Material-oriented Studies for Creating New Types of Ecological Architectural Spaces

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May 2019

FIRST EDITION

Abstract

It is not uncommon that most architectural projects typically start with the analysis of problems on a certain site and finding out solutions to address some of those problems. In this process, architectural concepts, forms, materials, details and spatial atmosphere would revolve around considerations on surrounding contexts. Indeed, every project would be unique in terms of its unique site conditions. This traditional way of thinking about architecture and its relationship with the context creates many excellent works. However, in some cases, this way of thinking also limits architects' imaginations to some extent and makes them come up with almost the same existing solutions for certain problems. This scenario becomes more obvious when it comes to ecological architectural projects since there are tremendous previous well-done templates that could be used to meet the requirement of sustainability. But what if we reverse the process, looking at architectural design from the perspective of materials first, being inspired by the outcomes of material studies, and finally focusing on the site conditions? In this case, a more special and interesting architectural space could be created. This paper would explain the idea of thinking ecological architectural design process in the view of material studies and environmental simulations by providing some examples from both studio works and some electives. Some initial ideas regarding the aspect of materials and simulations drawn from electives like the Detail by Rodolfo Reis Dias and History of Architecture: A realist and Environmental Approach to Urban, Landscape and Architecture Design History by Philippe Rahm would be talked about in the first half of the paper, and in the second half, how those ideas influence studio projects and how a material-oriented design process helps create special ecological architectural space would be fully illustrated through both texts and drawings.

Contents

1. Material Studies and Simulations in Electives

Building materials play an essential role in the field of architecture. The type and form of architecture are determined by the type of material used.[1] In some of the electives I have taken, by studying building materials in terms of their physical properties, textures, ways of organization, and also making simulations of physical environment enclosed by them, I developed a comprehensive understanding of what functions materials could serve in architecture. The use of a certain materials creates certain a spatial atmosphere and conditions. As Andrea Deplazes mentioned, "The architecture matter stands as unites in itself all architecture, cultural and atmospheric factors, which are broadcast into space. Architecture obtains its memoria, its spatial power and its character from this material." [2]

1.1 The study on gneiss wall types and concrete pavilion modeling

Using different materials and ways of the organization increases the diversity of space by providing different types of spatial scenarios that relate to a certain spatial atmosphere. Also, the way of using materials has an effect of creating a dialogue with the surrounding environment. In the first half of the Detail course, I did the case study of Thermal Vals by Zumthor, and mainly stayed focus on different types of wall construction methods. (Figure 1) Those specific wall construction methods determined particular spatial experience. For example, the construction of single-front walls which contain gneiss on the one side and concrete on the other side provides people with two different spatial experience. Since the concrete surface enclosing interior space has a smooth texture, it offers a sense of tranquility and artificiality. On the contrary, the gneiss surface defining exterior space offers a sense of dynamic and primitiveness as it has a rough texture. The idea of using different material textures to create different spatial atmosphere was then applied to the design of a concrete pavilion in a desert. The rough concrete surface with vertical line textures forces people to move while the smooth concrete surface encourages people to stand still or sit.(Figure 2)

1 Partha Sarathi Mishra, Aseema Das, *Building Material: Significance and Impact on Architecture* (Building Science, September 2014), 32-33.
2 Andrea Deplazes, *Constructing Architecture: Materials, Processes, Structures* (Darch ETH, 2008), *19-20.*

Course Title: The Detail
Instructor: Rodolfo Reis Dias

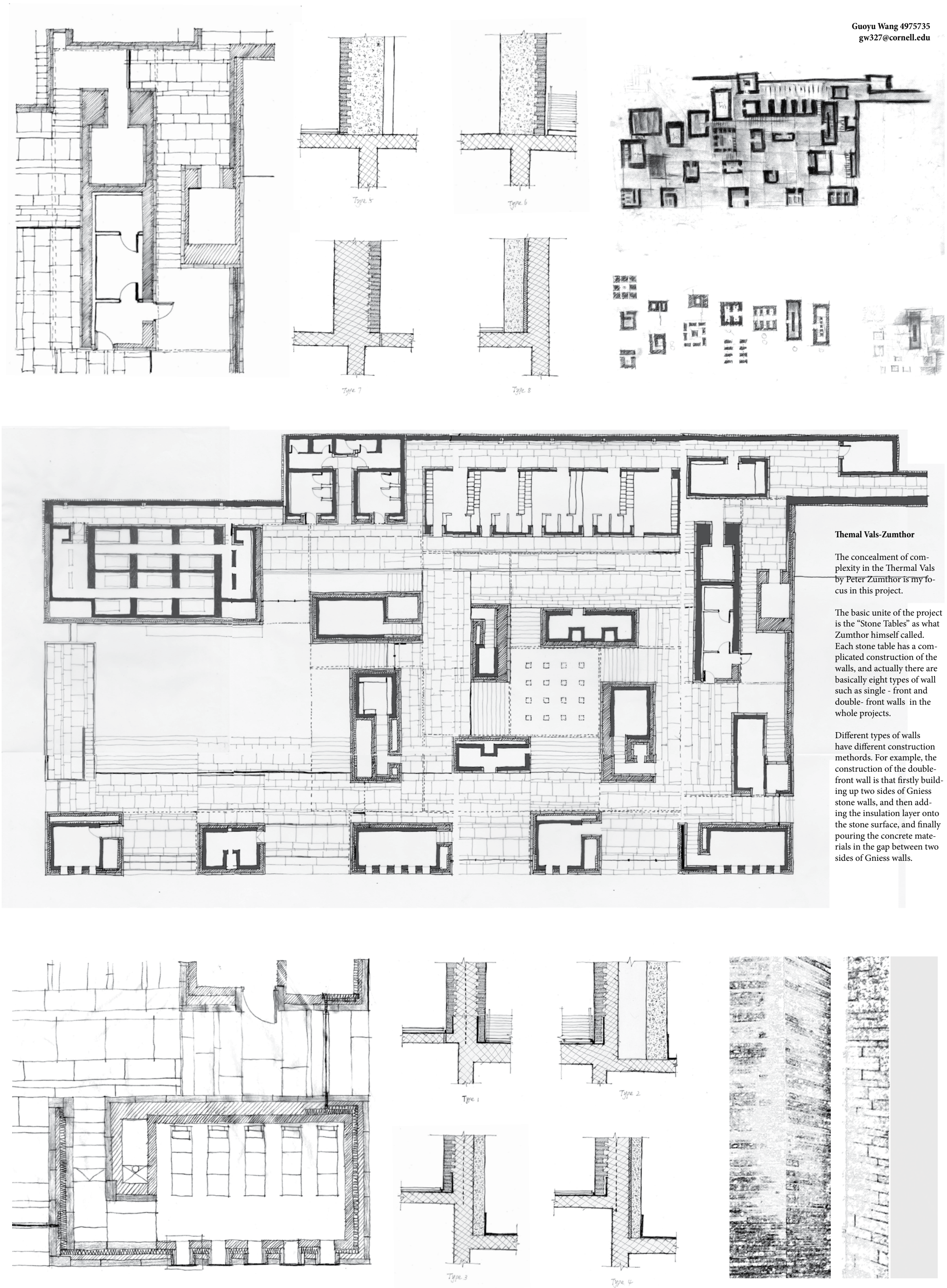

Figure 1. Case study of wall types in Thermal Vals (Drawn by author)

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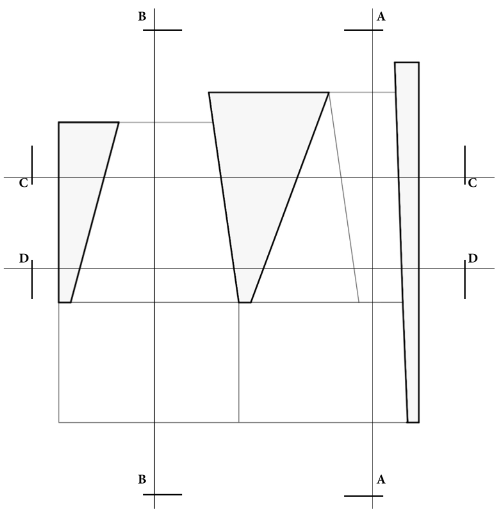

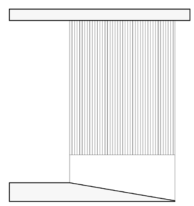
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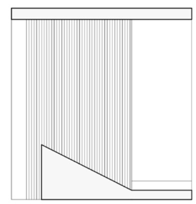
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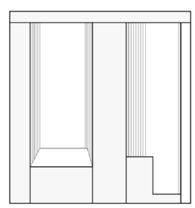
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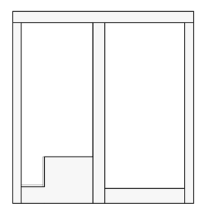
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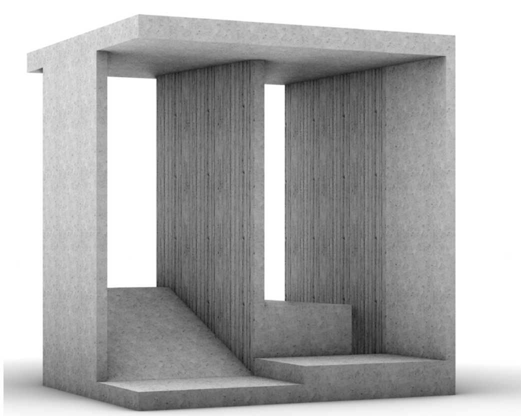
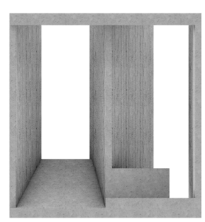
Perspective and Elevations

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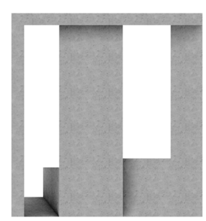
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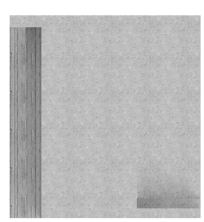
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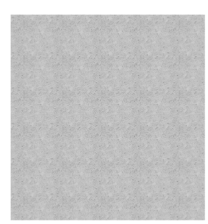
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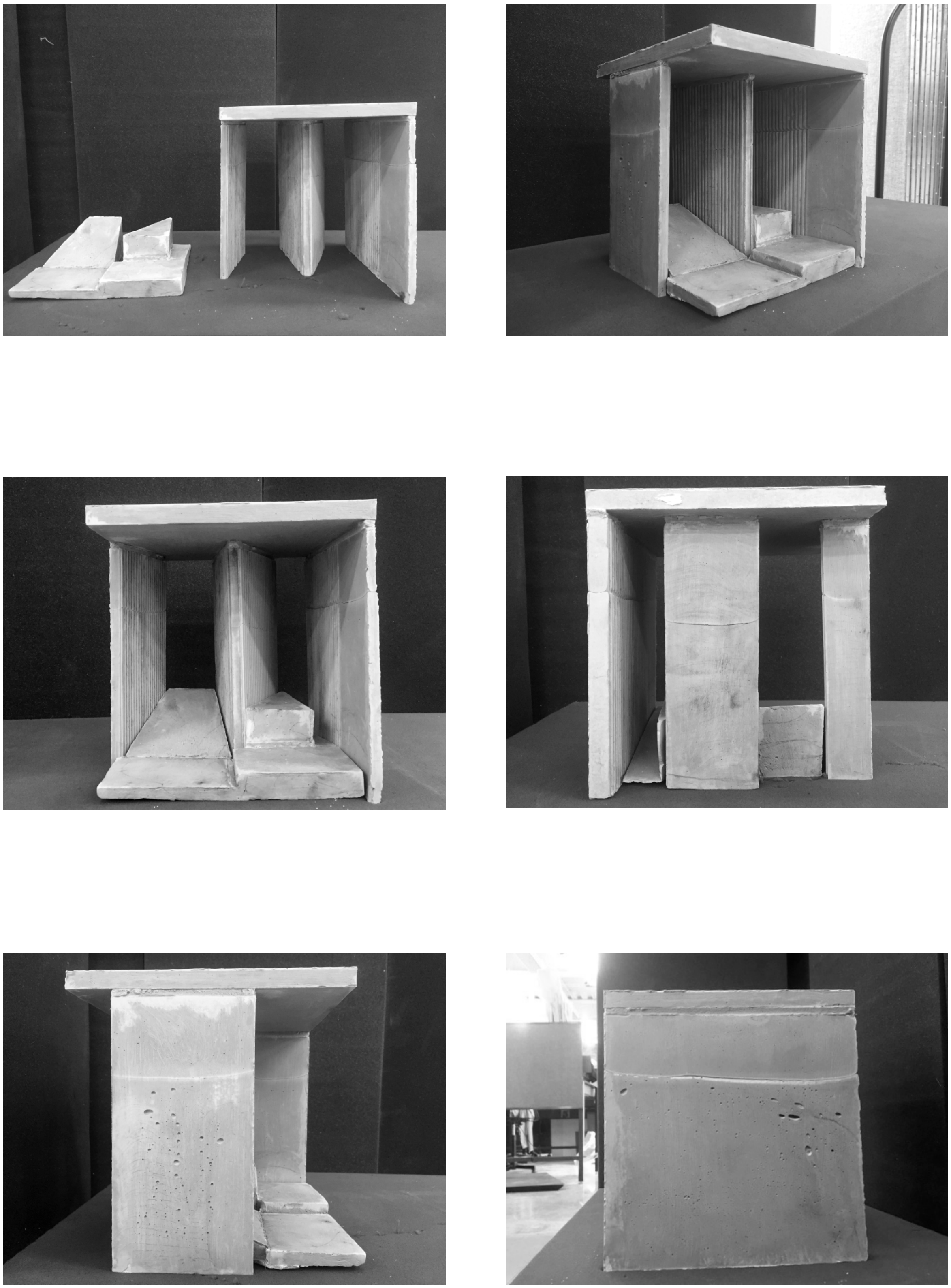


Figure 2. Design and physical model of concrete pavilion (Drawn and made by author)

1.2 The exploration of paper folding and kinetic modules

In some cases, when the form of a single material is changeable, it has the power to generate various spatial conditions that could interact with the environment. Starting with a piece of paper, I looked at how it could be folded and then rotated to become different forms. When a basic flat square-like shape paper was twisted for several times, it could be transformed into different 3D forms such as triangles and fusiform. (Figure 3) Then I moved into the creation of a single kinetic module by using Arduino systems and the material of Mylar that replaced the paper. This developed module system could be reactive to lighting conditions in the environment if used as a canopy. By controlling the degree of rotation of the Mylar, the brightness of interior space could be adjusted. The more overlapping layers of the Mylar there were when the Mylar was twisted, the more sunlight would be filtered by the canopy. (Figure 4)

1.3 The idea of making simulations on material organization

Apart from studying building materials in terms of their physical properties and their ways of organization, it is also really important to make simulations on the space organized by materials to see how the materials altered space environment. In the course of History of Architecture, Philippe Rahm introduced this idea of environmental simulations through a lot of his projects. Interior Gulf Stream, (Figure 5) is one of the classical examples. In this project, a climatic phenomenon is created by the polarization in the space of two different thermal sources: one high cold source at one side and one low warm source at the other side.[3] After this organization of materials, a series of thermal simulations of interior space are made showing different zones with different temperatures, which determines the placement of different residential programs in the space according to different requirements on temperature. By special material organization and visual thermal simulations, it gives a route to escape from the normalization and homogenization of the modern space. Similar simulations on another project with multiple layers of glass also defines different thermal zones that relate to different activities and programs. (Figure 6)

3 Philippe Rahm, Aseema Das, *Interior Gulf Stream* (Philippe Rahm architects), 1-3.

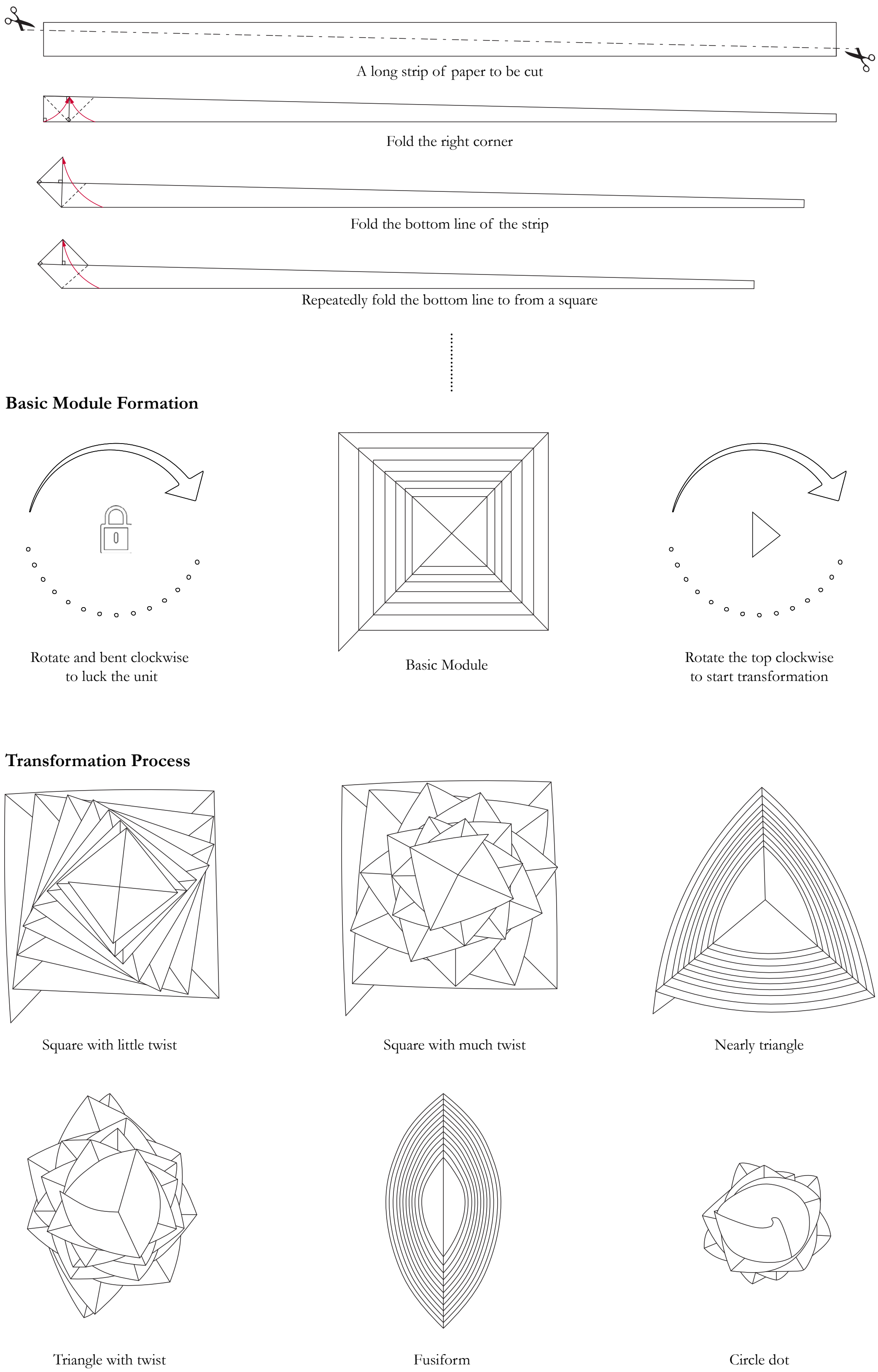


Figure 3. The analysis on the folding and rotation of paper slice (Drawn by author)

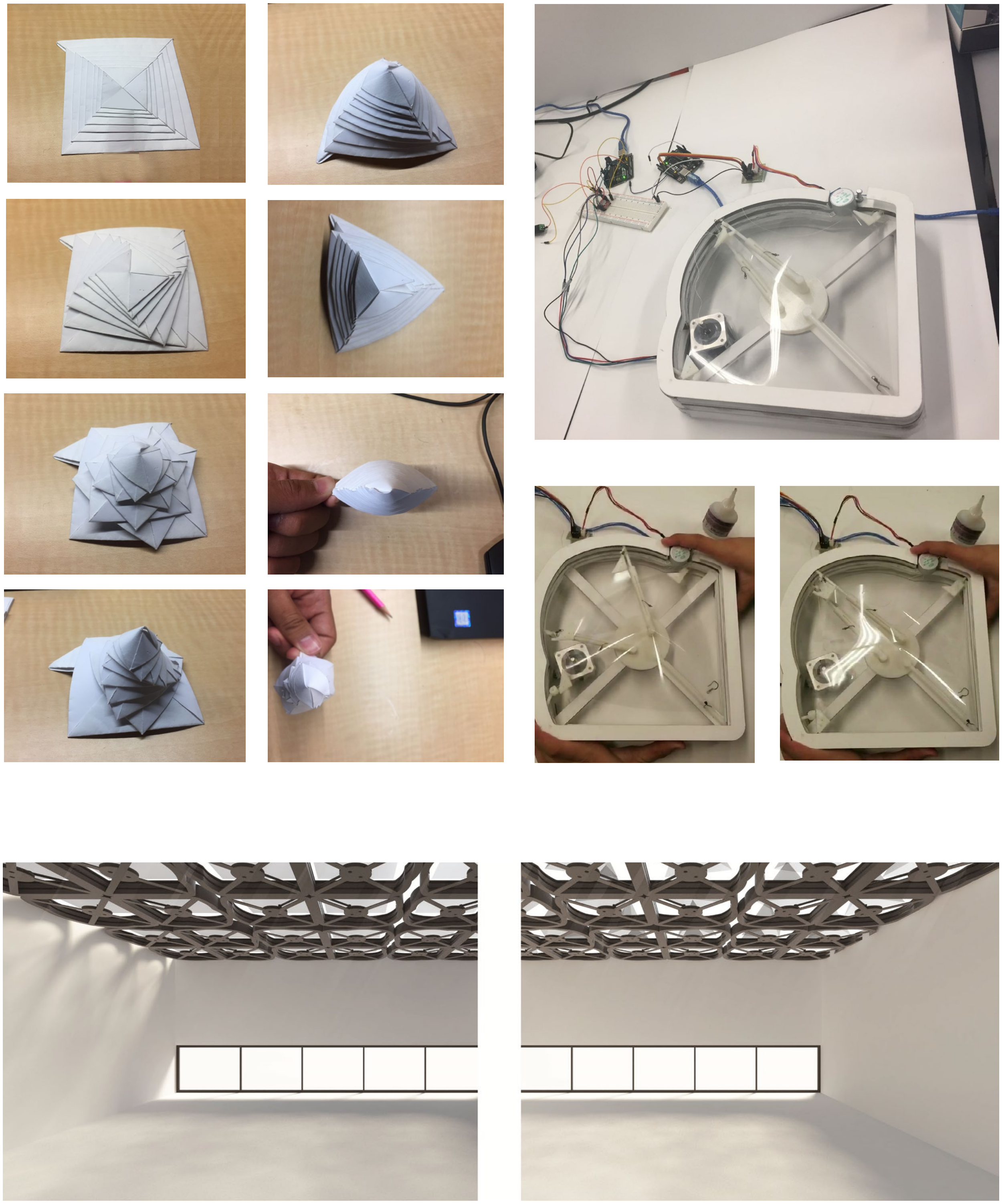


Figure 4. Kinetic modular canopy systems interacting with sunlight
(Made by author and Zijie Nie, Binhan Tang and Junda Liu)

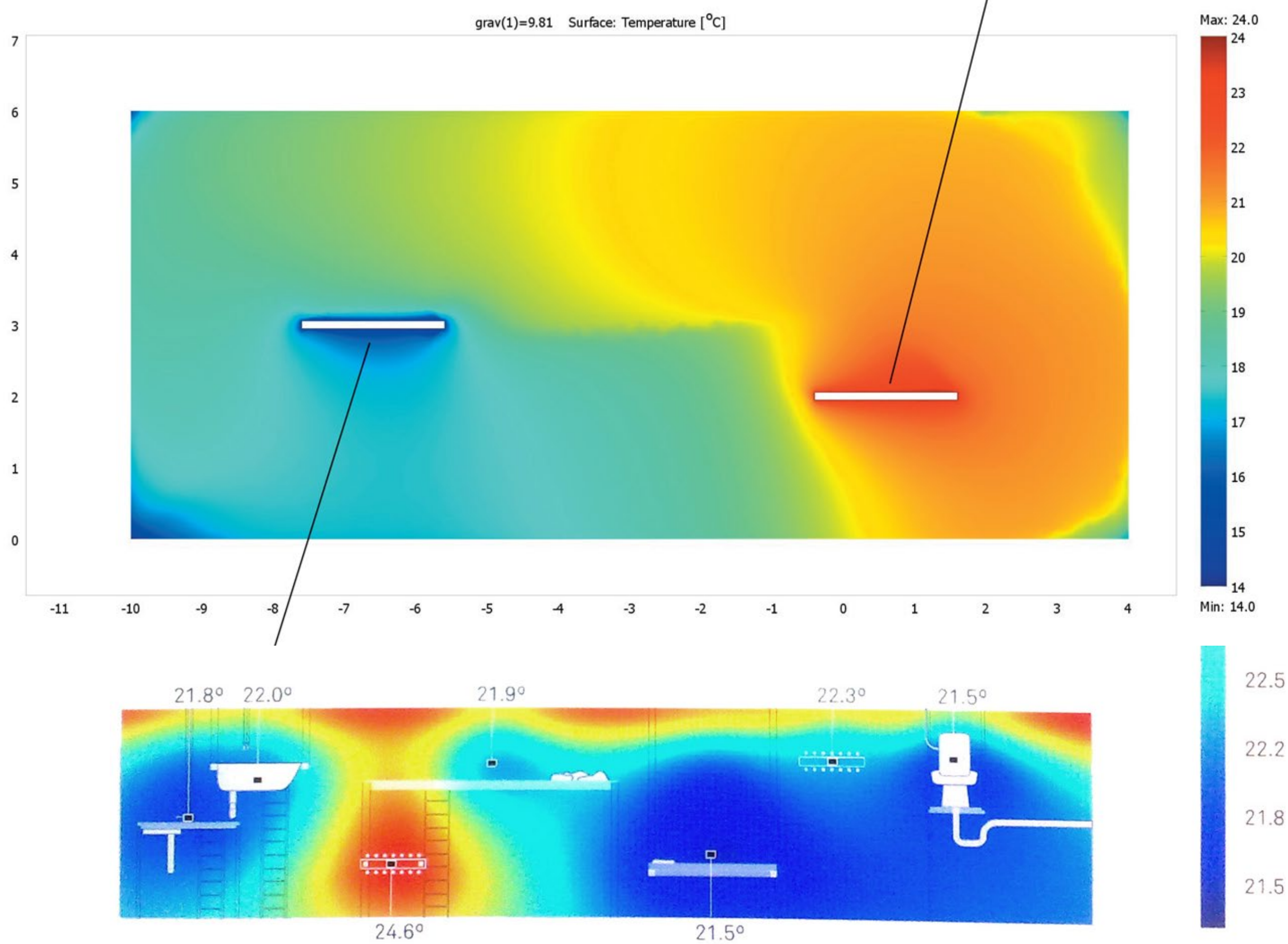


Figure 5. Thermal simulations of the interior space (From "www.philipperahm.com")

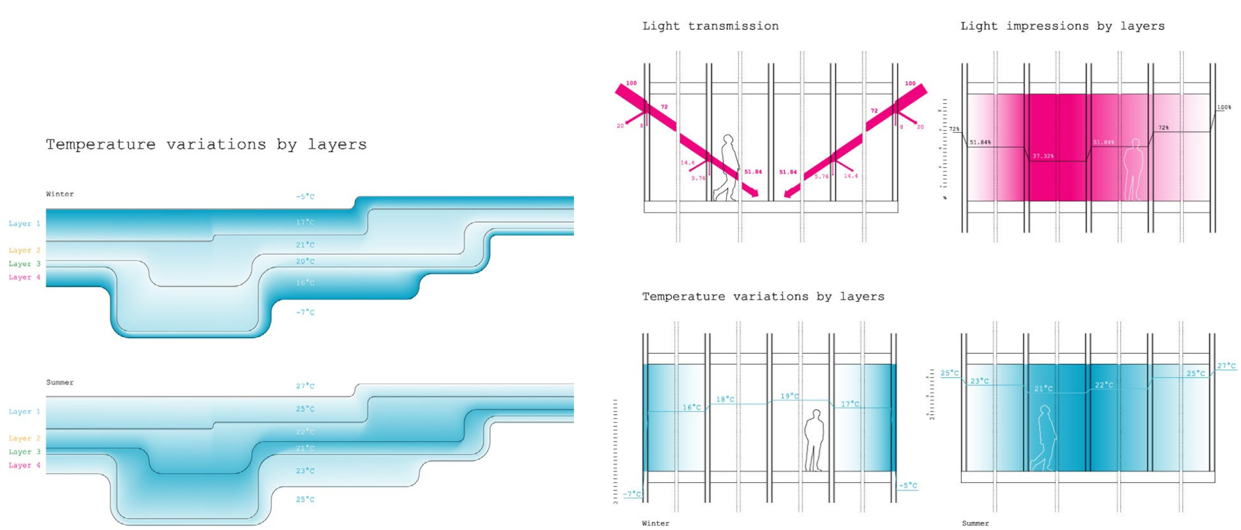


Figure 6. Different thermal zones for different activities (From "www.philipperahm.com")

2. The Material-oriented Design Process in Studios

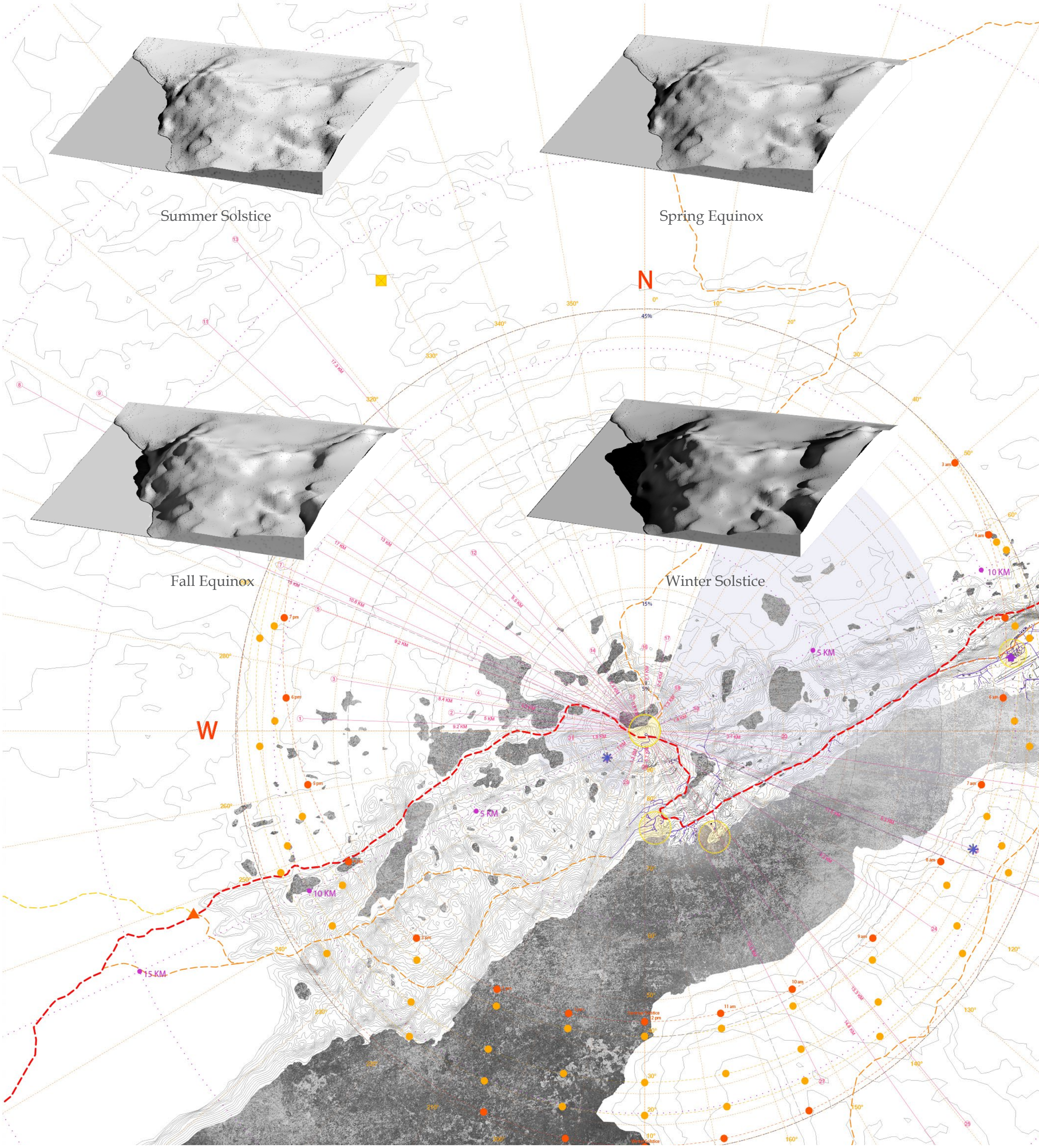
In order to avoid homogenous architectural space in the field of architecture and ecology, innovative design thinking and methodologies different from traditional ways are needed. I believe that a material-oriented design workflow is one of those. Thinking about the selection of materials, the ways they organize to define space, and their relationships with the environment definitely open up opportunities for creating new types of space. As for the selection of materials, the sustainable architecture uses materials that are found at the building site itself, or recycled materials that do have a negative impact on the environment.[4] The organization of materials depends on available building techniques and relationships with the surrounding context.

2.1 Stone as a thermal mass for passive heating strategies

Because of the fact that stone is available on site and is also used for the foundations in some vernacular buildings, the project initially began with the consideration of it as the main building material. The stone was stacked up and down to form continuous ground in interior space, and extended exterior landscapes into the interior space, which gave a sense of living on the landscapes. (Figure 7) The idea here is to create environmental friendly space and achieve the simplicity of space by the use of local materials and simple construction methods. Furthermore, the stone could also be used as thermal mass to absorb heat from sunlight and release it overnight, which could be helpful in an extremely harsh climatic setting of the site in Greenland. According to environmental simulations of sun path and shadow on the site in each season, (Figure 8) the organization of stones was adjusted to fulfill the potential of passive heating strategies. Sometimes the stones became a vertical wall at the back of the project to absorb and store the heat, sometimes the stones became a niche next to the wall for sitting and bathing which need most of the heat, and sometimes they formed bedroom and living areas that were more closed to the lake. (Figure 9) A unique space atmosphere was created by letting stones define all programs in the house.

4 Andrew Walker Morison, Dominique Hes, Margaret Bates, *Materials selection in green buildings and the CH2 Experience* (March 2005), 6-10.

Figure 7. The material study on stone in the lodge project (Made by author)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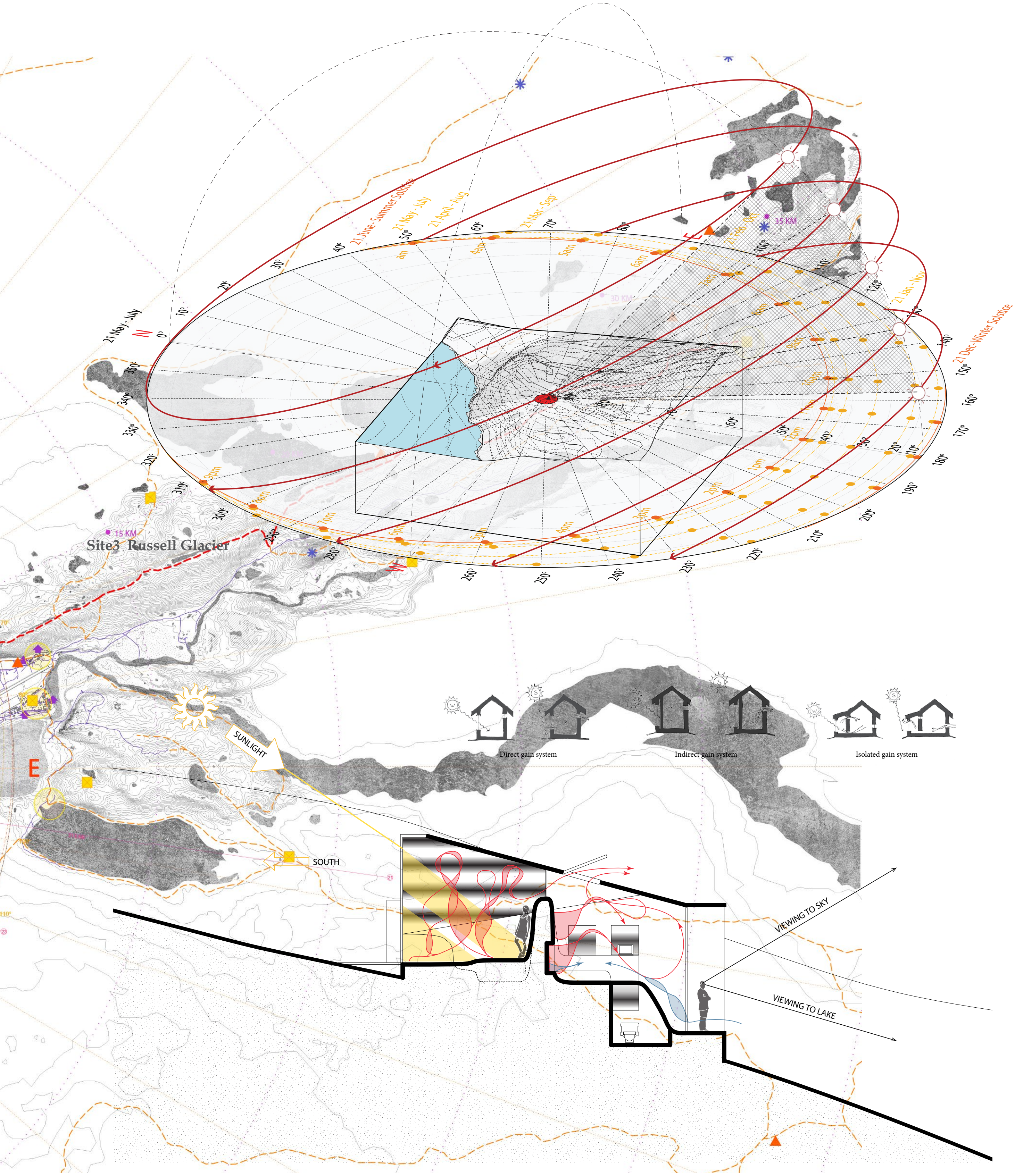
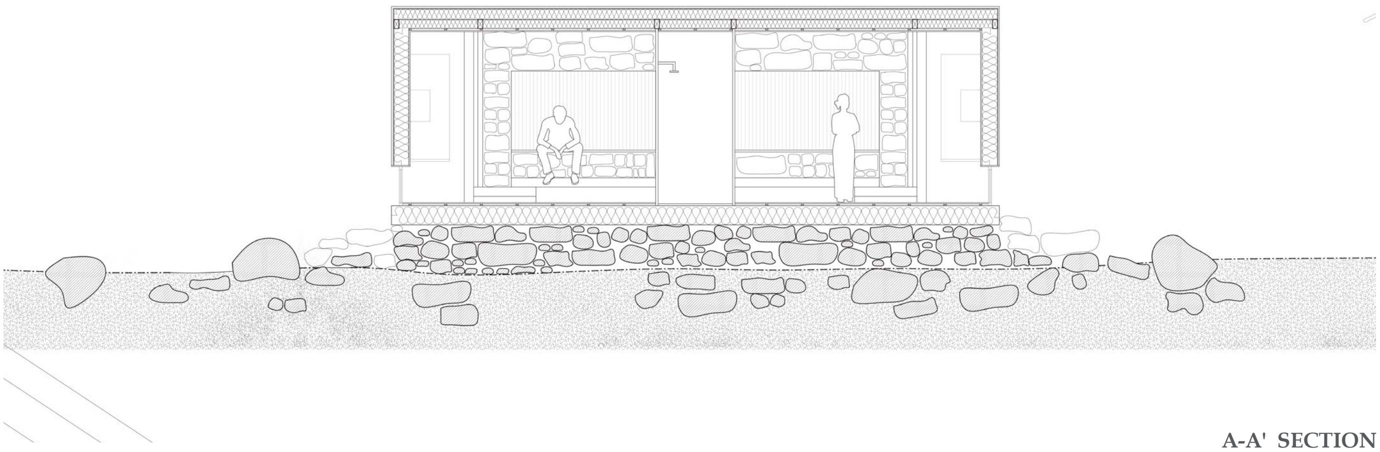


Figure 8. Sunlight and airflow simulations (Made by author and Meghan)



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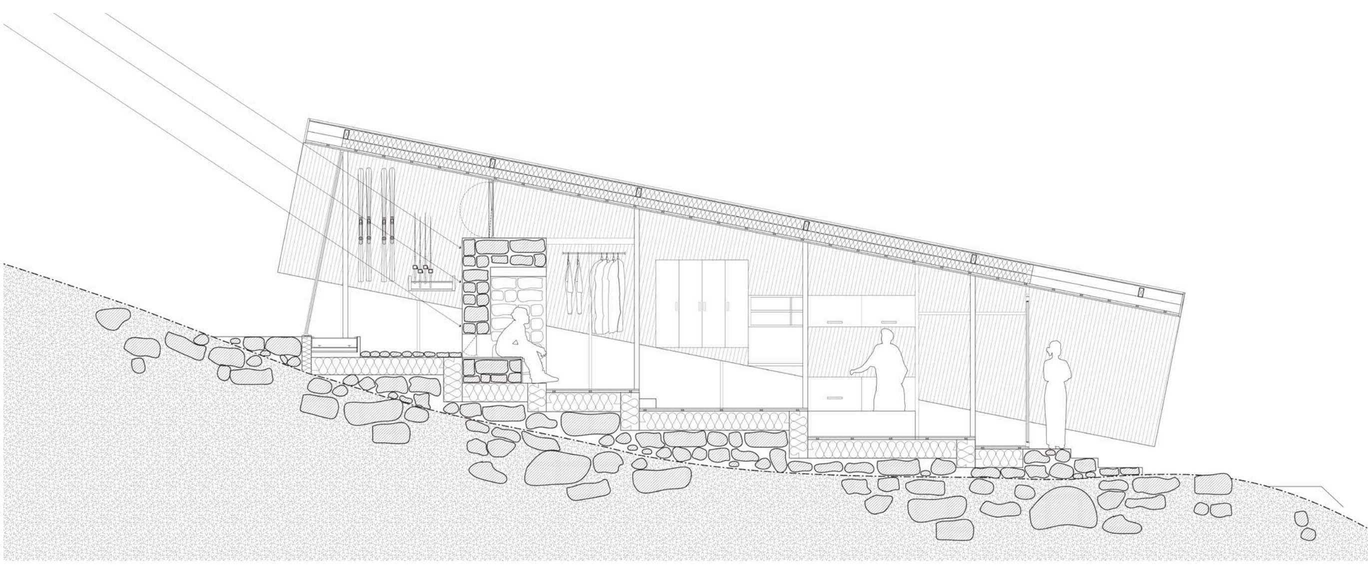
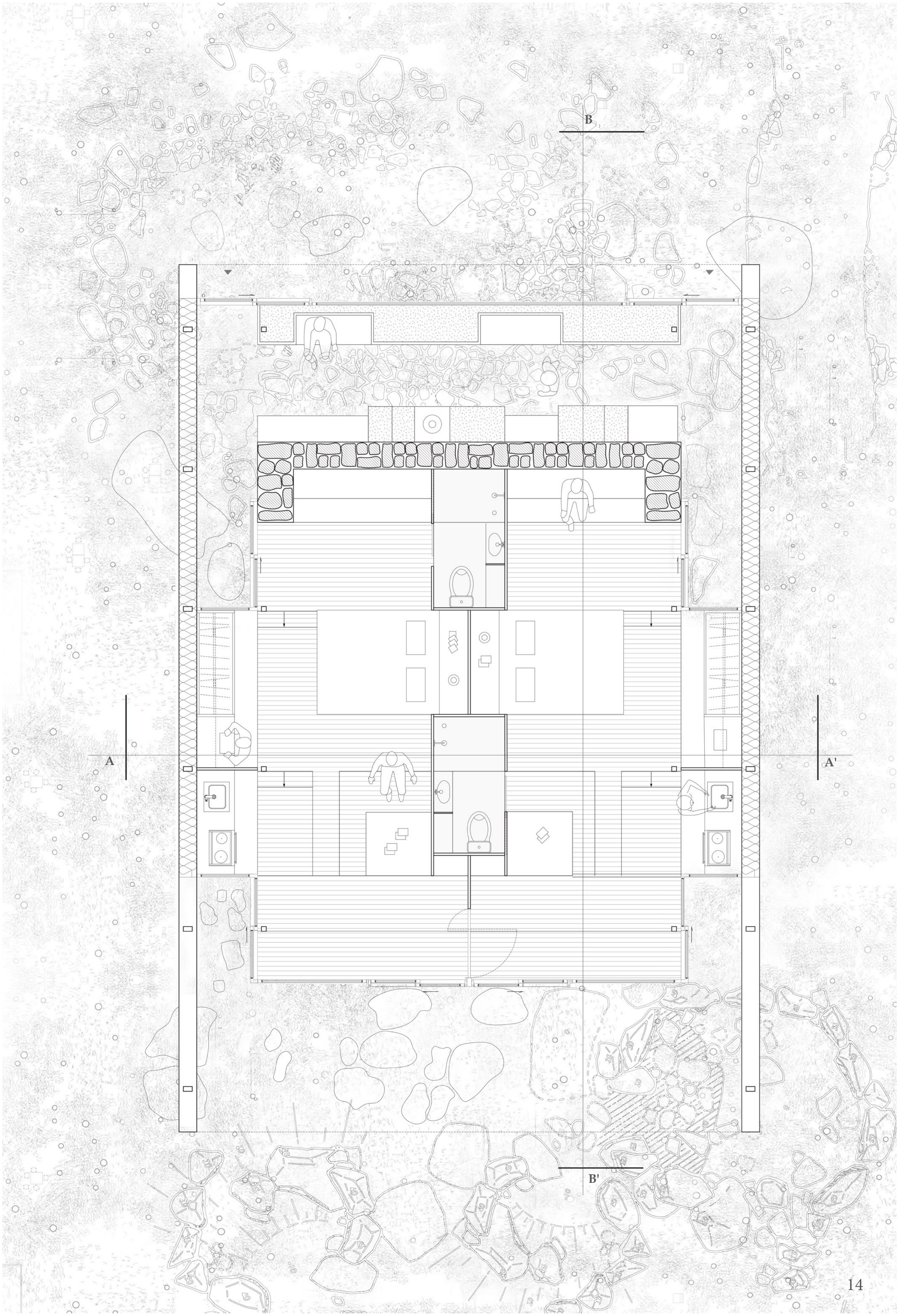


B-B' SECTION

Figure 9. Plan and secions in details (Made by author)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2.2 Digital fabricated material studies for environmental interaction

As a design representational medium, physical model making processes could result in new forms beyond the original concept. Digital fabrication provides designers with realistic opportunities for shape representation, evaluation, and redesign of complex design initiatives, and rapid prototyping in this process can lead to great potential significance for design.[5] Thus, studying materials in a digital fabrication process could be a good way to help create new types of ecological space that interacts with the environment. Even some uncertainties and errors in the process have the potential to inspire architects to create new forms for their projects.

In the design studio of Matter Design Computation, a biological nature model, the glass sponge, was chosen to study at first. During this phase, I learned how the living organism increases its body strength to withstand strong currents at the bottom of the sea by organizing materials of silica and proteins to form a highly hierarchical structure system. Because of the way in which the materials are organized, there are various porosities throughout different parts of the system, which allows the glass sponge to interact with the environment like filtering seawater, housing shrimps and emitting light. (Figure 10)

After the research on the nature model, I proposed an interface that could respond to the environmental conditions of the site of the design studio. An analogy could be made between the glass sponge and the designed interface. While the glass sponge could react to water, shrimps, and bioluminescence, the interface could interact with wind, people and sunlight. Some initial simulations on the wind filtration process through interfaces with different porosity were done. (Figure 11) Different interfaces with different densities were overlapped and organized to create a wide range of wind speed zones. Those zones could potentially create different thermal comfort conditions for different activities. Simulations, in this case, help determine the density of the interface and the number of the interface needed for environmental interaction. (Figure 12)

5 Larry Sass, *Materializing design: the implications of rapid prototyping in digital design* (Design Studies Vol 27 No. 3 May 2006), 325-333

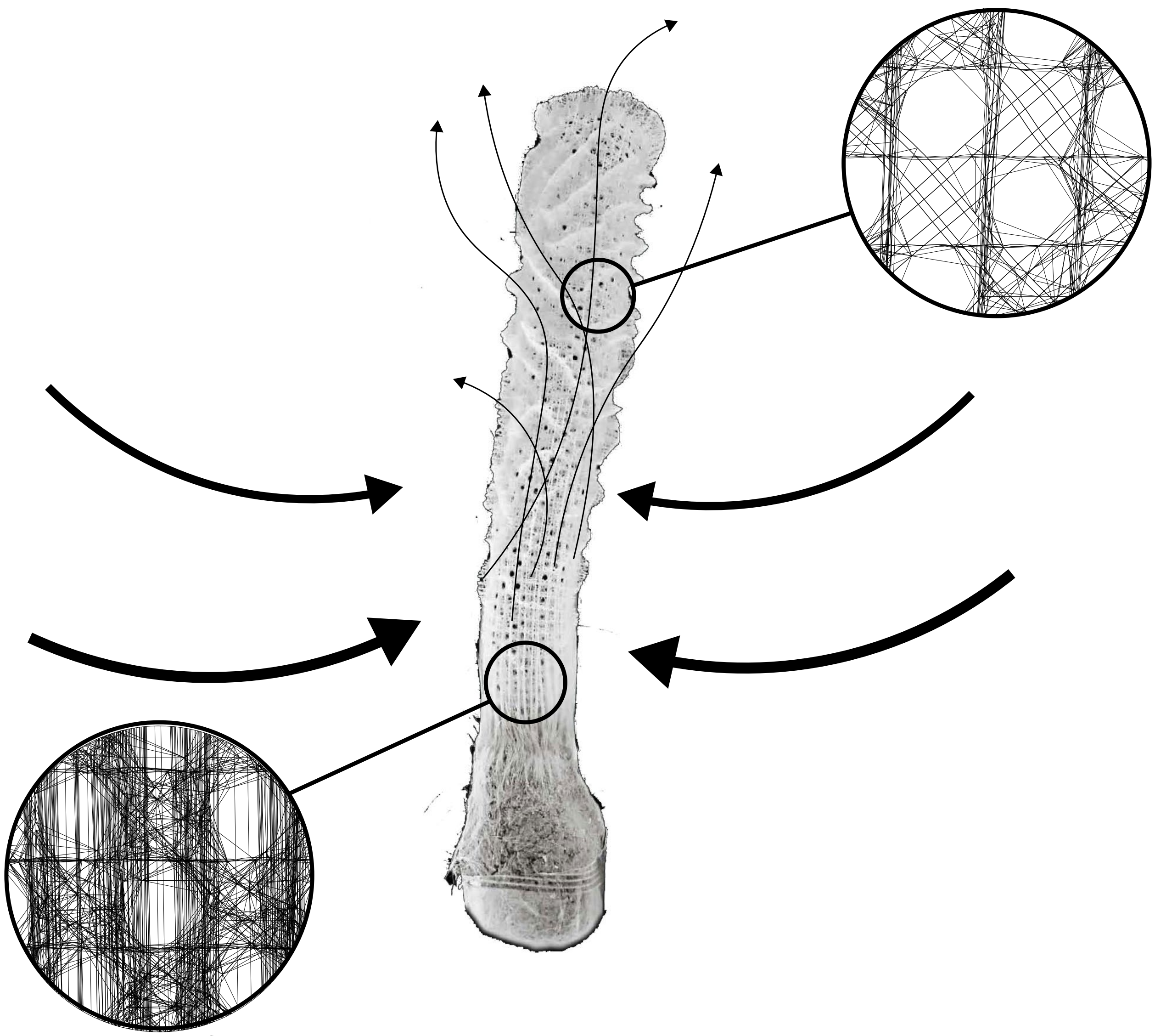


Figure 10. The nature model of glass sponge (Made by author and Binhan Tang)

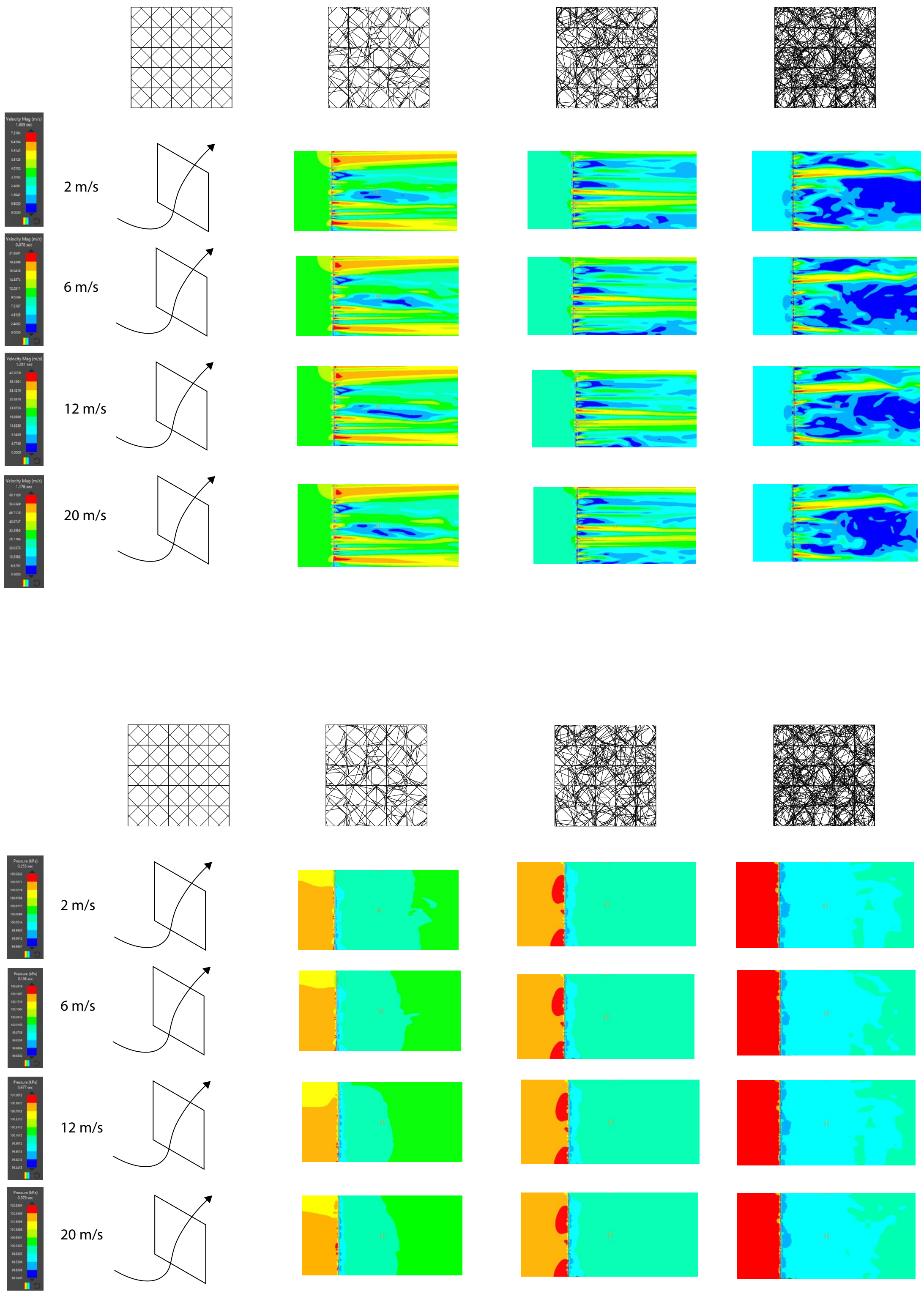


Figure 11. Wind speed and pressure simulations through single interface
(Made by author and Binhan Tang)

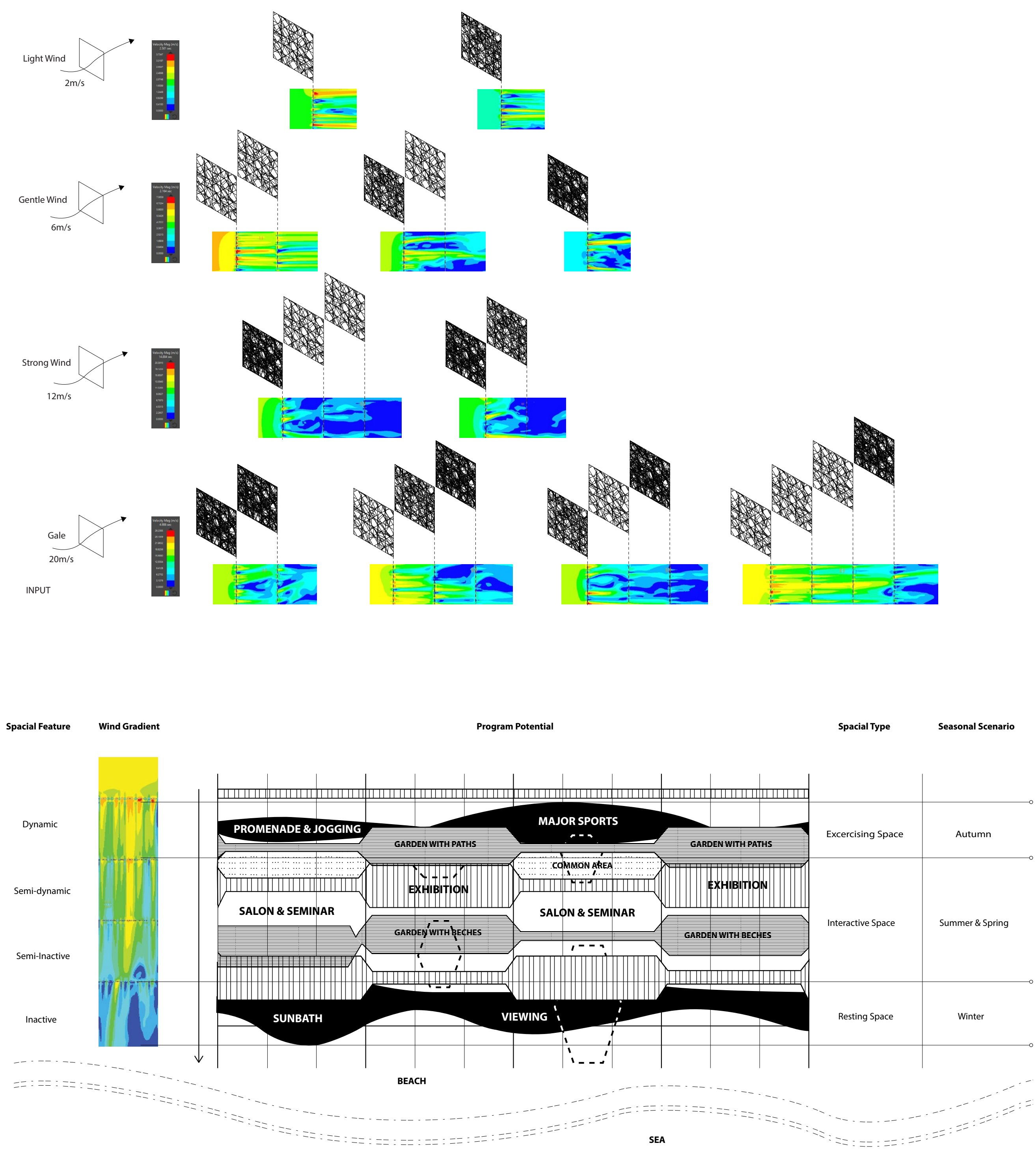


Figure 12. Wind speed simulations through multiple interfaces
(Made by author and Binhan Tang)

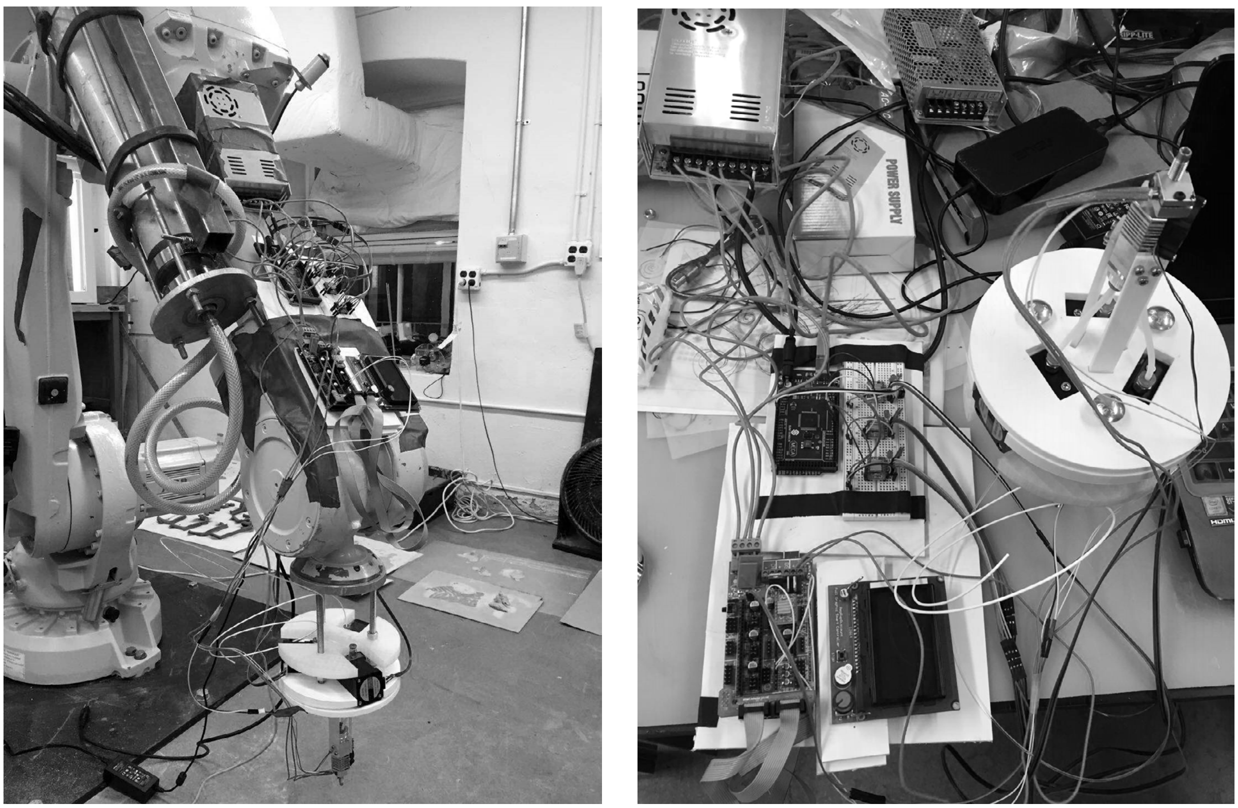


Figure 14. End effector and control board setup
(Made by author and Binhan Tang)

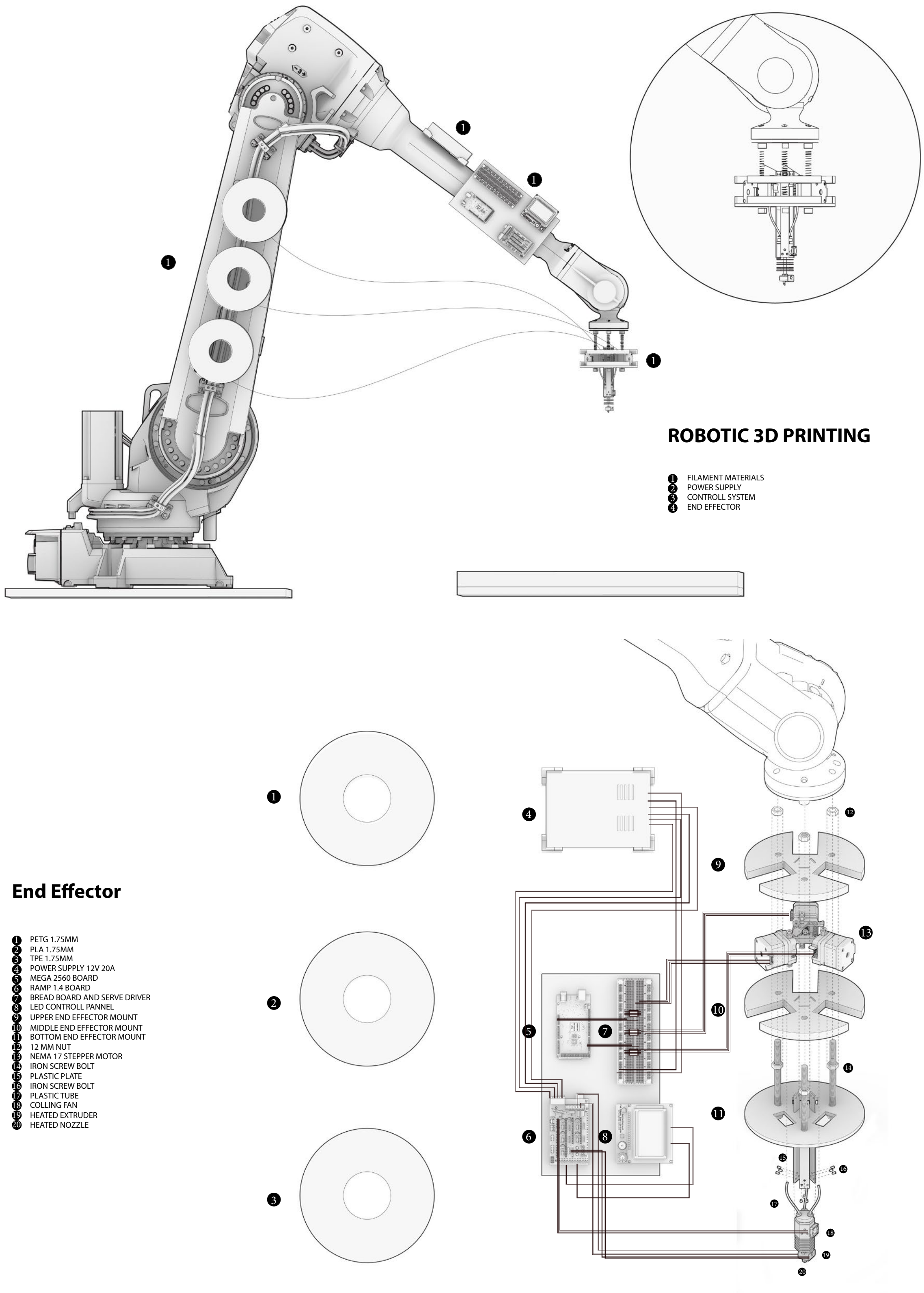


Figure 15. Self-made end effector systems (Drawn by author)

Figure 16. The initial study on the choice of materials
(Made by author and Binhan Tang)

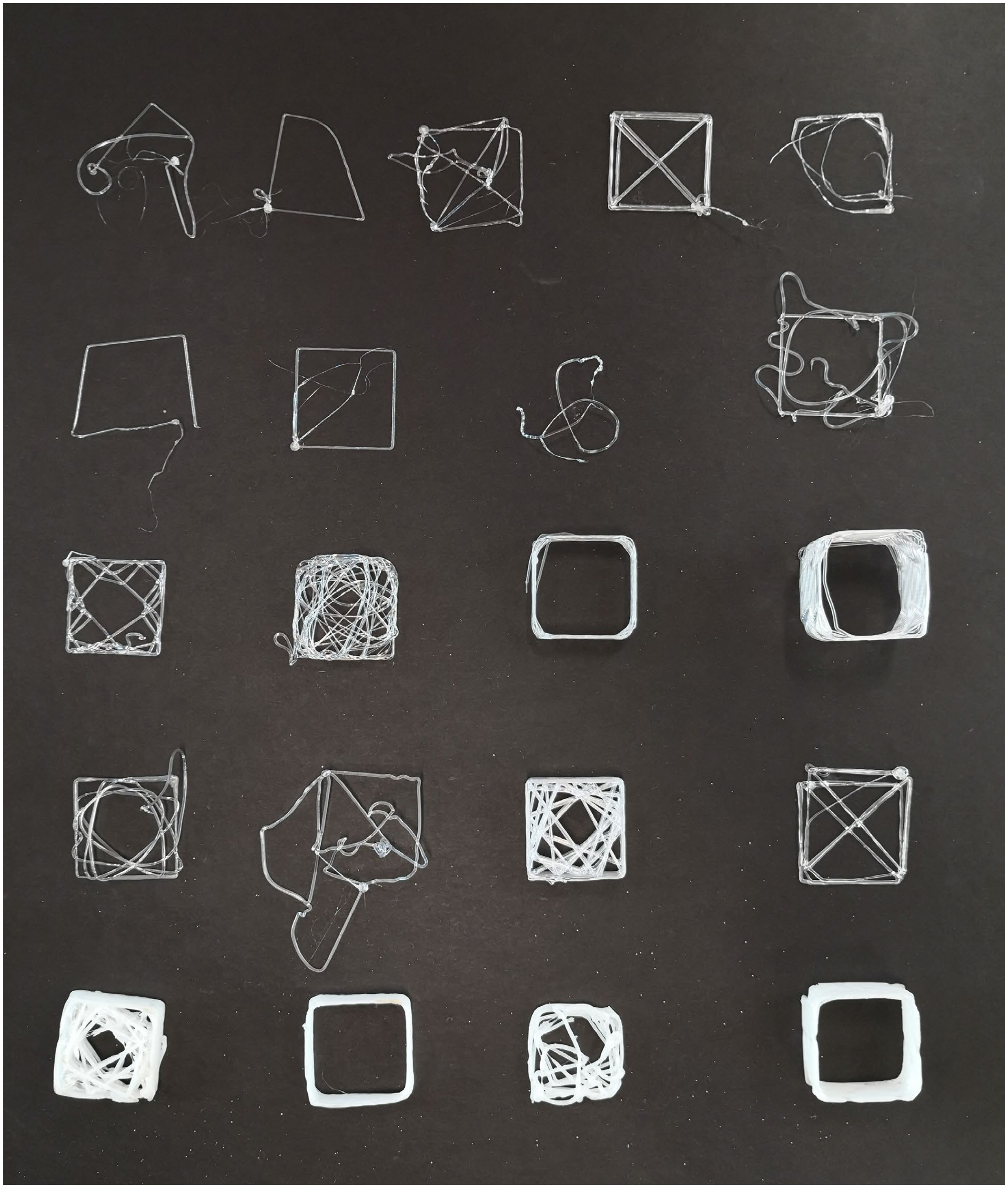


Figure 17. Initial materials tests by robotic fabrication
(Made by author and Binhan Tang)

At the same time, digital fabrication processes using a large scale 3D printing system (Figure 14, 15) brought many inspiring outcomes to the actual form of the interface and the space it defines. Since PETG, PLA and some other filaments are recycling materials, I chose them as the main building materials for creating ecological space in this project. In some original material tests, I was trying to see what degrees of flexibility and transparency of testing samples could achieve by a combination of different materials.(Figure16, 17) Also, different toolpath strategies were used to generate different forms. Those types of forms inspire the types of space in the project. Layering cubes with branches inside could be assembled together to form a square lattice that filter winds and the layering cubes without branches could be enlarged to be the passageway or some private space for people. An interesting part in the layering cube is that by controlling the number of segments of the toolpath, the degree of softness at the corners of it could be controlled. These corners could react to sunlight and sand, creating a special space atmosphere. Some direct sunlight and some sand could enter the space through these corners while some sunlight and sand were diffused by solid layering parts.

To be honest, this interesting corner phenomenon was initially made by the mistake of the insufficient segment numbers of the toolpath, but as I found its spatial potentials, I began to further explore it in terms of the degree of softness. In addition to interacting with the sunlight and the sand, the corners could also be used as furniture for sitting and lying when they get a high degree of deformation. That helps meet the requirements of different activities related to various wind speeds in the project. (Figure 21)

Finally, a basic prototype of the interface with both small squares for the filtration of winds and large layering squares were fabricated. (Figure 18) And also, basic square modules of the interface were fabricated. (Figure 19) By placing this prototype on the site of the project based upon site analysis, different types of spaces associated with different activities were created in a plan. And then by wind simulations of the plan, the density of each interface and the number of interfaces were modified. (Figure 20)

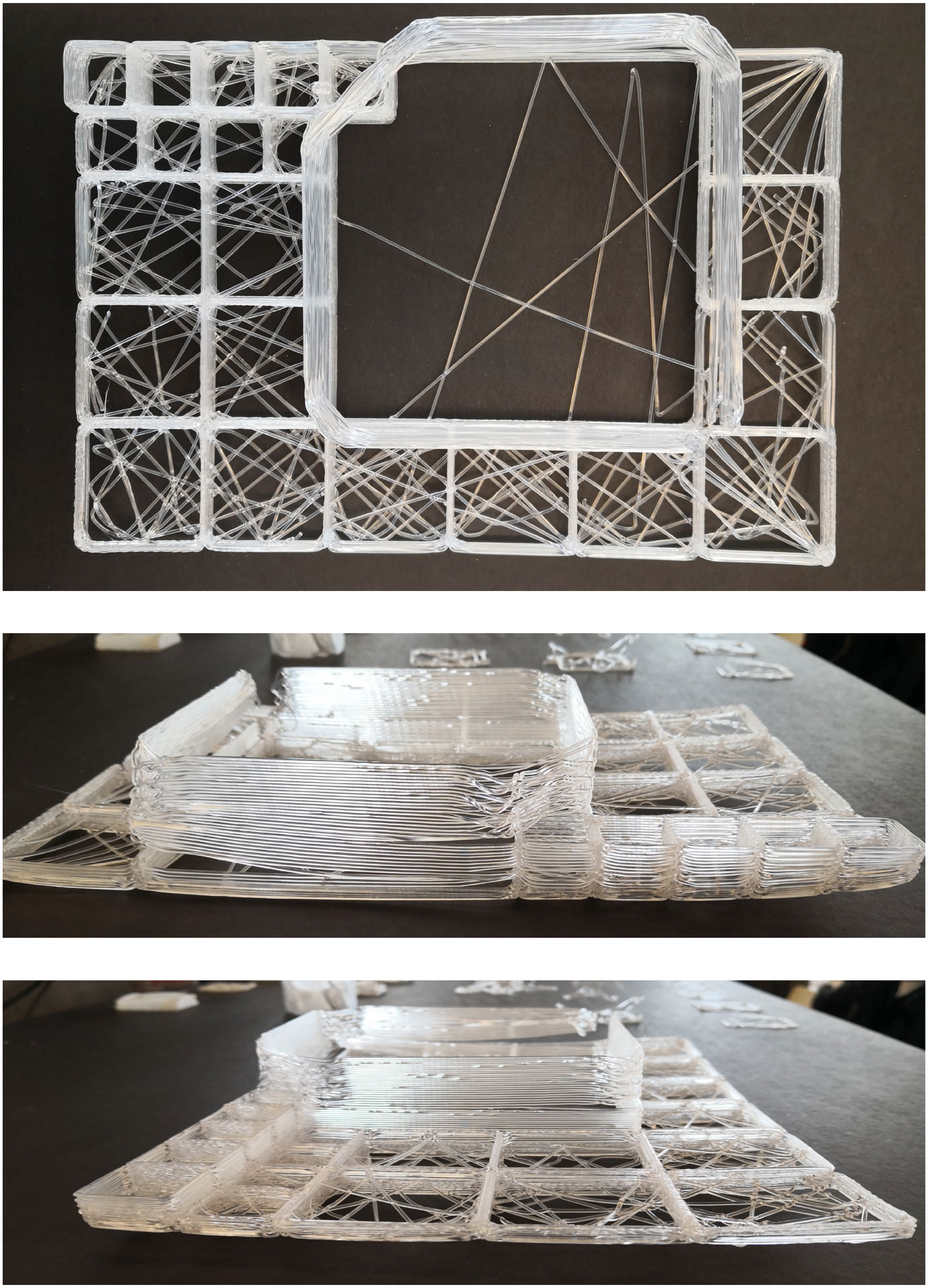


Figure 18. The digital fabrication of the interface prototype
(Made by author and Binhan Tang)

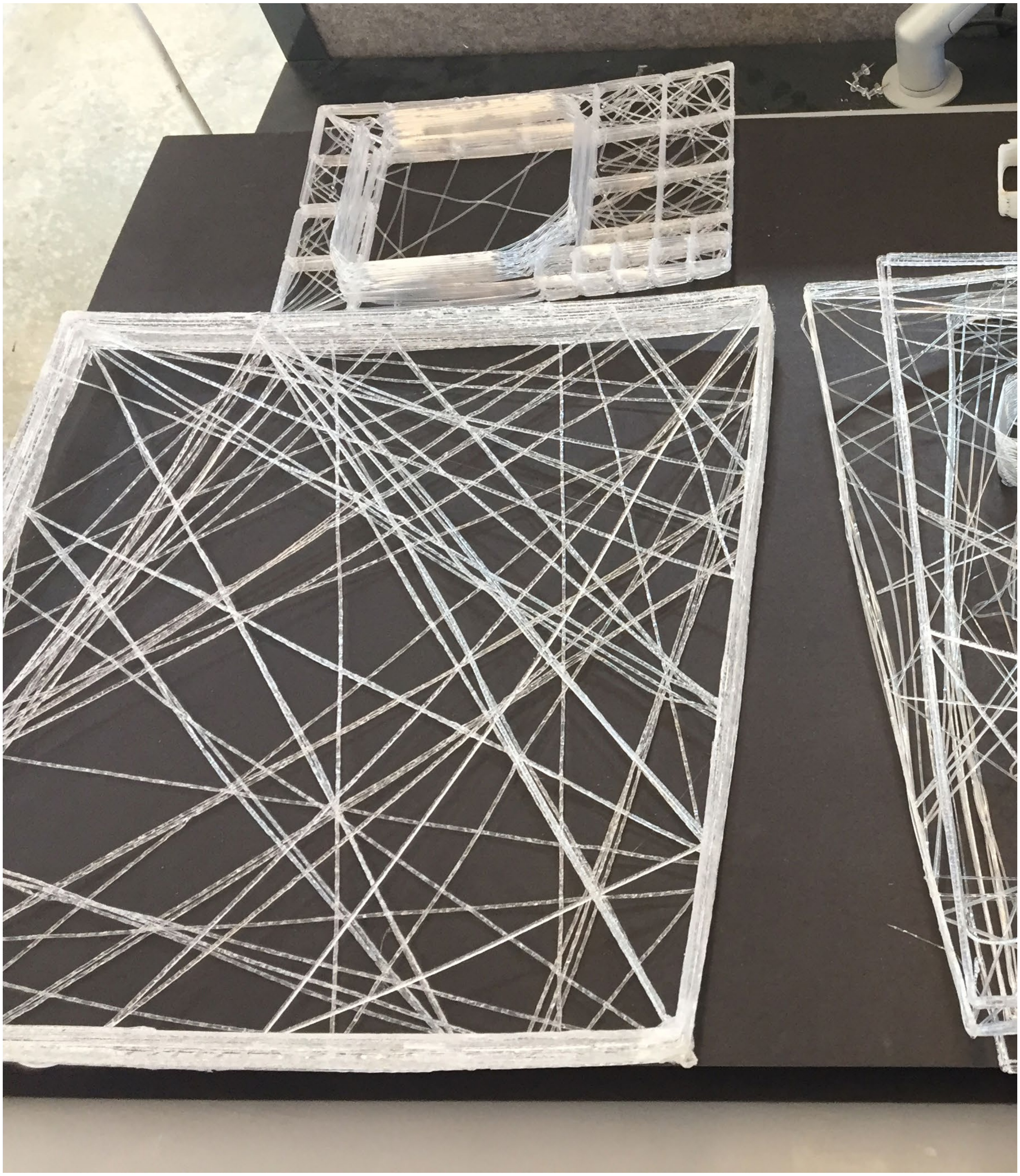
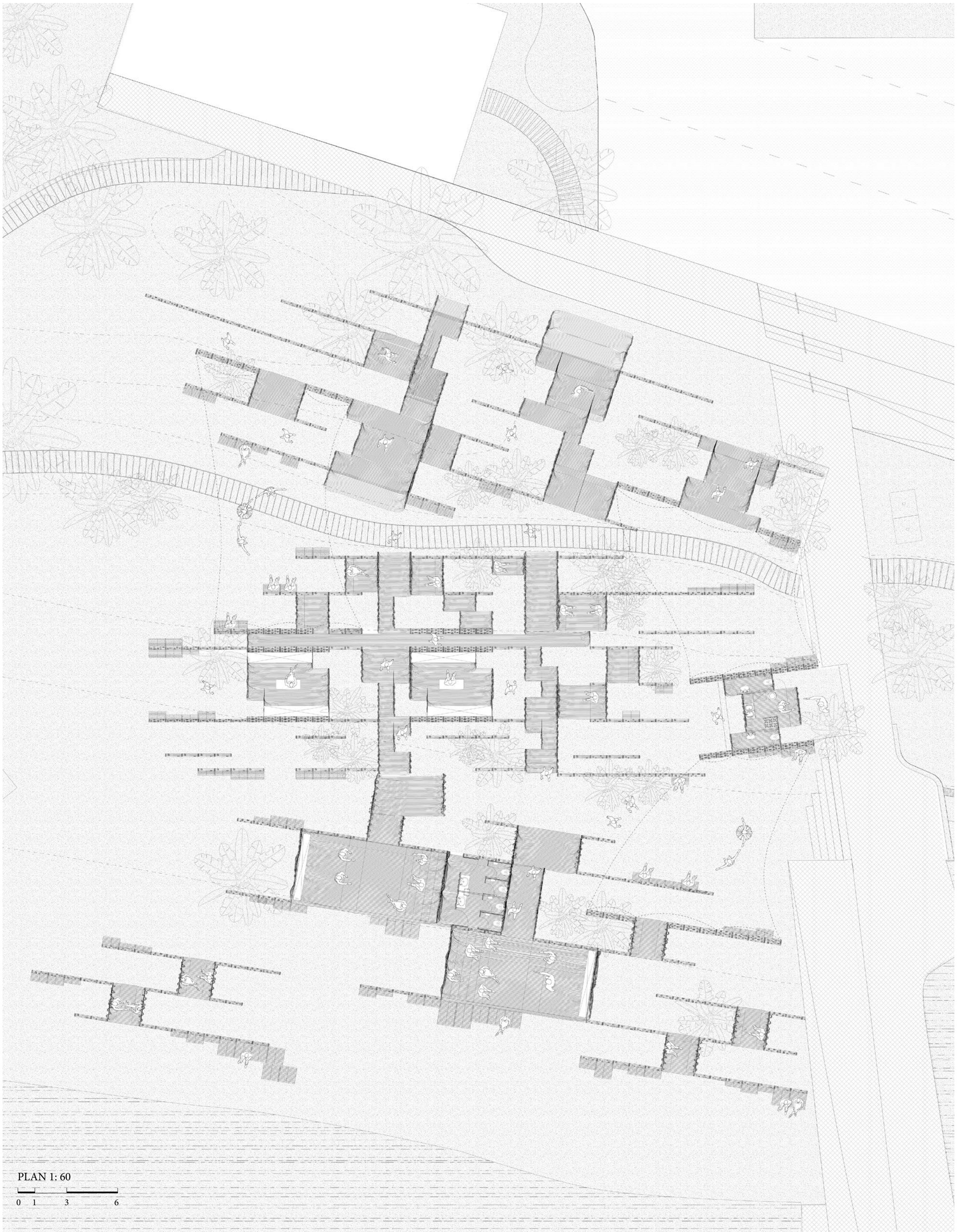


Figure 19. The digital fabrication of 1:2 square units (Made by author and Binhan Tang)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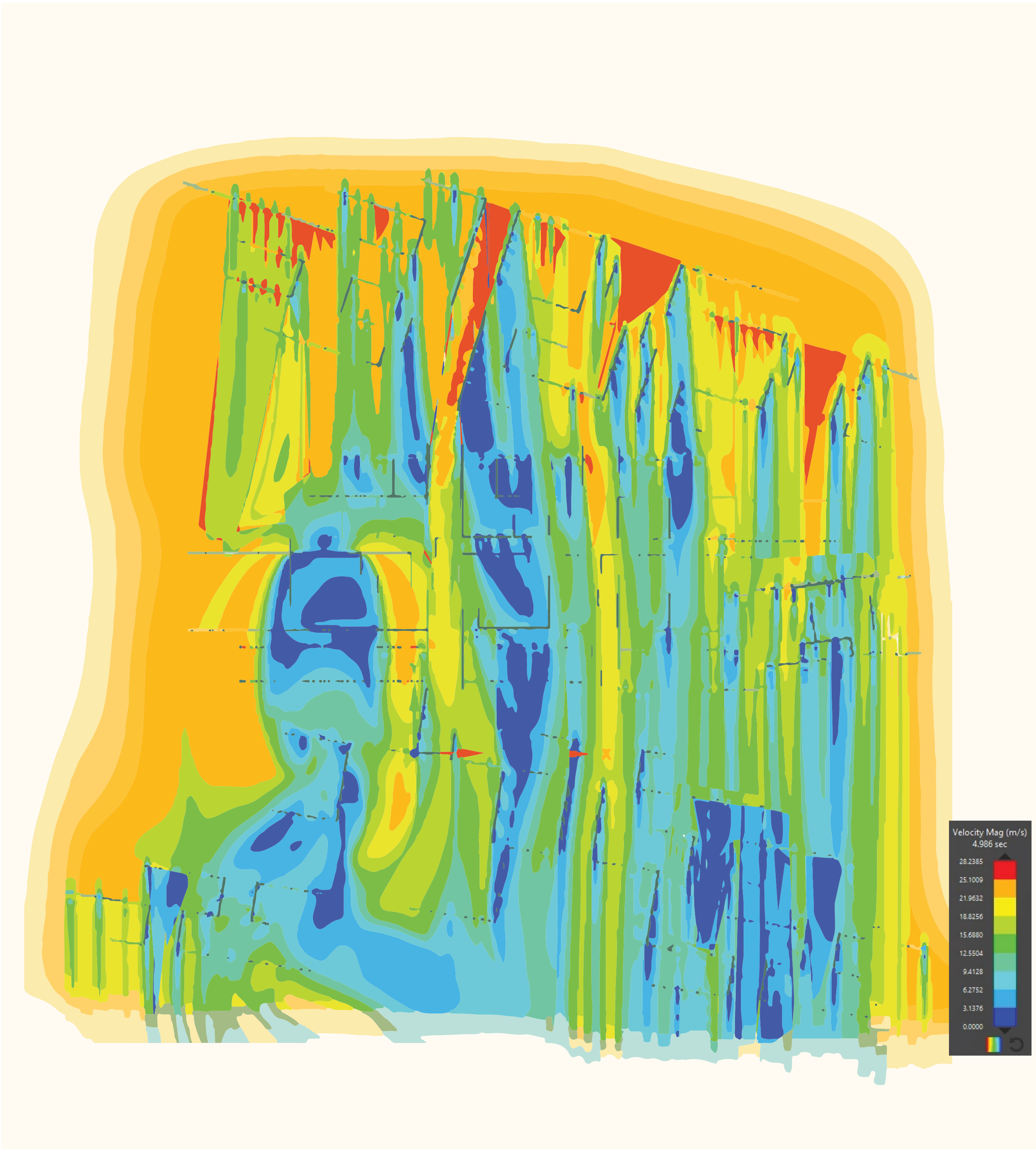

Figure 20. Detailed plan and wind speed simulations (Made by author and Binhan Tang)

Figure 21. Rendering of interactive space in the project (Made by author and Binhan Tang)

Conclusion

There are many different approaches in the process of designing ecological architectures, and different approaches may lead to different outcomes. Undeniably, site analysis and consideration of the contexts of projects are greatly important. However, it would be an interesting way to look at materials first. It does not compromise architects' imaginations for creating new types of spaces interacting with the environment. Some creative ideas regarding the spaces would not emerge if an architect does not study materials and make physical models. Many aspects of materials could be studied- their physical properties, relationships with emotions and the environment, and construction methods. Along with real-time simulations of the site of projects and the spaces enclosed by materials, more comprehensive understandings could be developed to better the design projects.

Bibliography

1 Partha Sarathi Mishra, Aseema Das, *Building Material: Significance and Impact on Architecture* (Building Science, September 2014), 32-33.

2 Andrea Deplazes, *Constructing Architecture: Materials, Processes, Structures* (Darch ETH, 2008), 19-20.

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4 Andrew Walker Morison, Dominique Hes, Margaret Bates, *Materials selection in green buildings and the CH2 Experience* (March 2005), 6-10.

5 Larry Sass, *Materializing design: the implications of rapid prototyping in digital design* (Design Studies Vol 27 No. 3 May 2006), 325-333