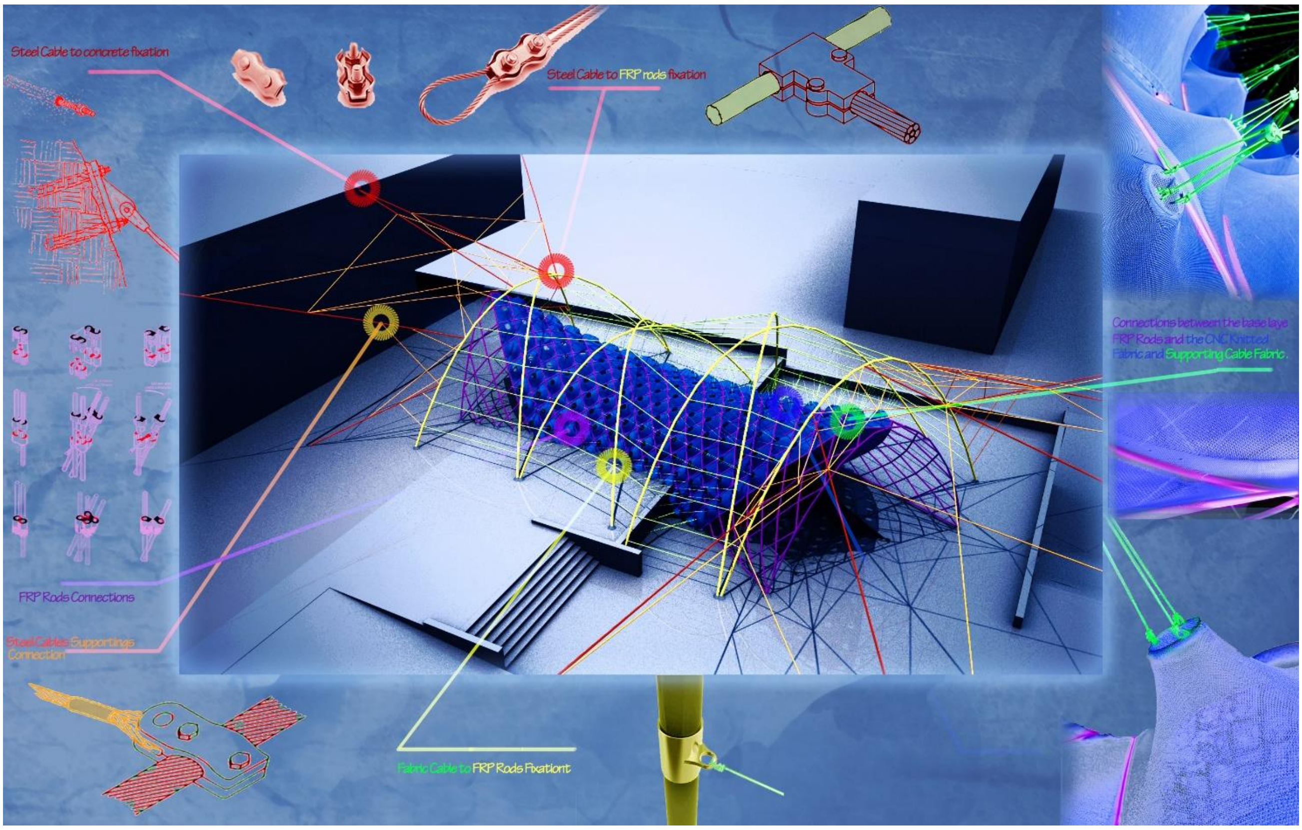


Figure 52, illustrating different structure details. Illustrated by the author.

7.4 DESIGN FUNCTION

After conducting all the researches desired for establishing an idea about the design concept of the structure the design is molded corresponding to this perspective as presented by the figure 48 below. Afterwards there is the functions that will be offered by the model, where all the emphasis for the design concept and the desirability and luring the structure will brand for the users, then the user concede to the structure it should acquire some sort of a value or intent for this attraction. As illustrated in figure 53.

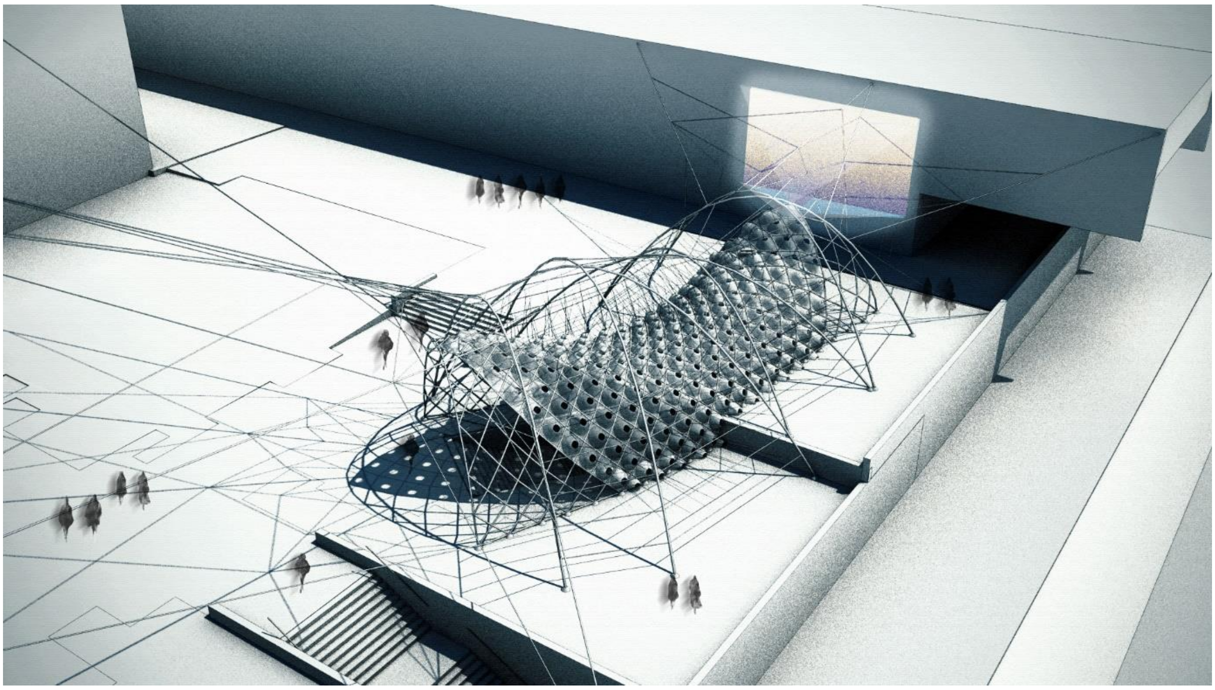


Figure 53, illustrates a bird's eye view for the structure. Illustrated by the author.

The locality of the site provide particular benefits from the space wise and above that for the design where under the selected location exists a concealed interior space that is used in the meantime as an electrical generators room, nevertheless in the proposal of the design this room will be transformed into a recreational space with a bar and a cafeteria and it will be accessed mainly from the main entrance of the structure where a stairs will be placed in order to access it. As illustrated in figure 54. While this space will have admission on the underneath space and the adjacent green space from its secondary access is placed on the lower level of the structure. In this manner the structure will play a role as a buffer zone between the upper in addition to the intermediate space and the lower one, admitting for the immense green space. Correspondingly the space will have to be fashioned and furnished by the same fabrics materials used in the structure, where in the concept it will play the role as the interior core of the spider net by way of in this way the connection between the materials will contribute a visual and sensational connection for the users.

The second part of the structure will play a role as a pavilion for an open air cinema as the screen will be the adjacent building wall. And the screening will be placed on the wall and the users will stay inside the structure, which will form the focal sitting area for them. As illustrated in figure 55 and 56 below. Likewise this part will play a role in giving the other part of the exterior space behind the building and importance whereas the first part of the structure will play a role as a buffer between the upper green space and the lower green space, this part will play a role as a buffer between the same level spaces but one which usually is not admitted by the users and now after implementing the design It will be admitted and have a grander role as a terrace for the landscape. Which before the location of the site used to attend. In this way the main purpose of the location which is give cleanliness view for the user is still expressed but shifted to a more cloistered location but with the same intent.

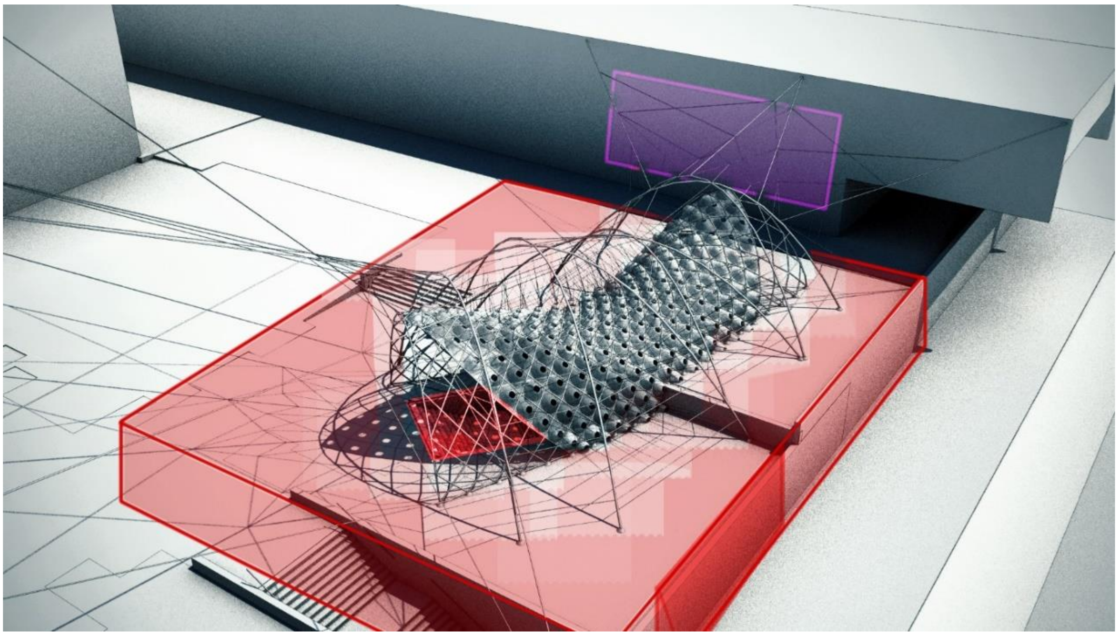
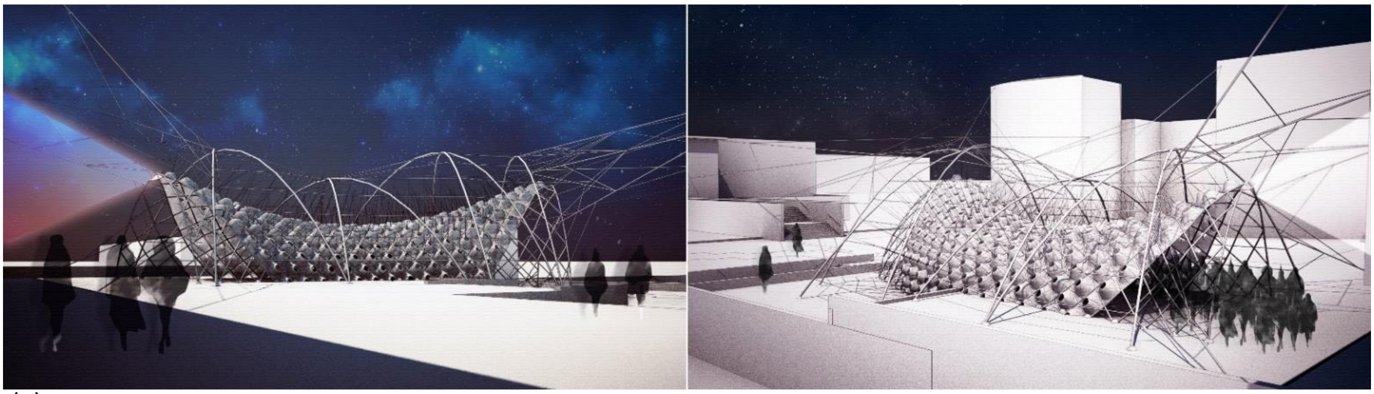


Figure 54, illustrates the different location of the function represented in the model. Illustrated by the author.



(a) (b)

Figure 55, (a) and (b) illustrates a bird's eye view for the structure. Illustrated by the author.

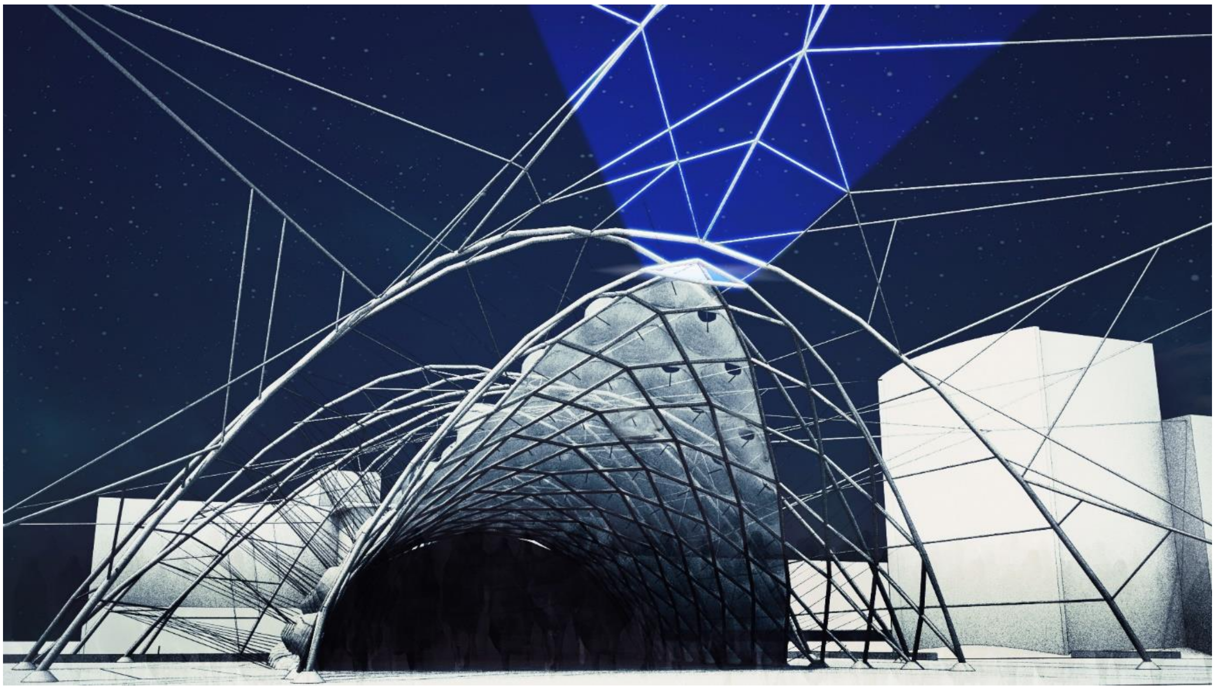


Figure 56, illustrates the focal sitting area the structure will provide. Illustrated by the author.

Another main purpose why the design was located in that fragment of the site, is the role that the design will play for connecting the chief circulation square of the university with its adjacent green space located throughout and alongside the campus of the university. As shown in figures 57 and 58 below. Nevertheless an actual connection between them does not exist, which give the attendance that they are independent of each other while the design will benefit and generate an association or a association between the two spaces by creating a link between them, where the users will access the structure and get out from the inferior side which admit them to the green space and by that a linkage of spaces will be arranged.

Figure 57, illustrates the connection of flow the design will establish. Illustrated by the author.

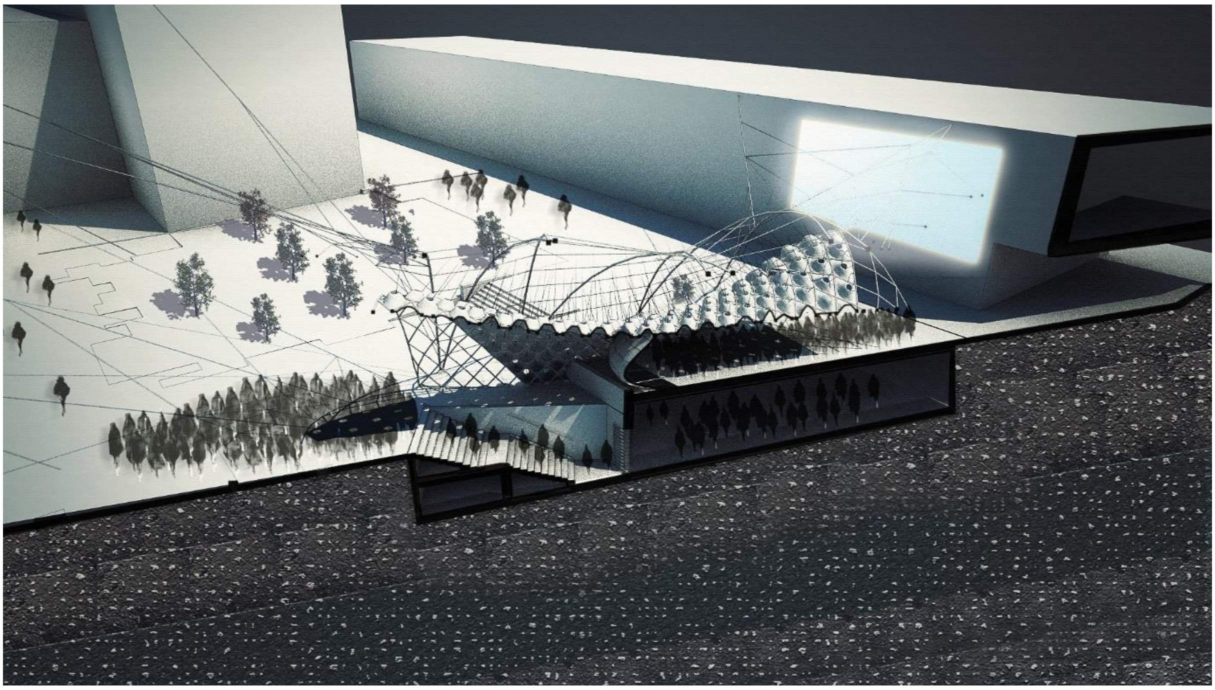


Figure 58, illustrates a 3d section for the design showing the different levels it's designed on. Illustrated by the author.

7.5 FUTURE DEVELOPMENT

The design and its concept that was adapted in this case, can be renovated into a more developed state. The concept that was studied in this case which is the early warning system of the funnel-spider web, and the way its lure and attract its preys and the conversion of this biomimetic concept to a real world architecture model that will affect and contact the humans being. This idea can be altered and adapted in being a brand or a customary technique. Whereas the elements that will be used and applied whichever if they are from the same materials or from diverse materials, nevertheless the idea and concept of making the architecture elements contact and affect and lure users into spaces will be a constant. As it can be converted into a considerably greater idea that can move all the world. As illustrated in figure 59 below.

Where in this case it was formed in a university, but the idea can get superior and the structure can be positioned on museums entrances on school entrances on rehabilitation cooperation and etc... This biomimcry concept can help in shape communities behaviors and engagements. By attracting and luring the users into meticulous establishments, as the attraction of this elements will connect all the world since at the end the human being is the similar in all the planet. And the outcome of this concept will be applicable in china as much as it's applicable in Portugal for example. Where authenticity the concept connects the feelings and nature of humans and not their moods or thoughts. It's in the human nature to be interested in discovering new aspects of the world and the ambiguity of the structure will appeal them.

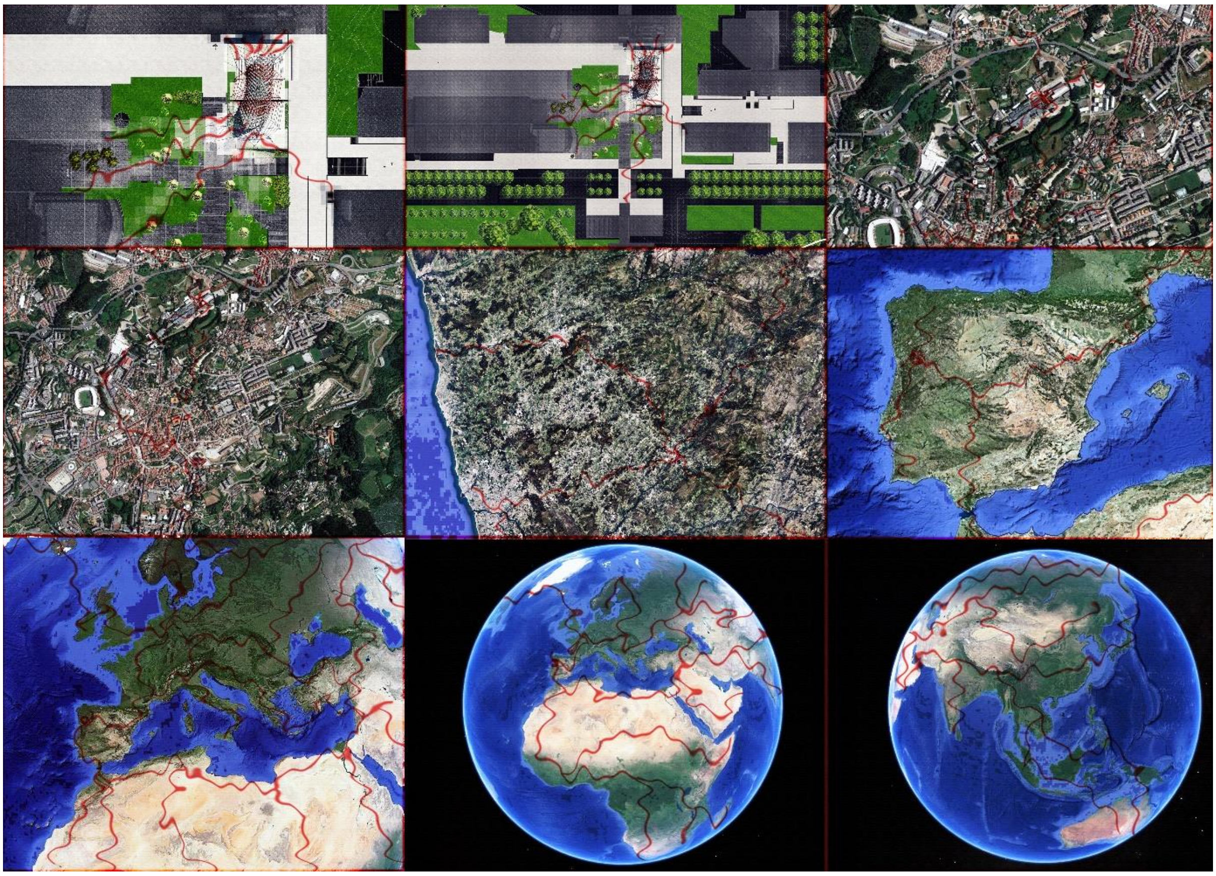


Figure 59, illustrates the future development that the design can brand. Illustrated by the author.

What is proposed here is to connect all the world with its differences on one concept on one trend that is demonstrated and educated and emphasized from nature, by means of possibly once again the nature will be the only motivation for humans from all around the world will be associated in their state of mind and engagements as for establishing an innovative enhanced generation and enriched intentions.

8 CONCLUSION

We know the answers we seek, the secrets for a sustainable world are literally all around us. And if we choose to truly mimic life genius then the future will be beauty and abundance and certainly fewer regrets, in the natural world a definition of success is a continuity of life you keep yourself alive and you keep your offspring alive that's success but it's not the offspring in this generation but success is keeping your offspring alive ten thousand generations and more. And that presents a conundrum because you're not going to be there to take care of your offspring ten thousand generation from now. Therefore what organisms have learned to do is to take care of their place then that's going to take care of their offspring. Life has learned to create conditions conducive to life and that's really the magic perceived of it. Life creates conditions conducive to lifecycle, and that's also the design brief for all the people concerned in this right now we have to learn how to do that and fortunately we are surrounded with the answers and millions of species are willing to gift us with their best concepts. It's not solitary about regenerating energy from nature, or only by using green materials and green architecture it should be profound than this. We should change our way of construction habits and norms, our way of crafting concepts in architecture. The dialogue in architecture concepts shouldn't be either that form follow function or function follow form rather that it should be form and function follow nature and sustainability. We are in this phase currently in our lifespan as human beings on earth. We need to discourse this matter, and then and only then we can take a minor step for living in a thriving and sustainable methodology on earth.

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