Kinetic Architecture: Reimagining the Facade of the UW Tower

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Abstract

Kinetic Architecture: Reimagining the Facade of the UW Tower

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How can kinetic building components be implemented to improve the performance of a building? How do new interventions affect the original uses of an existing space? How does a building interact with nature and its residents?

This thesis explores the potential of kinetic elements, and applies them to a facade renovation design of an older, existing building: the UW Tower. By developing the building envelope from a static system to a multi-layered and dynamic system, the proposed renovation imagines an adaptive environment to satisfy the changing needs of users. In addition to the building facade, the roof and the entrance of the building are also renovated to create a richer experience for both users and the public.

Acknowledgments

I would like to express my sincere gratitude to my instructors: Kimo Griggs and Daniel Stettler. Your excellent knowledge and patient guidance through each stage of the thesis help me to make the idea real. Your thoughtful suggestions and continuous encouragement helped me to refine the design and representation of the project.

Besides, I would like to give thanks to my family and friends, whose support cheered me up and supported me all the way.

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1. INTRODUCTION

1.1 Background

WHAT IS KINETIC ARCHITECTURE?

The concept of Kinetic Architecture includes the design of buildings with movable elements, or the design of entire structures that are transformable. It can allow human interaction, improve environmental performance (sound, light, wind, heat and humidity), create a dynamic spatial experience, change the function according to the user's needs and address the pursuit of aesthetic interests.

DEVELOPMENT OF KINETIC ARCHITECTURE (Nelly Ramzy and Hatem Fayed, 2011)

Early Stage (before the industrial revolution)

Kinetic architecture has existed since humankind first began to build. It can be divided into two categories: kinetic components like doors and windows, and whole kinetic structures (portable architecture) like tents, tipis, and yurts. A kinetic component such as a drawbridge used on castles as a gateway or an additional barrier to the entrance can be traced back to the Middle Ages or earlier. Portable buildings such as yurts have been used as dwellings in Asia for over 3,000 years, allowing nomads to collapse and rebuild their homes as they moved to new locations to adapt to the seasons' changes or other changing conditions (Kronenburg, 2000).

Figure 1. Drawbridge
Image Source: Wikipedia

Premature Stage (Industrial Revolution)

Architects began to imagine the combination of kinetics and building thanks to the development of techniques and hardware that allowed motion during the industrial revolution. In 1908, Thomas Gaynor proposed a residence building with a conventional exterior that could rotate. Even though it was never built, it was patented and became the starting point of the development of the modern rotating house (Randl, 2008). Later in 1964, Ron Herron from the Archigram group introduced the idea of a Walking City, in which giant robotic cities can move and land wherever they are needed to deliver resources (Cook, 1973). It has been a great influence in architectural theory ever since.

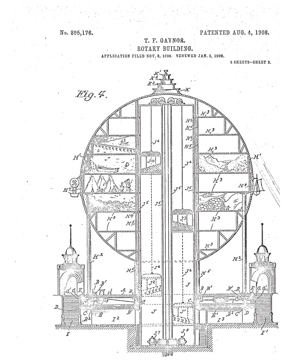


Figure 2. Rotary Building
Image Source: Google Patents

Developed Stage (20th Century)

With advances in kinetic and digital control systems, more and more architects start to bring kinetics into their designs. A notable early design was the Arab Institute Building (1987) by Jean Novel. It has 240 motor-controlled apertures to control the natural light based on the amount of sunshine. Although it stopped working after a few years because of the maintenance, it was a very intelligent attempt, given 1980s technology. In the 21st Century, kinetics in architecture has taken different forms such as sliding, rotating and folding, mostly aiming at providing shading for buildings. Examples are like the moveable sunscreen of Quadracci Pavilion (2001), the folding shades of Kiefer Technic Showroom(2007) and the rotating glass discs of RMIT Design Hub (2012).


Figure 3. Quadracci Pavilion
Image Source: Arch2o

Advanced Stage (Future)

Developments in architecture have always been intrinsically tied to developments in materials (Fox, 2016). The development of smart materials gave rise to a new vision into the future of kinetic architecture. Some smart materials can change their property when exposed to external stimuli such as stress, temperature, moisture, pH, electric or magnetic fields (Wikipedia). For example, the maze-like Homeostatic Facade, made from Electro Active Polymers (EAPs), flexes and bends according to solar heat gain.


Figure 4. Homeostatic Facade
Image Source: Material District

CLASSIFICATION OF KINETIC ARCHITECTURE

Kinetic Component (Embedded)

Kinetic components are permanently embedded in the whole building system, where they are essential to the operation of the building such as doors and windows. They are inseparable components of the building system and they are the most commonly used type in buildings.

Kinetic Component (Stand-alone)

Compared with the embedded kinetic component, the stand-alone kinetic component can be separated from the main structure without reducing overall building integrity. This class includes various types of kinetic facades, which will be discussed further.

Kinetic Structure (Partial)

When the scale goes beyond the scale of a component, it becomes the scope of kinetic structure, which means that part of the structure is movable and can adapt its shape or function to the building program. Architect Edward Peck, AIA, of Thornton Tomasetti's Chicago-based building skin practice, expressed his idea towards the world's largest operable glass doors of the new U.S. Bank Stadium for the Minnesota Vikings. "It's not a component," he observes, "it's a major part of the wall, so it's all the structural system and the skin system moving."(Millard, 2015)

Kinetic Structure (Whole)

When the building moves like a total unit, it is always referred to as portable architecture. This structure is intended for easy erection on a site remote from their manufacture (Kronenburg, 2008).

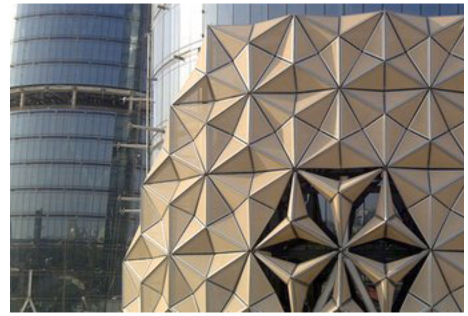


Figure 5. Al Bahar Towers
Image Source: Archdaily

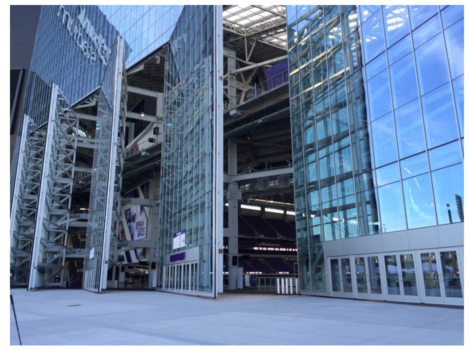


Figure 6. New U.S. Bank Stadium for the Minnesota Vikings Image Source: Star Tribune

Figure 7. Tree House Image Soure: Ten Fold Technology

DEVELOPMENT OF BUILDING FACADES

Windows and Glass

The earliest windows arose circa 13th century BC as unglazed openings in a roof to admit light during the day. In the 16th century, windows remained unglazed, but could be closed by the use of sliding or folding wooden shutters, oiled cloth, paper or even thin sheets of the horn. During the 16th century, windows became larger and the size of the window became one way in which prosperous building owners could display their wealth (Sharman, 2017). Glass, as a material that can provide both transparency and protection from the weather also became available throughout the century. Later, as glass-making technology advanced, glass became more and more transparent, to what we can see today. Today, various types of glazing are applied to windows, including single, double or triple glazing, Low-E glazing and intelligent glazing (Sharman, 2017).

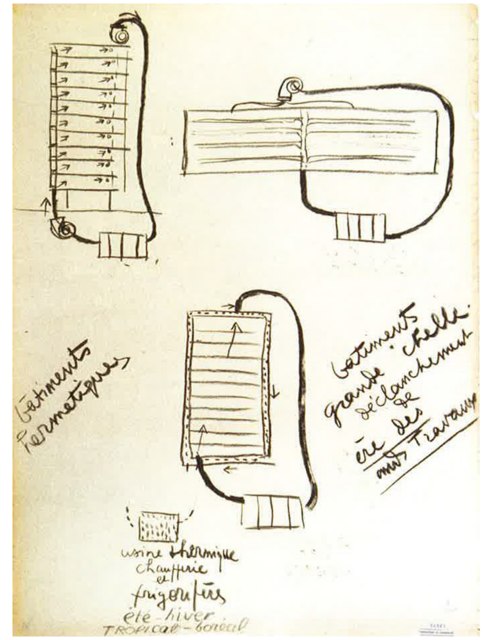


Figure 8. Mur neutralisant
Image Source: Façades Confidential

Double-Skin Facade

Double-skin facade refers to a system of a building consisting of two skins, or facades, placed in such a way that air flows in the intermediate cavity (Wikipedia). The concept was first explored by Le Corbusier in his idea called “Mur neutralisant”, where mechanics that provide heating and cooling shifted to the external skin.

Today, double-skin facades are widely used, particularly in high-rise buildings. One of the oldest examples of the “modern” double-skin building, the Occidental Chemical Center, dates back to 1980. It has a cavity that is 1.5 m width with open louvers at the top and bottom, with shading devices installed. The shading louvers are fixed, and the result is that the building is reported to be either too hot or too cold most of the time (Capeluto, 2017).

Figure 9. The Occidental Chemical Center
Photographer: Kate Harrison

The advantage of a double-skin facade includes acoustic insulation, thermal insulation, better protection of the shading or lighting devices, reduction of wind pressure, Natural Ventilation and thermal comfort (Harris Poirazis, 2004).

WHY PUT KINETIC FACADES ON BUILDINGS?

Dynamic building environments can be more adaptable than static environments, saving more energy for the building and satisfying the emotional needs of people.

1.2 Theoretical Framework

Empathic Environment: An environment that supports a mutual relationship between individuals and their environment. These environments interact and react to their inhabitants in ways that suggest emotional intelligence and empathy, and invite an emotional response from those inhabitants.

Dynamic systems and environments of scales from molecules to cities.
A refined "body" expands the border and embraces the surrounding environment.
We hope for profound participation in the world around us. -- Philip Beesley

E-motive Architecture: Buildings are input-output machines.
No one leaves a building as the same person that enter the building.
All building element will behave like intelligent agents, they will know one another, they will know you. -- Kas Oosterhuis

Entertain and Performance: The Natural world is not excluded from the building environment. A building might “put on” performances to entertain and enlighten their occupants. -- Stephen Gage

Human and Machine: Humans will accumulate artificial and mechanical abilities, while machines will accumulate biological intelligence. -- Mark Pauline

Infrastructure as a “Platform”: Building in the future will go beyond being smart to actively being able to learn; go beyond sustainable to regenerative; It will be more than resilient and adaptive to future challenges. -- Ponglas Machlead

1.3 Methodology

This thesis explores the relationship between buildings and humans, aiming at creating an environment that can adapt, evolve, feel, entertain and learn. Through case studies of kinetic facades and installations, the thesis examines the pros and cons of different applications, and applies what is learned to a specific building.

2. CASE STUDIES

2.1 Case Studies of Kinetic Facade

Case studies were chosen to cover typical projects in the development of kinetic facades and related installations. They are categorized in the following classifications in a website format. Among all the case studies, three distinctive projects are chosen to be explored further due to their representative characteristics.

Classifications: { “application” : [“external”, “internal”, “integrated”],
“control”: [“center”, “local”, “center and local”, “no control”],
“movement”: [“fold”, “slide”, “rotate”, “twist”, “roll”],
“sensors”: [“light”, “temperature”, “moisture”, “touch”, “acceleration”] }

Website Link: https://students.washington.edu/xueqi77/hello-thesis/case.html

Case Studies Collection: Al Bahar Towers, One Ocean Pavilion, Royal Melbourne Institute of Technology (RMIT) Design Hub, St Andrews Beach House, SUVA House, Extension and Alteration of an Apartment and Office Building, Kiefer Technic Showroom, Media-ICT Building, Haus am Milsertor, BRAUN Headquarters, Lotus Dome, SolarLeaf, Reef, Wind Solos, Blur, Garden by the Bay,Tessellate, U.S. Pavilion Montreal Expo and Hylozoic Ground.

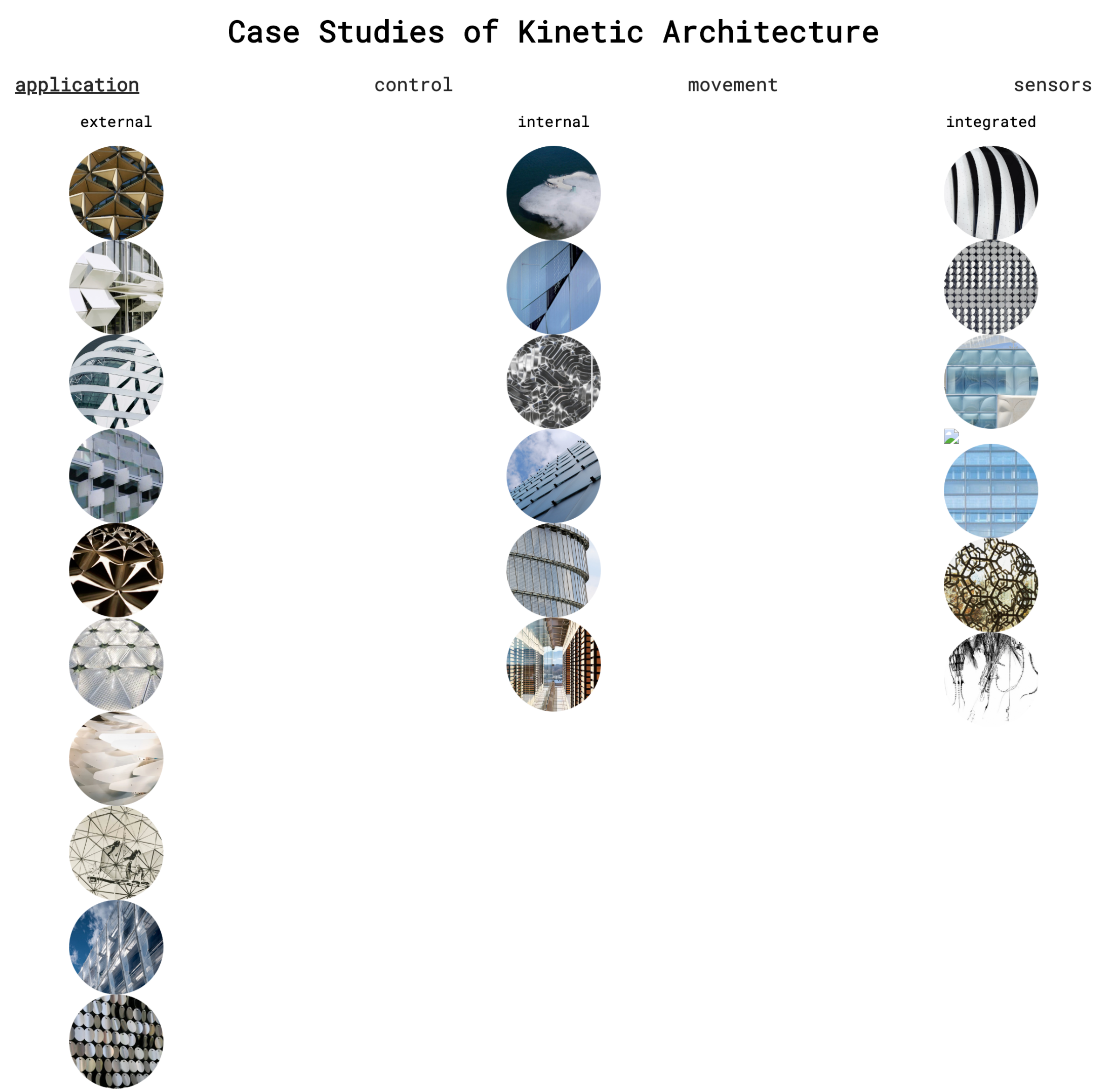


Figure 10. Categorize of the Case Studies According to Application

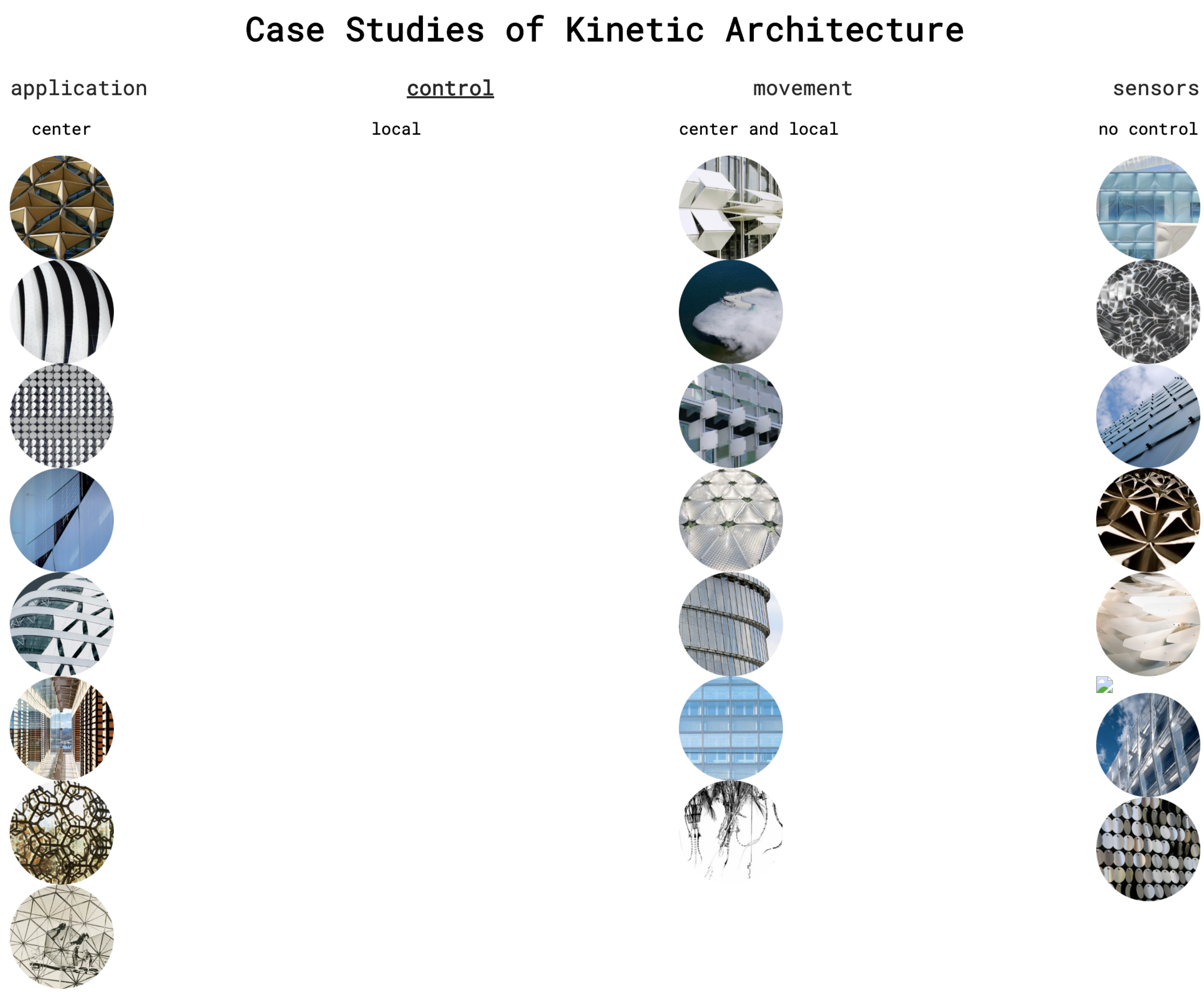


Figure 11. Categorize of the Case Studies According to Control

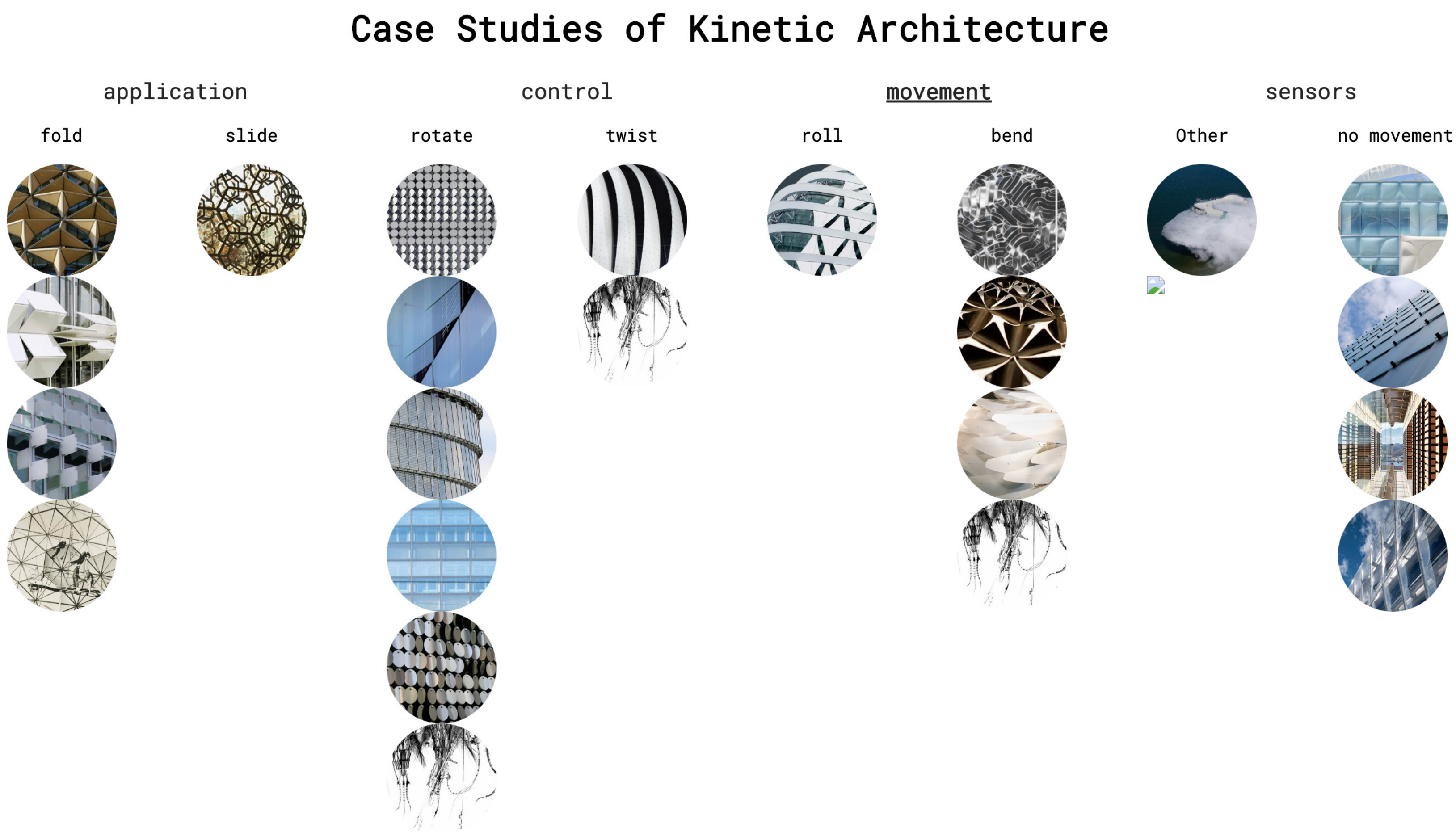


Figure 12. Categorize of the Case Studies According to Movement

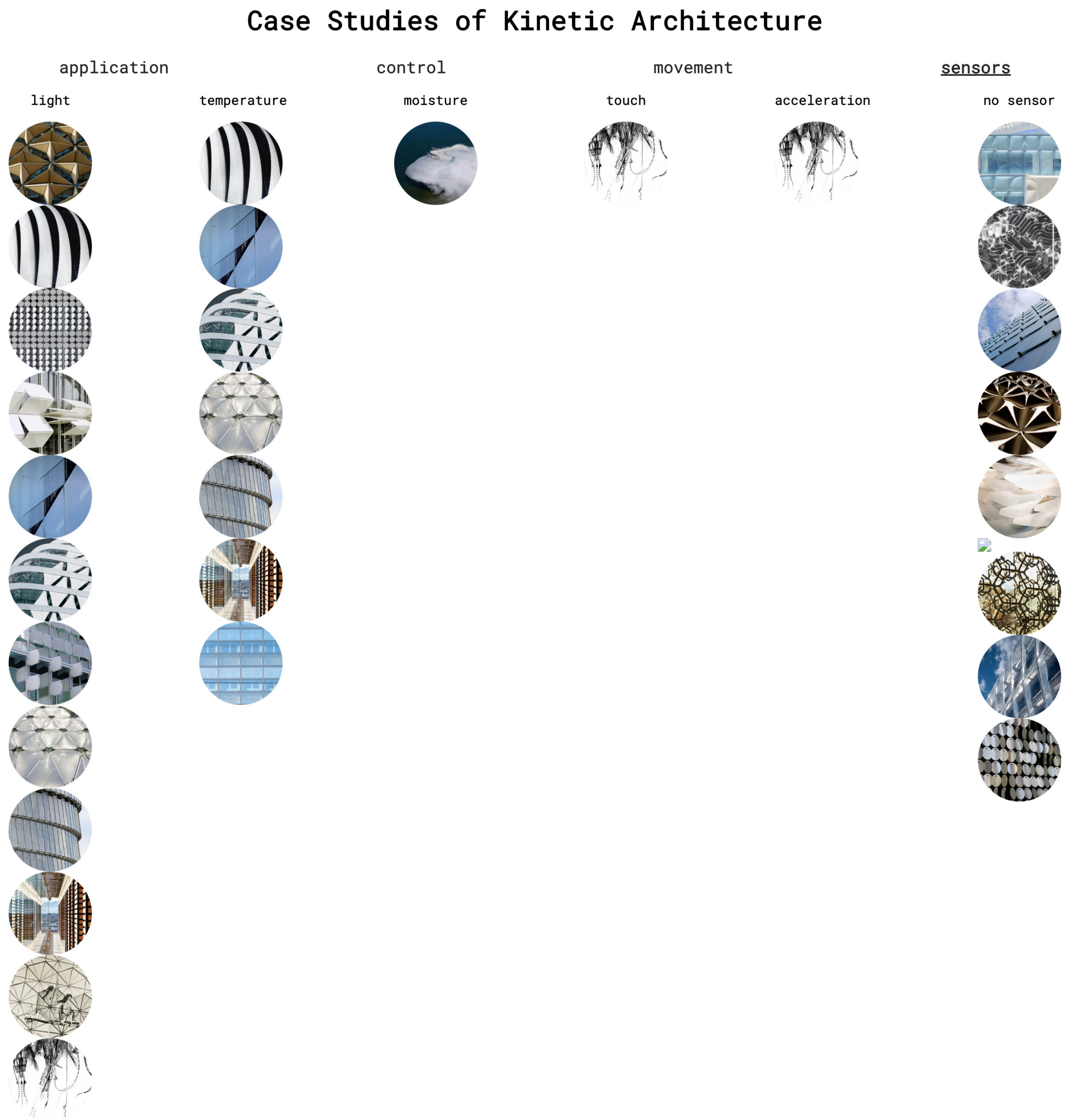


Figure 13. Categorize of the Case Studies According to Sensors

2.2 Three Case Studies

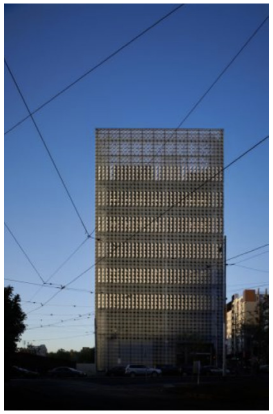


Figure 14. Royal Melbourne Institute of Technology (RMIT) Design Hub Image Source: Sean Godsell Architects

Figure 15. Media-ICT Building Image Source: Archdaily

Figure 16. Hylozoic Ground Image Source: Iaac Blog

These three case studies are chosen to explain in detail because of the following reasons:

1. They reveal the development of kinetic facades(installation):

-The RMIT Design Hub represents mechanical kinetic facades using traditional materials like glass and aluminum. This type of kinetic facade is the most dominant. Similar projects include Al Bahar Towers, U.S. Pavilion Montreal Expo. and One Ocean Pavilion.

-The Media-ICT Building uses a relatively new material: ETFE, and applies it in two different ways to shade the building. The advanced facade and the bold structure together create an iconic expression.

-The Hylozoic Ground explores the future relationship between humans and the environment. It uses a shape memory alloy to decrease the use of mechanisms, similar projects include Reef and Lotus Dome.

2. They are applied to the building in a different way:

-The four facades of RMIT Design Hub are the same and they are embedded in the building envelope.

-The Media-ICT Building has four different solutions of four facades, but the shading ETFE is just applied outside of the building for shading.

-The Hylozoic Ground is an indoor installation for now, which is made mostly of acrylic and silicon, but the potential of the project is not limited to the indoor environment.

3. They have different control system and movement:

-The RMIT Design Hub

Has central control. This type is inflexible when compared to local control.

-The Media-ICT Building

Local control is safer and more flexible than central control.

Inflation and deflation makes it is more fluid.

-The Hylozoic Ground

Local control and Curiosity-Based Learning Algorithm allows it to learn and evolve overtime.

Curing and chemical process is more gentle and involved with chemicals.

2.2.1. Royal Melbourne Institute of Technology (RMIT) Design Hub

Architect: Sean Godsell Architects

Location: Melbourne, Australia

Year: 2012

Material:

-shading: sandblasted glass

-frame: galvanized steel frame

Control: Center

Keywords: sun shading, airflow, “sweat” facade, research testbed, iconic facade, landmark building, design as a catalyst

The Design Hub of Royal Melbourne Institute of Technology is located in the corner of Swanston and Victoria Streets, occupying one of Melbourne’s most prominent sites and is visible from the civic axis. The building, with the iconic facade with ESD(Environmentally Sustainable Design) credentials, has become one of Melbourne’s most recognizable – and awarded – new buildings (Sean Godsell Architects).

The Design Hub provides a research and education space where researchers and postgraduates from various fields of design can gather, including architecture, aeronautical engineering, industrial design, landscape architecture, urban design and so on. Because research may take in different experiments such as physical modeling, three-dimensional printing at different stages of design, the space in Design Hub is designed to accommodate the organic nature of research, which is ever-evolving, adapting, changing and growing.

Figure 17. Royal Melbourne Institute of Technology (RMIT) Design Hub Image Source: Sean Godsell Architects

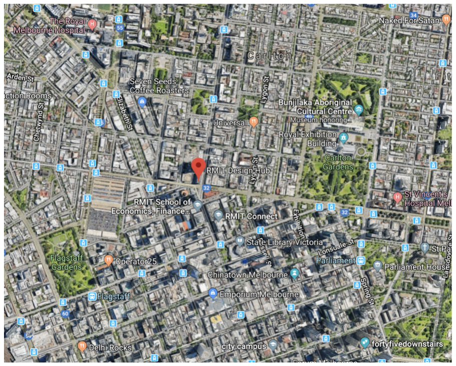


Figure 18. Location of the RMIT Design Hub Image Source: Google Maps

Human Skin Facade

Sean Godsell's idea was to simulate a human skin in the building facade, which can "sweat" in the hot weather. When the air moves through the double-skin facade, it will bring the moisture of a membrane in perimeter grille that is wetted by harvested rainwater, thus cooling the interior during summer.

The facade has two layers, an automated operable outer layer, and an argon filled double-glazed inner layer. In between the two layers of the facade, there is a service walkway. The outer skin of the Hub incorporates automated sun shading that includes photovoltaic cells, evaporative cooling and fresh air intakes that improve the internal air quality and reduce running costs.

Evolving Building

The northern facade is dedicated to ongoing research into solar cells in RMIT, "The solar project will also support RMIT research and teaching in sustainable energy, realizing the original vision of the building becoming a true 'living laboratory'," Pro Vice-Chancellor Design and Social Context, Professor Paul Gough said.

The cells have been designed to be easily replaced as solar energy technology improves. The entire building facade, "has the capacity to be upgraded as solar technology evolves and may one day generate enough electricity to run the whole building."(Sean Godsell Architects)"This approach to incorporate new solar technologies will continue and expand into the future across the building, as further innovation in this strategically important area of research becomes available." Gough said.

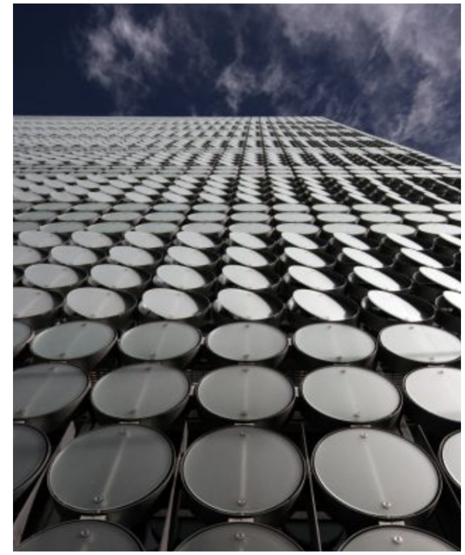


Figure 19. Facade of the RMIT Design Hub
Image Source: Sean Godsell Architects

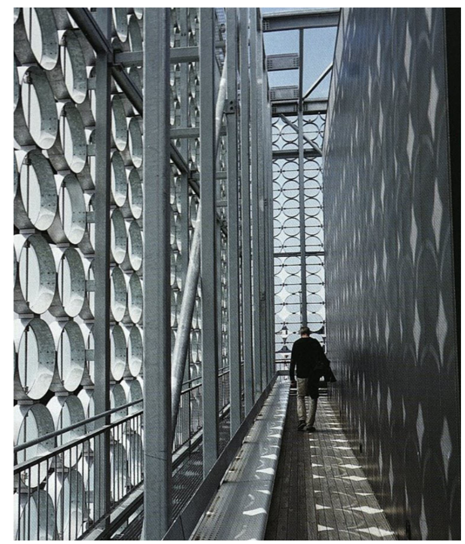


Figure 20. Space In Between the Facade of the RMIT Design Hub Photographer: Earl Carter

Making of the Facade

Sean Godsell has a tough attitude about his design, “I wanted the Design Hub to feel ‘made’ rather than processed. I wanted my signature on the work so that the building was unique. I wanted my window details, not some manufacturer’s.” He said. Insisting on his unique idea about “making” the unique facade also brings a lot of conversations where he was told about why he could not achieve something. Sean successfully defends himself against the committee by producing the detail drawings for manufacture and heavily engaged in meeting with consultants and subcontractors. “To ensure this I drew every critical detail of the building in pencil, moving from 1:20 to 1:5 and, in the case of the facade, to half and full scale.”

It has brought a renewed focus on the critical role of design as a catalyst for innovation and growth, encouraging collaboration across disciplines and engaging thousands of people through its exciting public programs. --Gough

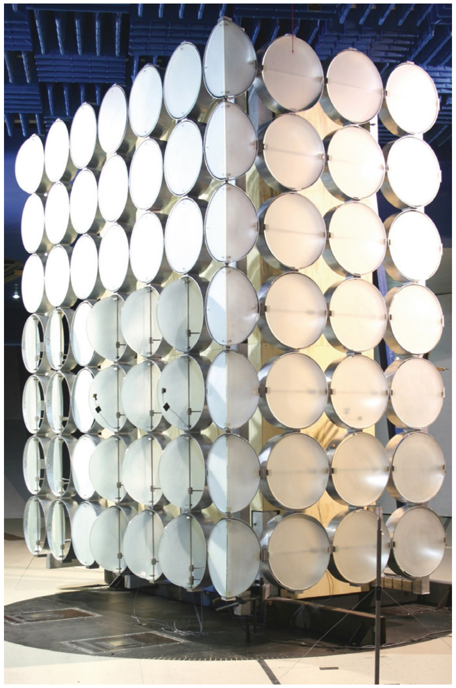


Figure 21. Model of the Facade
Image Source: Architectural Review

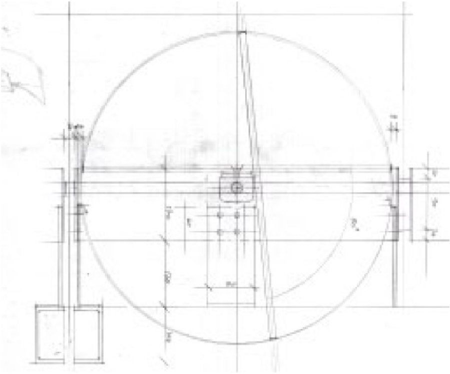


Figure 22. Drawing of the Rotating Disc
Image Source: Sean Godsell Architects

2.2.2. Media-ICT Building

Architect: Enric Ruiz Geli

Location: Barcelona, Spain

Year: 2009

Material:

-shade: eco-efficient Ethylene tetrafluoroethylene (ETFE) cushions

-frame: steel

Control: individual

Keywords: “Performative” architecture, digital manufacturing processes, parametric design application, distributed intelligence, vertical cloud filtering solar radiation

(Media-ICT building is also referred as Media-TIC building, where “I” is “information”, “C” is “communication”, “T” is “technology”.)

“In the industrial age, solar solutions were physical, mechanical, hydraulic… but the digital world moves with particles, with simple elements, with steam, gas with atmospheric and gaseous worlds.” -- Enric Ruiz Geli

Figure 23. Media-ICT Building
Image Source: Archdaily

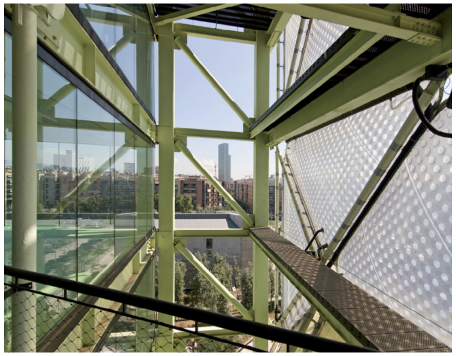


Figure 24. Space Between the Facade
Image Source: Archdaily

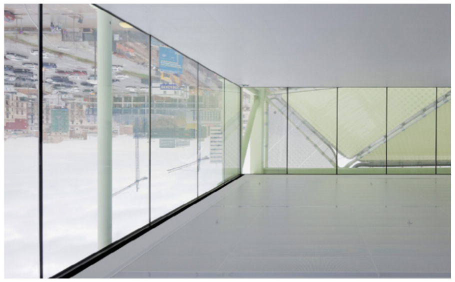


Figure 25. Interior View
Image Source: Ruiz-Geli

ETFE Facade

What caught people's eye on the first expression is the ETFE cushions, found in south-east and south-west facades in the Media-TIC building, creating and ordinating a vertical cloud to filter the sun. The building uses 2,500m² of ETFE cladding and achieves energy savings of 20%. ETFE is a teflon based polymer, it is very light at the same time highly-resistant(1,500kg). It can also be accurately assembled through digital fabrication.

The south-east facade includes 6 different combinations of single ETFE sheets, all of them are printed in white or green in either positive or negative patterns of dots. The cushion containing three layers of ETFE sheet can actively change the transparency from 65% to 45% by adjusting the position of the middle sheet closing or far from the exterior sheet. Each cushion contains a chip(Arduino Pro) and a light sensor, controlled through 104 unique IP addresses.

The south-west facade receives six hours of sunshine a day, the shading system operates by injecting fog into the cushions. By increasing the density of the air of the ETFE cushions with nitrogen particles, the SF (solar factor) of the building goes from 0.45 to 0.1, which reduces the solar heat gain by up to 90%.

Along with the building, two patents are created: ETFE Diaphragm, ETFE Fog.

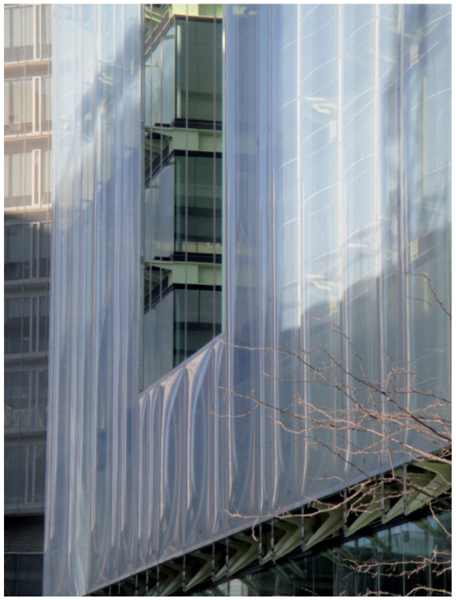


Figure 26. South-West Facade
Image Source: Designboom

Figure 27. Interior View
Image Source: Designboom

Distributed Intelligence

There are more than 500 sensors in Media-ICT, proximity sensors on the ground floor count how many people, light sensors prevent consumption of lighting, 104 sensors connected to the ETFE cushions contributing to the facade intelligence. Compared with central control, the distributed system is safer because it is not relying on a central computer. The ETFE cushions controlled separately by the 104 sensors, making the facade a responsive skin.

“Our buildings should be performative. Architecture is no longer on/off, a/b, it is a dynamic architecture. We have to make architecture as similar as possible to these natural plant processes pursuing and performing, what activates its photosynthesis, its physics, its chemistry, its inner material.” -- Enric Ruiz Geli

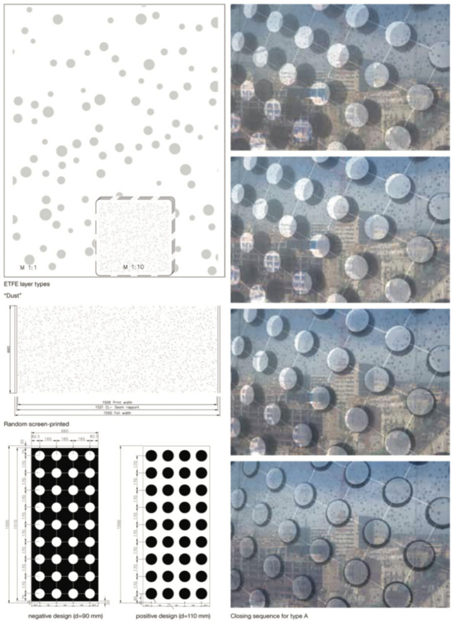


Figure 28. Printing Pattern of the ETFE Cushions Image Source: Media-ICT

Sustainability and Data

Media-ICT targets and achieves:

1.20% Co2 reduction due to the use of District Cooling, clean energy.

2.10% Co2 reduction due to the photovoltaic roof.

3.55% Co2 reduction due to the dynamic ETFE sun filter.

4.10% Co2 reduction due to energy efficiency related to smart sensors.

Total 95% Co2 reduction, the Media-ICT is a NET building almost a net zero building.

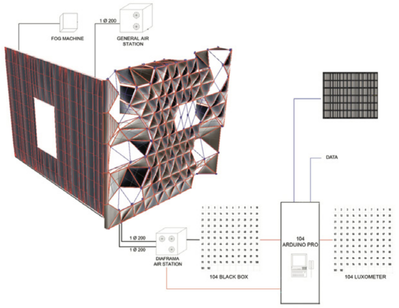


Figure 29. Controlling System
Image Source: Media-ICT

2.2.3. Hylozoic Ground

Architect: Philip Beesley

Location: Venice Architecture Biennale (similar series in Quebec City and Mexico City)

Year: 2010

Material:

Acrylic, copolyester and silicone, which are resilient, flexible and self-supporting materials.

-(Impact Resistant) IR acrylic (used in chevrons and skeletons) : strong, free of “grain”

-copolyester(used in breathing pores): more flexible, cloudy appearance

-silicon(used in flexible joints and vibration dampeners for motors): extremely flexible and elastic

Control and actuator:

IR proximity sensor: detect presence

Accelerometer: measuring acceleration

SMA wires: shape memory alloy wires

Ambient light sensor: It is a photodetector that is used to sense the amount of ambient light present

Keywords: Generous surface, light weight and minimum material consumption, Geotextile, Curiosity-Based Learning Algorithm (CBLA), sensitive and emotional, evolving biochemical exchange, “Predator”, “quease”Constructing synthetic ground

Figure 30.Hylozoic Ground
Image Source: Iaac Blog

“It’s an immersive environment, it is about being inside something, not being on top of it and owning it, but by swallowed by it, with a sense of vertigo.” -- Philip Beesley

“By questioning what the nature of architecture could be, Hylozoic Ground proposes vivid possibilities for a renewed responsive relationship between humanity and the built environment.” -- Eric Haldenby, University of Waterloo

“...part creatures, part environments; part mechanical, part biological..” -- Detlef Mertins, University of Pennsylvania.

Hylozoic Series

Hylozoic Ground, Canada’s entry to the Biennale di Venezia 12th International Architecture Exhibition, is part of a series of collaborative installations that have developed several years by researchers in different places including Toronto, Waterloo, London, and Odense. The project’s title refers to ‘hylozoism’, an ancient perception of life arising out of material. “It implies a belief in enlivening the vital force within materials,” said Neil Spiller. “The material changes are conceived as the first stages of dependent interactions were living functions might take root within the matrix.” said Beesley.

Operation Process

The environment involves in both air cycling, and particle exchange, between system and visitor, creating a mutual interaction between people and the environment.

Breathing Cycle:

The movement of the system can be thought of as a breathing process where the outside air is taken in by the environment and filtered through the meshwork membrane, then returning to the interior space. The air motion is triggered by people’s existence, and is realized by the following three assemblies highlighted: the sensor lash as a catalyst, the breathing pore as an amplifier and the whisker as a random distributor.

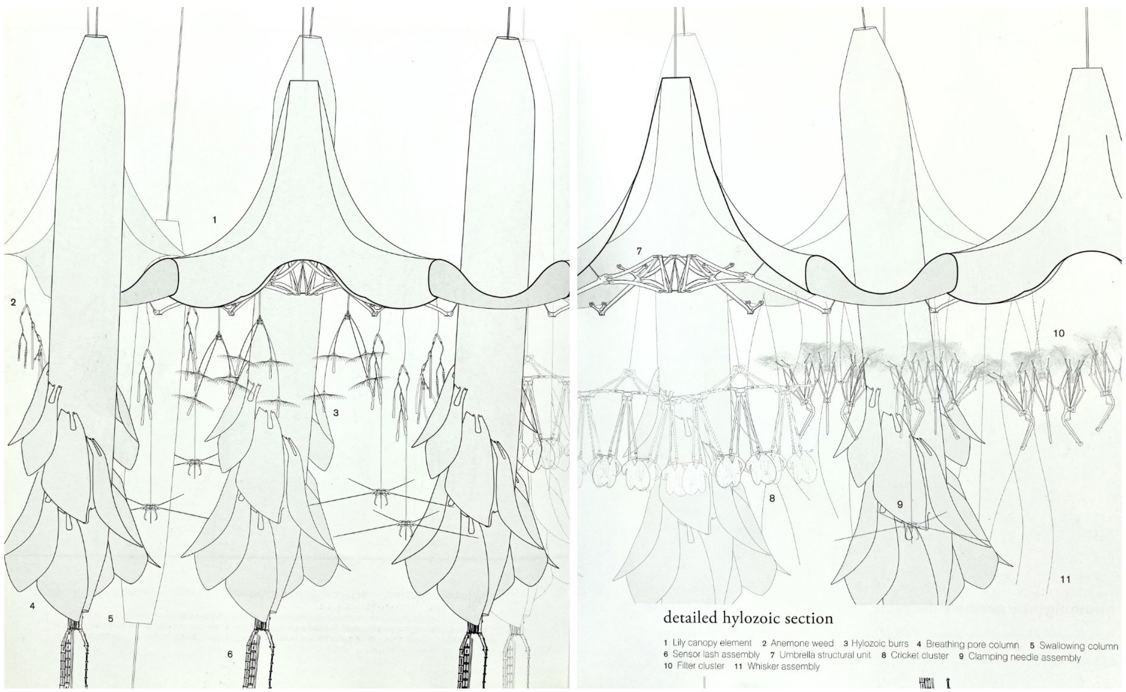


Figure 31.Hylozoic Ground Section Image Source: Hylozoic Ground

1. Lily canopy element: Structure support
2. Anemone Week
3. Hylozoic burrs
4. Breathing pore column: They act as an amplifier. The upward-curling motions of the pores amplify small amount of energy and contribute to the overall spiralling air flow.
5. Swallowing column: They are driven by air muscles, which can create expand and contract movement, displacing the column meshwork.
6. Sensor lash assembly: They are catalysts in the Hylozoic environment. Proximity sensors are at the top of each tongue, when triggered, the shape-memory alloy will power the silicone lashes to curve, sweeping the air upward.

7.Umbrella structural unit: Structure support

8.Cricked cluster

9.Clamping needle assembly

10.Filter cluster

11.Whisker assembly: Driven by motors, they can spin and wave to impel tiny spirals of air to the environment.

Carbon-fix Cycle:

Similar to the organic soil which is made of structurally repetitive organic materials that possess heterogeneous properties, the Hylozoic environment also has "soil" performing transformation through physical and chemical processes. The soil matrix includes protocells and chells(chemical cell), which are chemical models of primitive artificial cells working together to form tissues and organs. The key ingredients include incubators(protocells), carbon-capture 'photopearls'(protocells), and Traube membranes(chells).

Figure 32. Incubators Image Source: Dezeen

Control

"Hylozoic Ground builds upon previous generations of hylozoic series, developing a developing a decentralized structure where much of the system is distributed and extensible, based on localized intelligence."

Figure 33. Filter Cluster Image Source: Dezeen

Interaction

There are four types of interaction: static, dynamic-passive, dynamic-interactive and dynamic- interactive (varying). To date, the majority of systems developed in the literature are of the non-varying dynamic - interactive type, as their responsive behaviors do not change over time. Hylozoic ground creates an environment that goes beyond physically responsive to a stage of transformation through a computational and chemical process.

Curiosity-Based Learning Algorithm (CBLA)

"This learning architecture allows the system to learn both about itself, and also about interactions with occupants, whose movements and actions create new and "surprising" responses, activating the system's curiosity." --Beesley

3. SITE - UW TOWER

3.1 Background

WHY UW TOWER?

-It is an institutional building, where research and renovation are encouraged by the University. The Living Lab Project regards UW as a living laboratory for sustainability, placemaking, real-world learning, collaborative action, etc.

-It is not an energy-efficient building because of out-dated facilities and building envelope, but the structure was built to last a long time.

-It is an icon of UW

BUIDING FACTS

The Safeco tower was built in 1975. In 2007 the UW bought it from Safeco when it then became the UW Tower. It is a 23-story building with a concrete structure and central core. It is among the tallest buildings in the U district.

WHY RENOVATION INSTEAD OF BUILDING NEW?

-Reducing embodied carbon

-People's attachment to old buildings and school history

-Good structure but poor energy performance

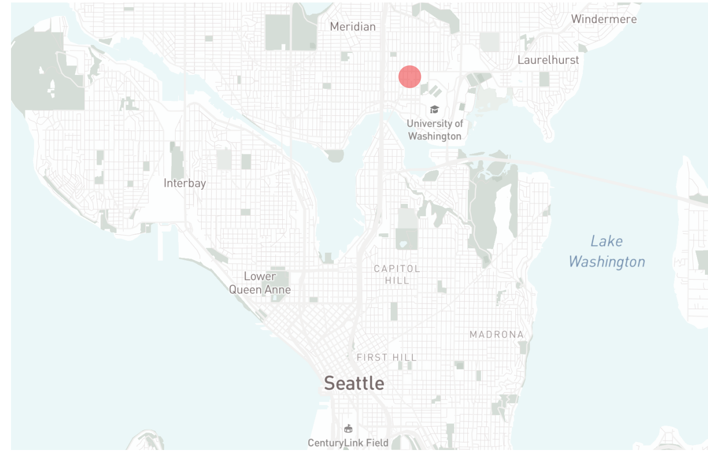


Figure 34. Location of the UW Tower Image Source: Mapbox
Modified by author to locate site

Figure 35. Figure-ground Diagram Image Source: Mapbox
Modified by author to show the future development of the site

WHAT ARE THE PROBLEMS OF UW TOWER?

1. The exterior is concrete with no insulation.
2. The air seal of the windows is poor.
3. The single-glazed windows lose heat directly.
4. The data center loses heat that could be exchanged.
5. The dual duct AHU system is not efficient.
6. The lighting does not satisfy people’s needs.
7. The air quality might be a problem during the smog conditions.

Problems 1, 2 and 3 can be solved through building envelope renovation. Problems 4 and 5, which are about HVAC systems, can be solved by adding a heat recovery chiller and replacing the dual duct AHU system with a single duct VAV system. About problem 6, there are some lighting renovations on several floors of the tower. The ceiling lights are replaced and implemented by the human-centered desktop lights. The lighting situations are also different in different zones. Regarding problem 7, there are some ongoing surveys about air quality, which monitors the air filter at the penthouse. The furniture of the UW Tower is all low emission because UW has a green purchasing policy.

CURRENT HVAC SYSTEM OF UW TOWER

- Air Distribution System:
    - Parameter: 60% (No longer preferred because of the high pressure, noise, maintenance and it is blocked by furniture)
    - Individual unit: 40%
- Chilled Water Cooling System
- Domestic Hot Water System

ANALYZE ENERGY EFFICIENCY USING SIMULATION TOOLS

The big windows of UW tower contribute to great heat gain and heat loss. After exploring different scenarios through energy modeling in simulation software, it was shown that, despite not being the most dramatic improvement scenario, natural ventilation and interior shading devices can reduce at least 25% of the heating and cooling loads.

FIVE SCENARIOS OF THERMAL SIMULATION

1. Base case(without shading)
2. Interior shading (current uw tower situation)
3. Natural ventilation
4. Interior shading + natural ventilation
5. Exterior shading + natural ventilation
6. Exterior shading (low transmittance) + natural ventilation

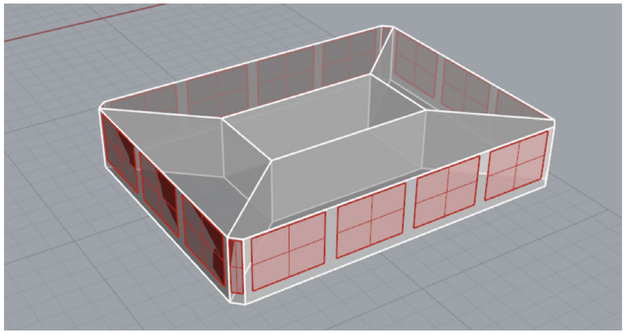


Figure 36. the Model for Thermal Simulation

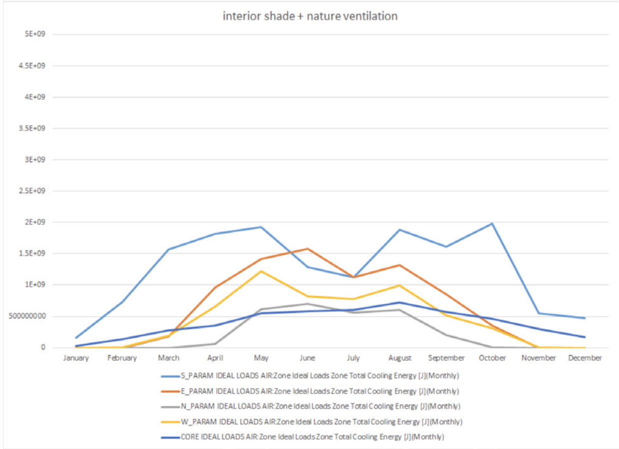


Figure 37. Monthly Heating and Cooling Load

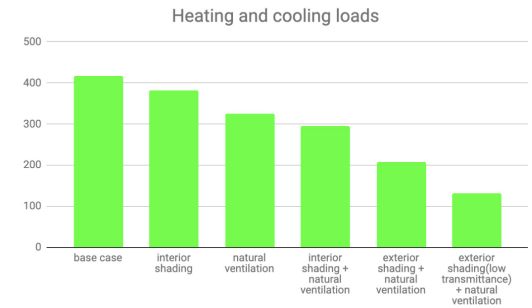


Figure 38. Comparison of Different Scenarios

3.2 List of Criteria

How to shade the building?

Problem(current situation): There is significant heat gain and heat loss through single-glazed windows.

Solution(proposed): Add shading device that can adapt to the sun position and weather situation.

How to shade the interior (How to make good use of natural light and at the same time prevent glare)**?**

Problem: UW tower only uses interior curtains for shading which is not sufficient for creating a comfortable working environment.

Solution: Create dynamic shading devices to create a moderate working environment for people.

What is the airflow in the building?

Problem: There is no natural ventilation in the building.

Solution: Add natural ventilation to increase indoor air quality, especially when the occupancy is high.

Can the facade or roof make use of solar energy to supply the building?

Benefit: Additional energy value add to the building.

How does the new facade fit the weather of the pacific northwest?

Problems: The situation is the same for all the four facades.

Solution: Create unique facade solutions for four facades.

How does the renovation make the building provide a better working environment?

Problem: The original floor plan lacks a variety of spaces and the furniture arrangement does not take the characters of the building into account.

Solution: Open up some parts of the floors to create more possibilities for different activities, rearrange people's activities to make the best use of natural resources including sunshine, lighting, and ventilation.

How does a kinetic facade interact with people?

Problem(static facade): There is no interaction between people and the environment.

Solution(kinetic facade): Entertain people, make people relax, exchange information with people and create an emotional connection with people.

What are the potentials of future development that can be built upon the framework I proposed?

Benefit: Can evolve with the advance of technology.

4. Design

4.1. Facade

Figure 39. After the Facade Renovation

Figure 40. Before the Facade Renovation Image Source : Google Maps

OVERVIEW

The existing building is single-glazed, does not have appropriate sun-shading and is uninsulated. In addition to making improvements in these areas, this thesis explores opportunities to improve natural ventilation and daylighting to greatly improve the building's interior environment.

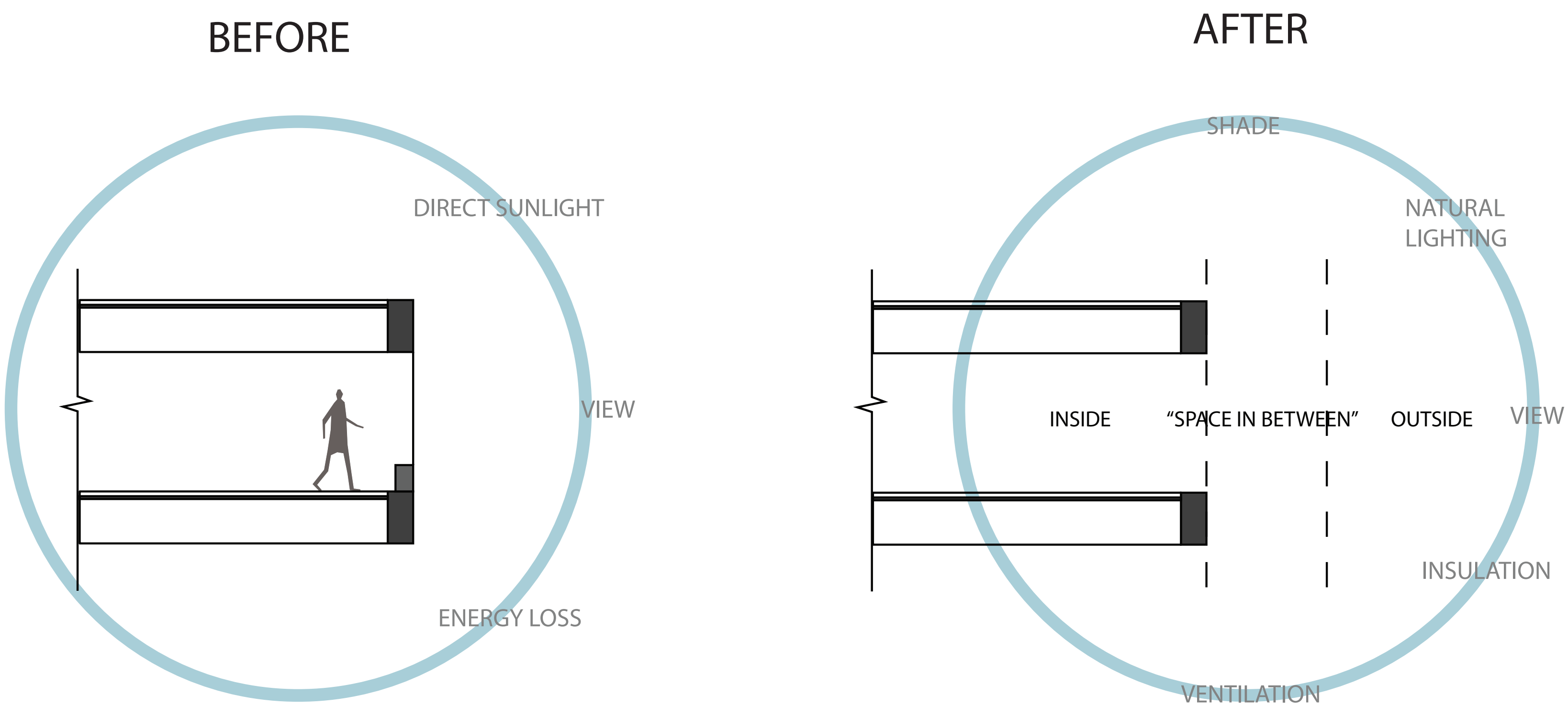


Figure 41. Function of the Double-Skin Facade

LAYERS OF THE FACADE

The first step in renovating the building is to remove elements of the original building envelope. The original window and the parameter heating devices will be removed, leaving a bare concrete structure to be redeveloped. Different layers can be added to the existing building structure, each with a different function including redirecting sunlight, providing natural ventilation, and providing shade while preventing glare.

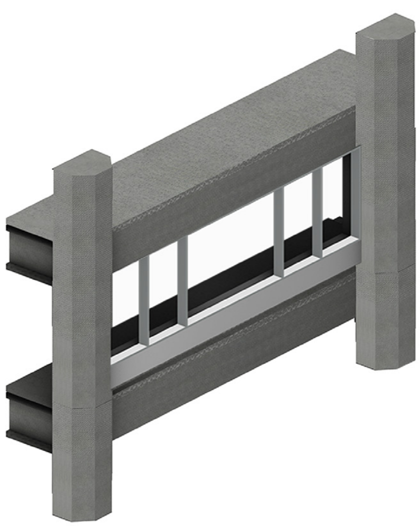


Figure 42. Layers of the Original Facade

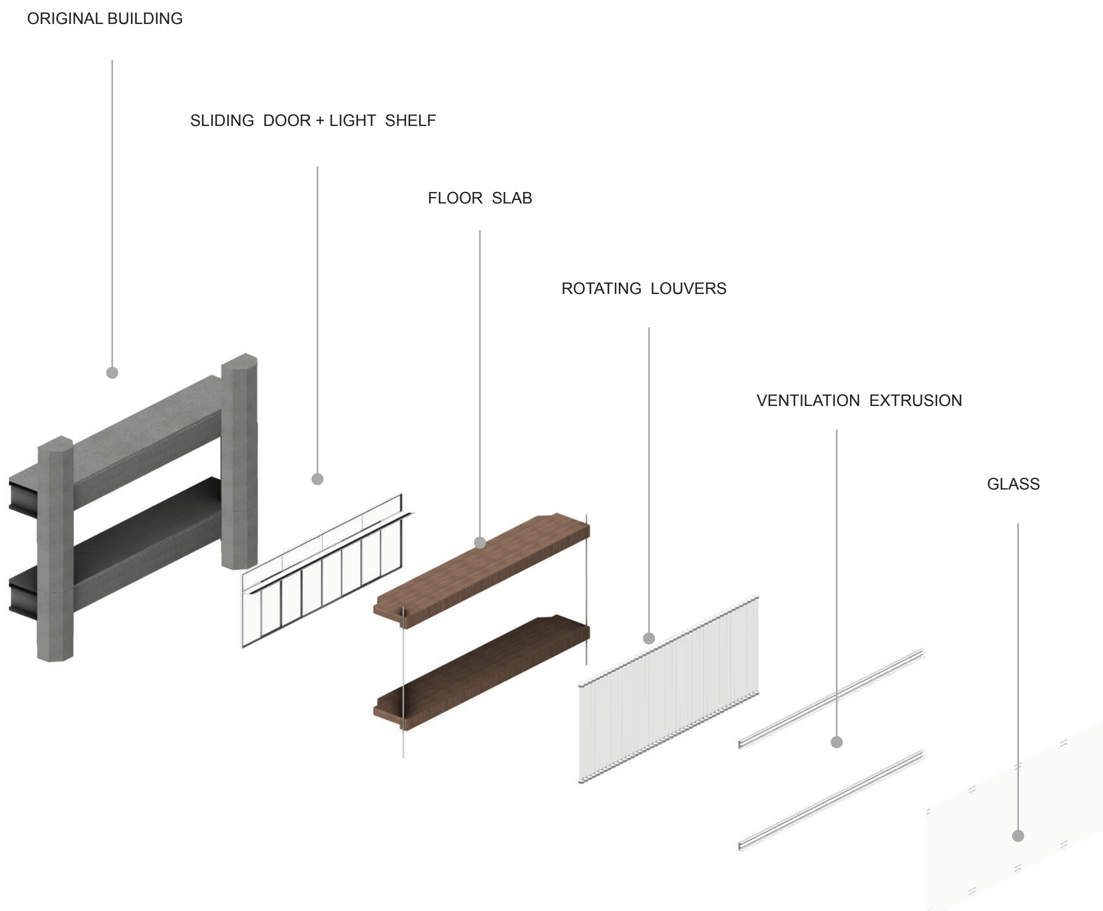


Figure 43. Layers of the New Facade

STRUCTURE

The new facade is designed to hang from a roof-supported, lightweight tensile rod system, minimizing the depth of structural elements, particularly compared to a cantilevered structure. The tensile rods support each floor which, along with attachments to the existing concrete structure, create a rigid hanging structure.

The floor is constructed with CLT panels, a material that adds warmth to the “space in between” while also reducing the carbon footprint of the building. The floor construction consists of a 5-ply CLT panel, sound insulation boards, plywood subflooring and solid wood finish flooring.

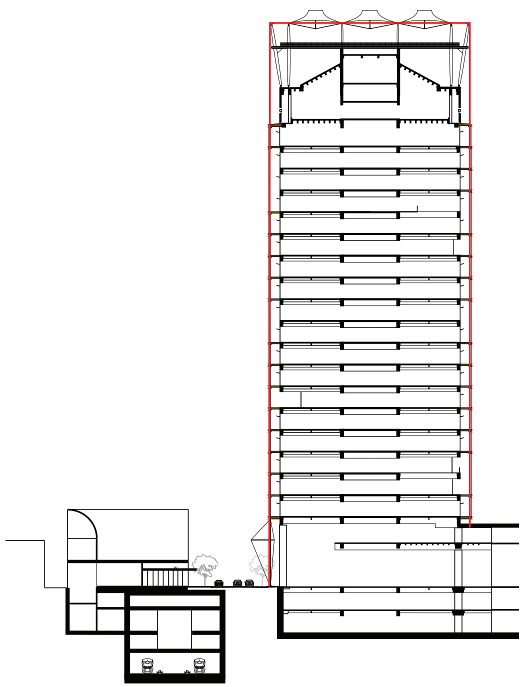


Figure 44. Diagram of the Hanging Structure

Figure 45. Floor and Steel Rod

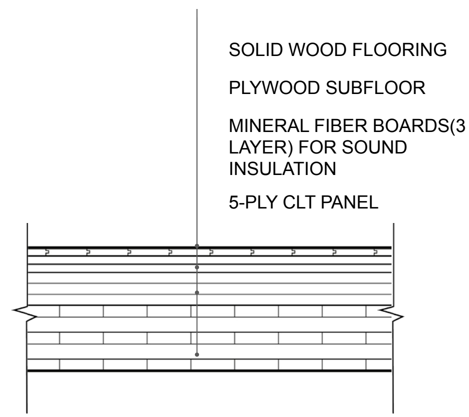


Figure 46. Floor Construction

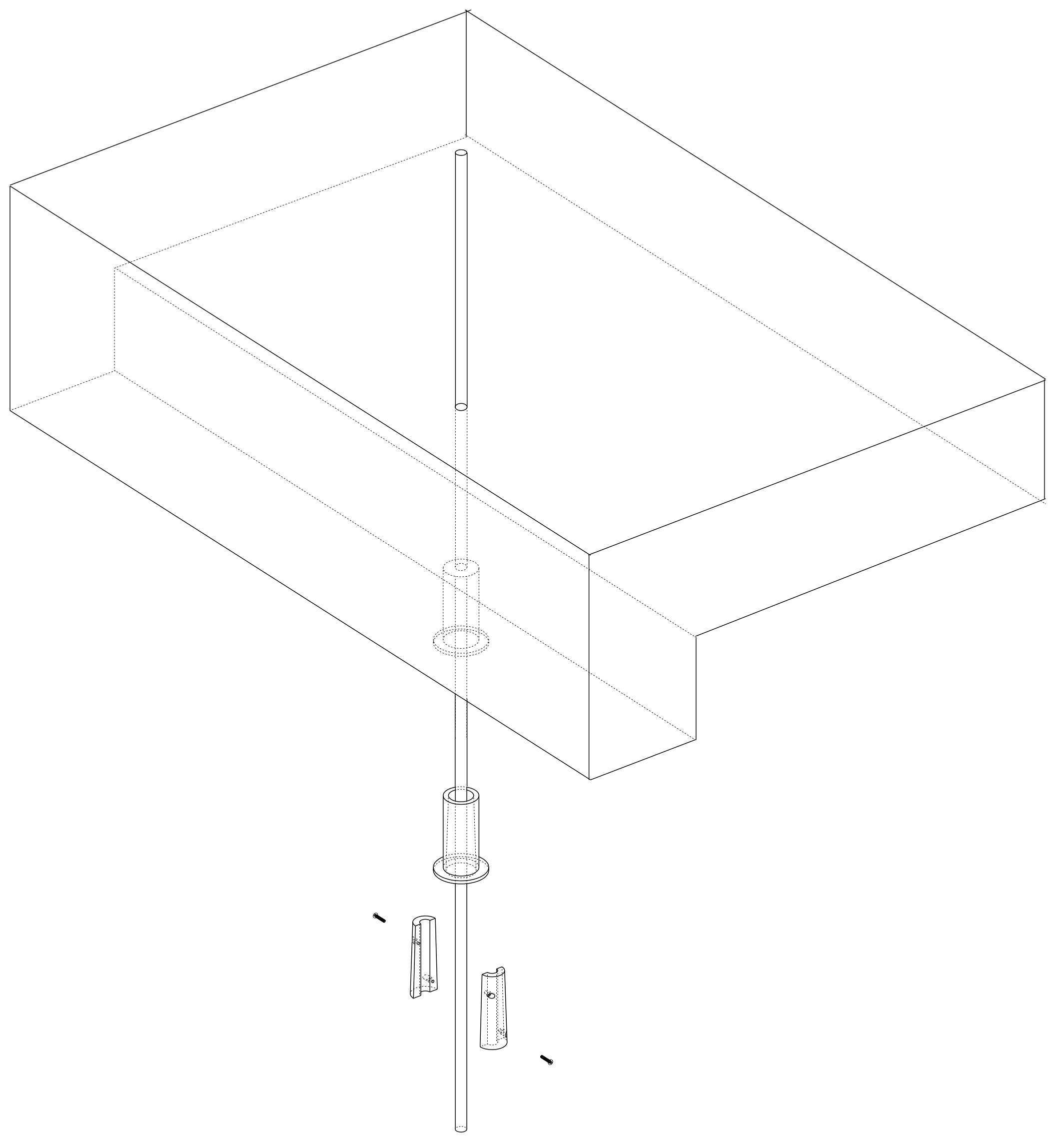


Figure 47. Tapered Clamp Assembly

LIGHT SHELF EXPLORATION

This exploration set out to find a light shelf to fits the existing structure by adjusting different parameters such as different curves, height, and tilt angles. The curve is chosen by manually adjusting the control point of the “reflecting curve”. After a curve is determined, several height options were compared around 7 feet above the ground, though it turns out that the height doesn’t much affect the result. Then the tilt angle was tested on an average of summer months (July-September) which have a higher sun position and winter months which have a lower sun position (October-December)

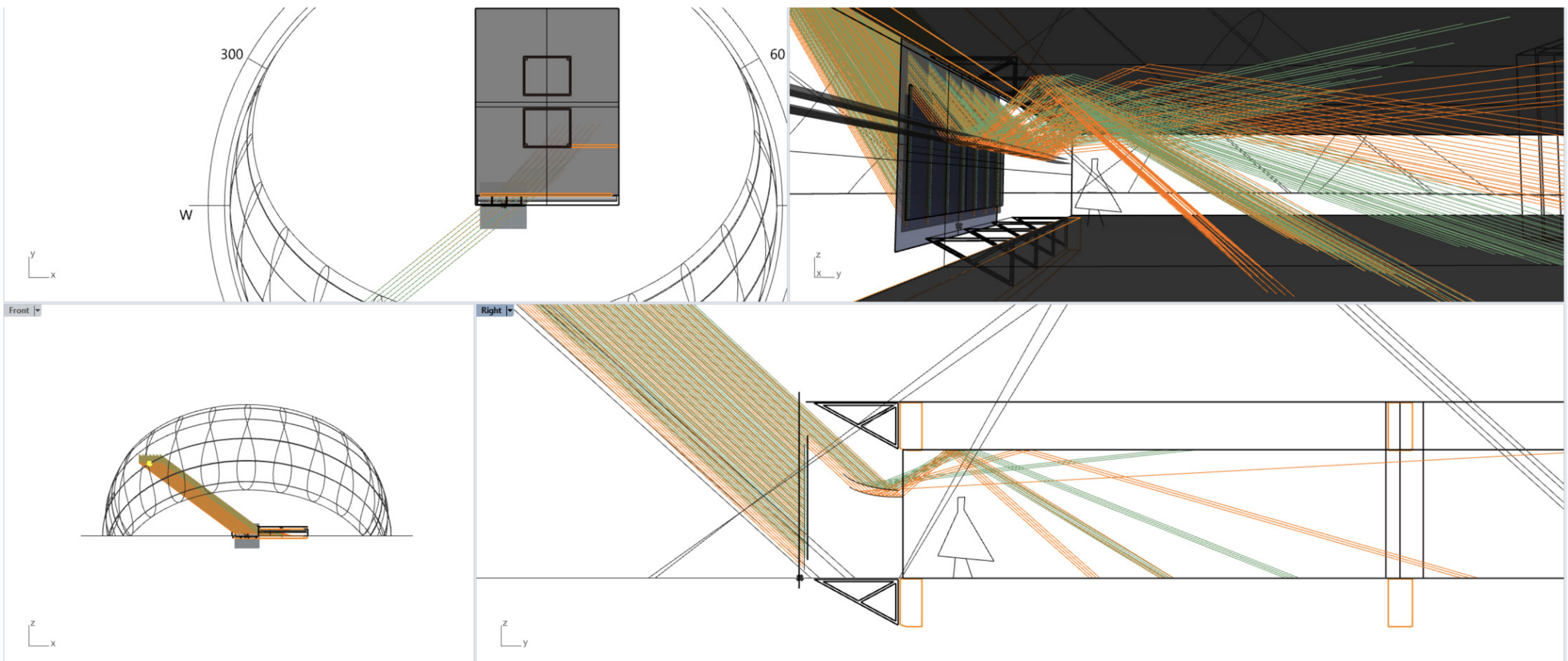


Figure 48. Light Exploration Using Grasshopper and Ladybug

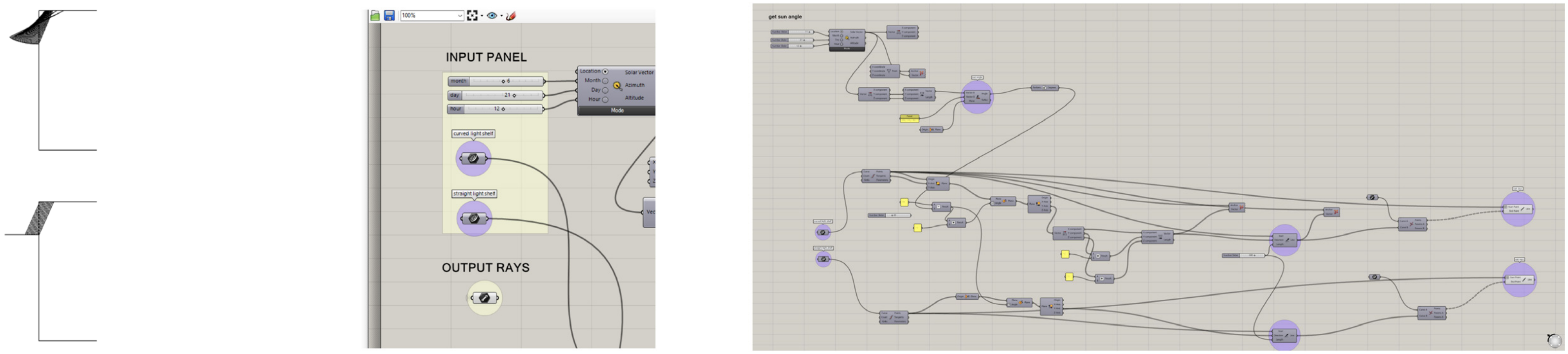


Figure 49. Light Exploration using Grasshopper and DIVA

Figure 50. Light Reflection from December to June

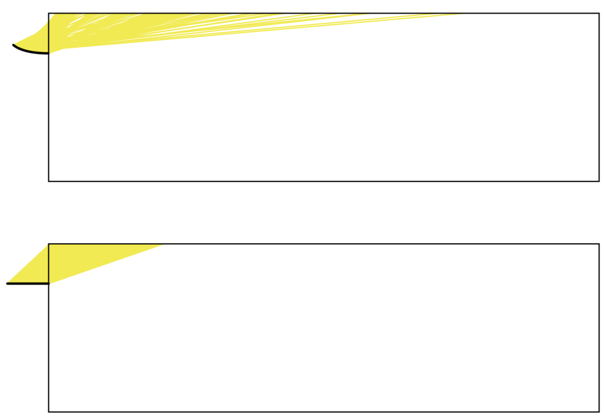


Figure 51. Light Reflection from December to June(Overlay)

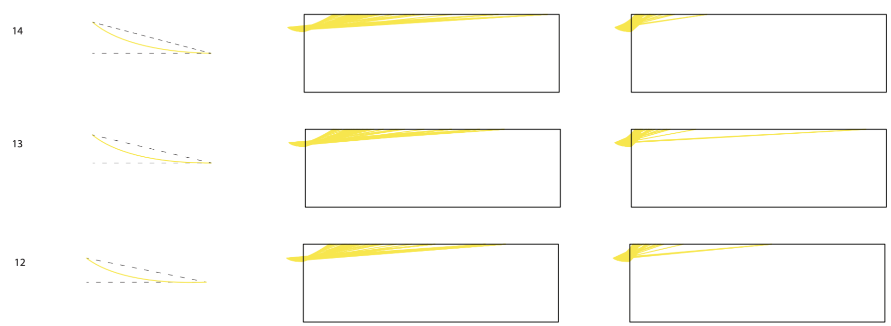


Figure 52. Light Shelf Angle Exploration

LIGHT SHELF

Based on the light studies before, a light shelf made of curved aluminum is added to the “space in between”, redirecting sunlight into the room. Compared with a straight light shelf, the curved shape reflects the sunlight deeper into the room. The light shelf is attached to the top frame of the sliding door.

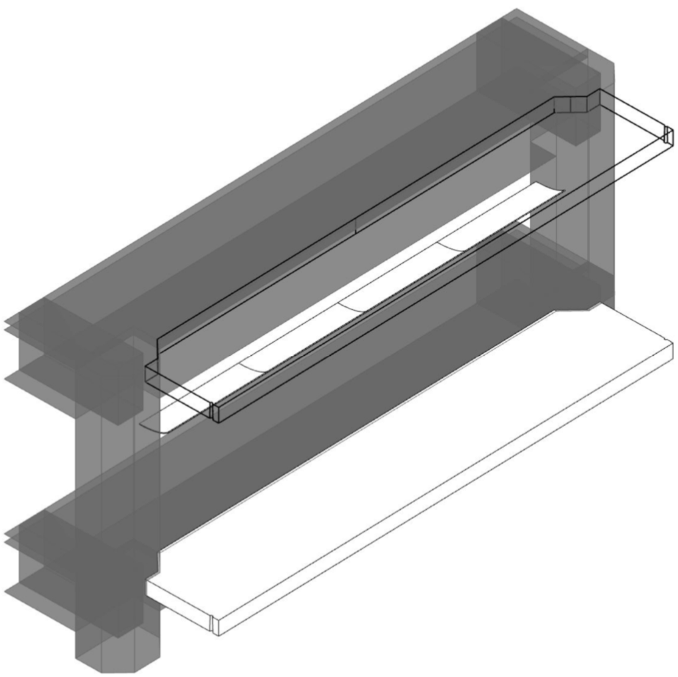


Figure 53. Location of the Light Shelf

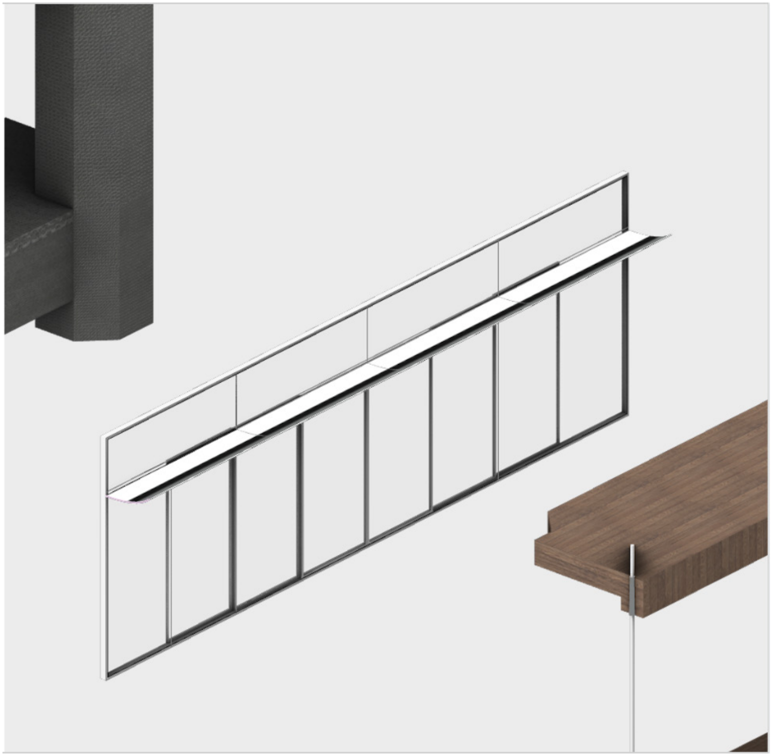


Figure 54. Light Shelf and Sliding Door

AIR FLOW

A perforated aluminum extrusion is placed at every floor, providing natural ventilation. When inlet and outlet vents are placed ar each floor, the lowest degree of air heating and therefore the most effective level of natural ventilation is to be expected (Andrea Compagno, 1999). When the temperature is high, an operable glass panel opens to let cool air in. When the temperature is low it is closed to keep the building warm. The perforated aluminum extrusion is separated into two parts, the upper part serves the air supply of the upper level and the lower part serves the lower level. Each can be individually controlled so the temperature of each floor can differ.

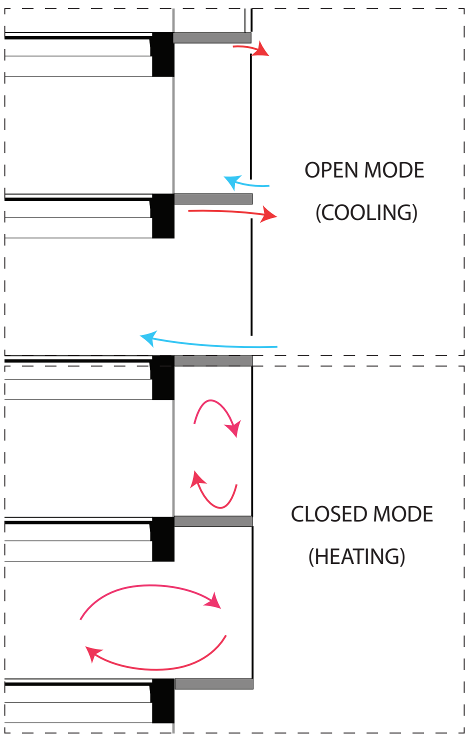


Figure 55. Diagram of the Open Mode and Closed Mode of the Facade

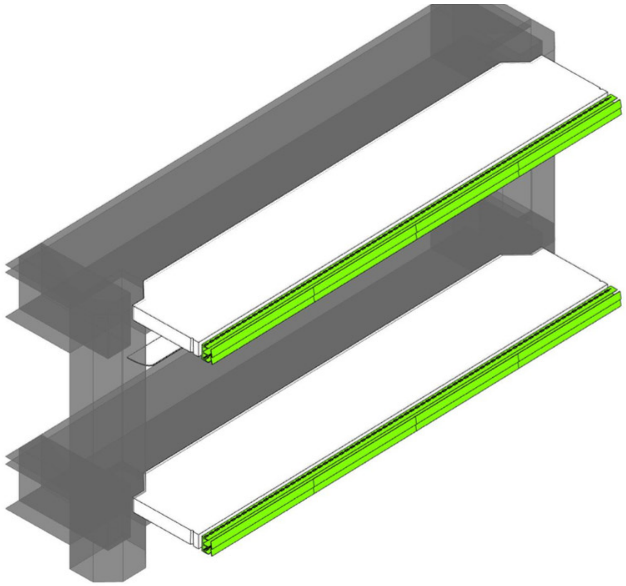


Figure 56. Location of the Ventilation Extrusion

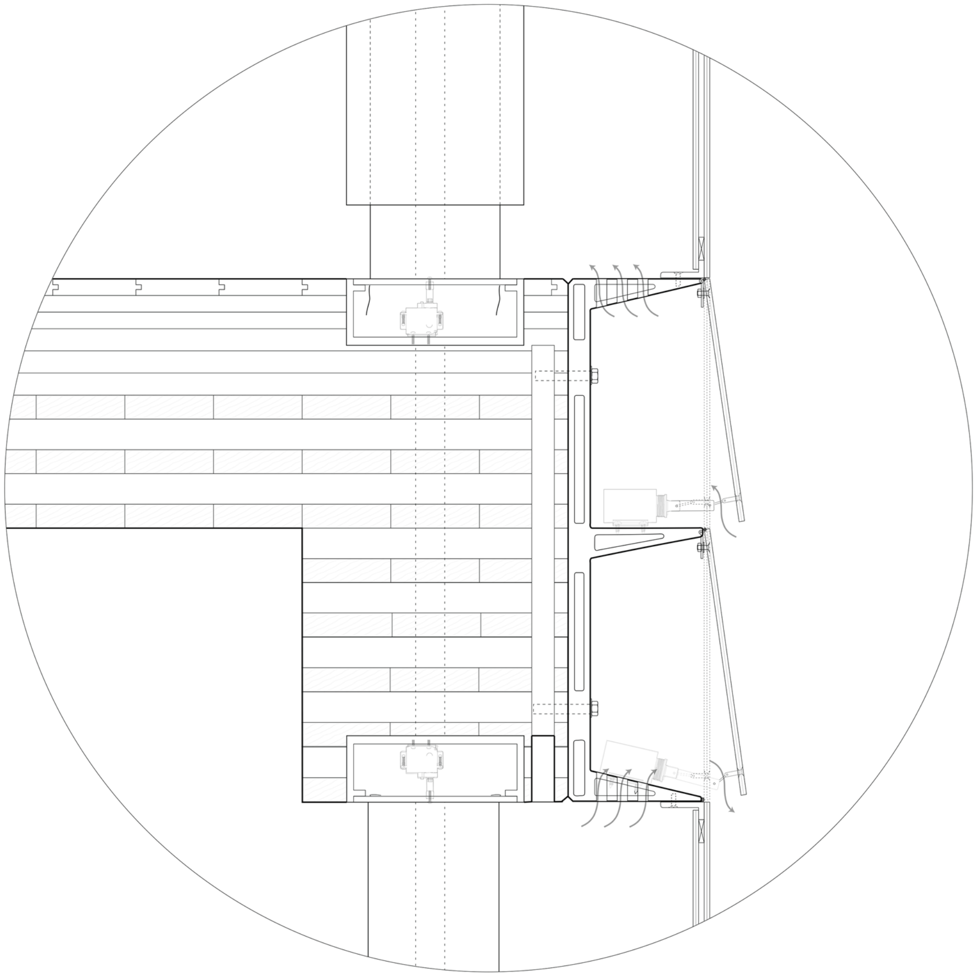


Figure 57. Detail Drawing of the Ventilation Extrusion with Operable Glass Panel

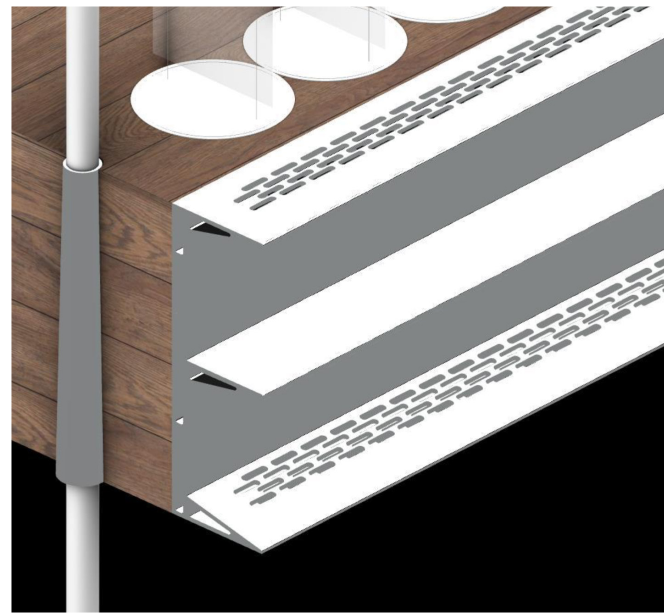


Figure 58. Rendering of the Ventilation Extrusion

SHADE

On the outer layer of the facade, there are rotating louvers that can adjust their angles automatically to block the sun. Each louver has a servo for rotation, providing each location an individually manipulated experience. The louvers are made of fabric and are connected to the aluminum rotating plates with two strings. In the middle of each plate, there are screws for fastening to the servo.

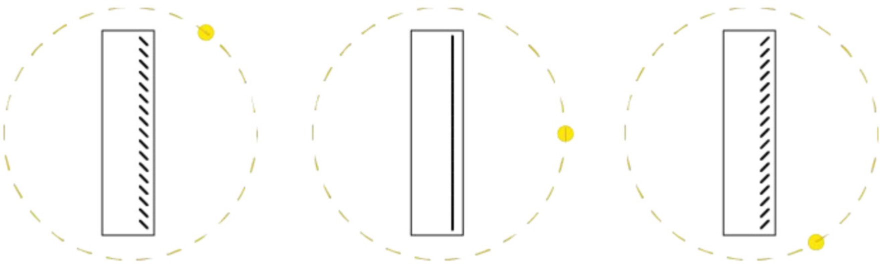


Figure 59. Diagram of the Louver (Plan View)

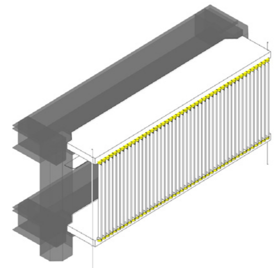


Figure 60. Location of the Louver

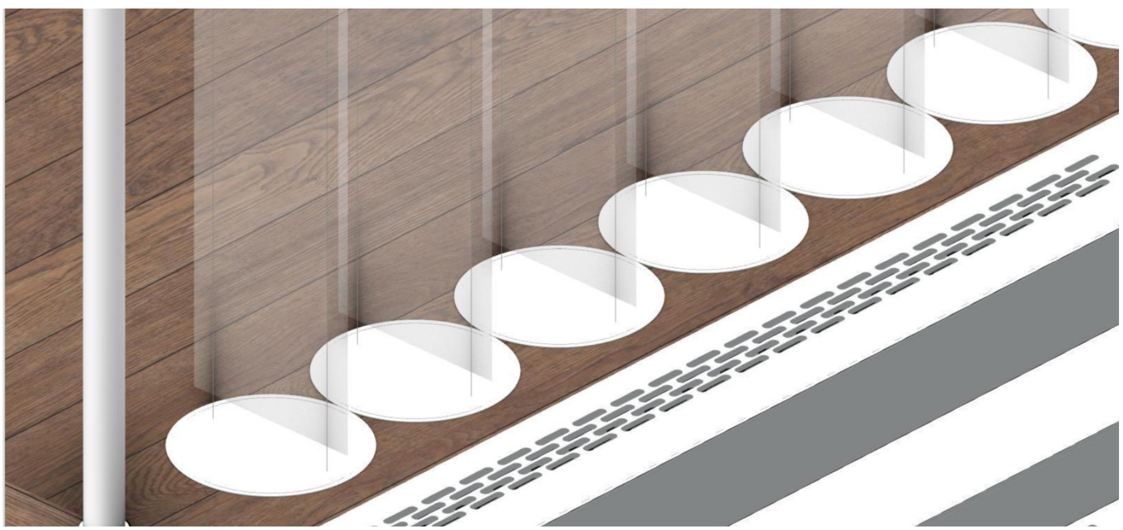


Figure 61. Rendering

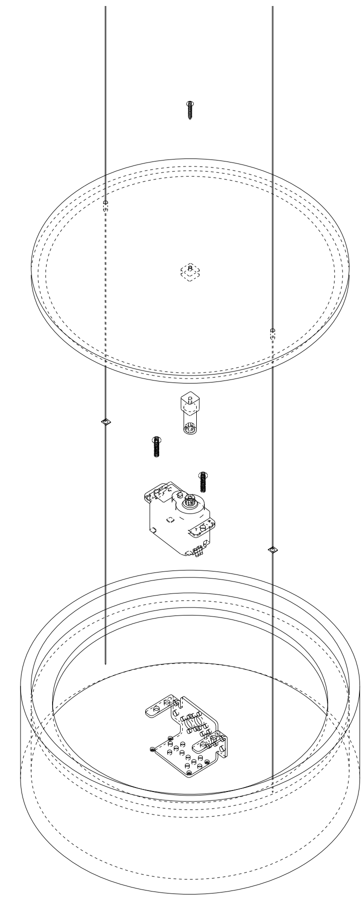


Figure 62. Exploded Diagram

CONTROL

The ventilation and shading devices are controlled automatically from temperature and light sensor inputs to create a normal, comfortable indoor environment. However, people can also override the default settings via a smartphone app or web-browser, to adjust the angle of the louver in a specific area to let sunlight in, for example. The control system might remember the overwritten values and learn from them, in order to automatically make adjustments according to preferences. Sensors placed in the building will detect the presence of individuals. When a person leaves, the building can return to default settings.

When more than one person wants to change the lighting environment or the temperature, a request may be made through their phones. The control system would take requests and make adjustments to satisfy the majority of people's needs. In addition, each office floor plan is divided into different areas with slightly different environments, providing a chance for people to choose their favorite spot in the office.

FACADE SECTION

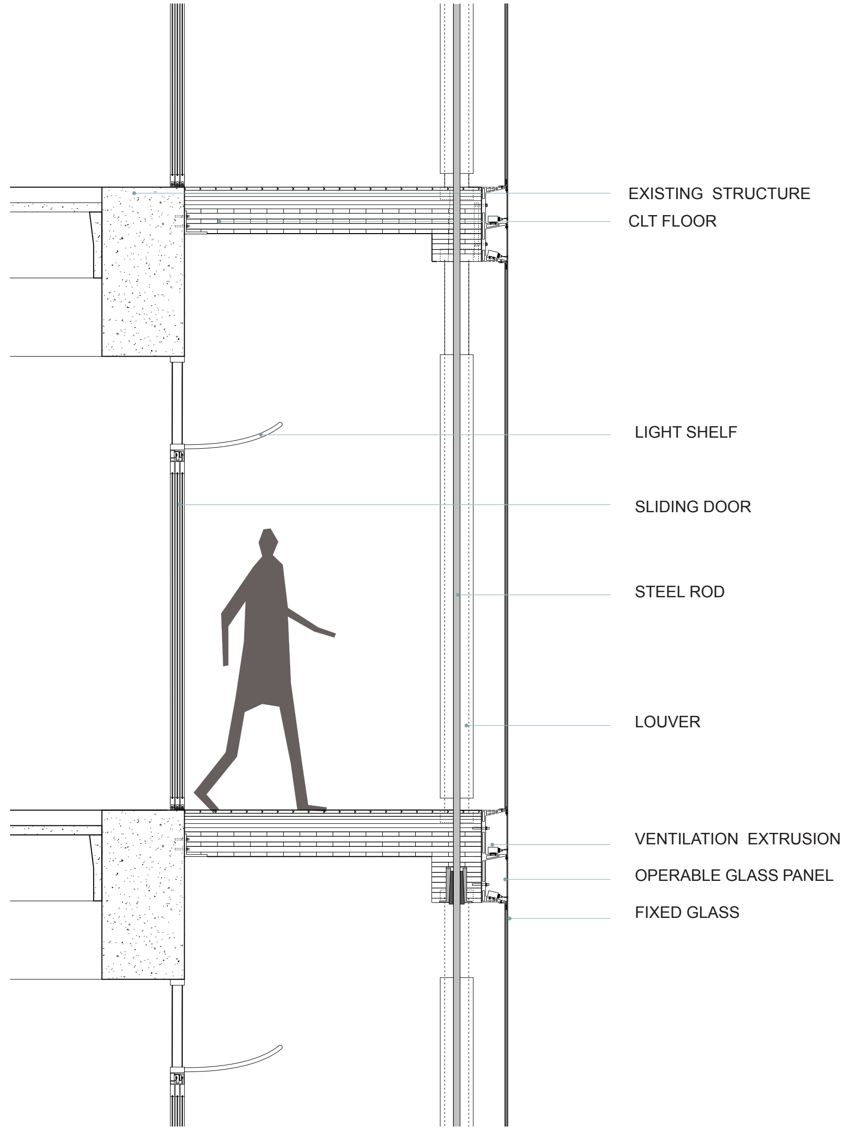


Figure 63. Facade Section

SPACE

The “space in between” also serves as vertical circulation. It provides people in a department occupying several floors the opportunity to circulate at the outer layer of the building, where most dynamic activities might occur. The office floor plan is divided into different areas including open office, closed office, meeting room, and dining and cafe areas. Depending on the use, the “space in between” has the ability to adapt to a variety of spatial needs. When the “space in between” is expanded, it brings the wood texture inside the original building. The extra space might act as dining and cafe areas for people to relax, or as a sitting area.

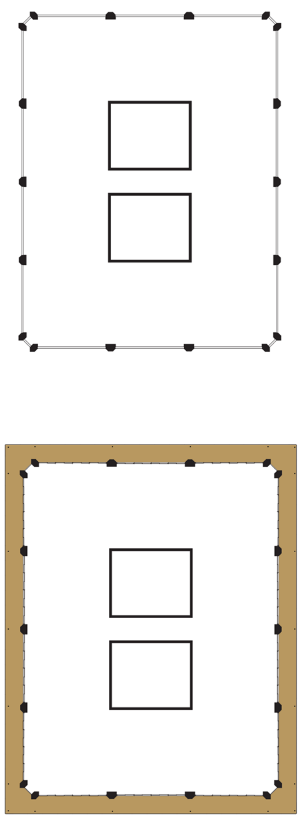


Figure 64. Before and After the Renovation (Plan View)

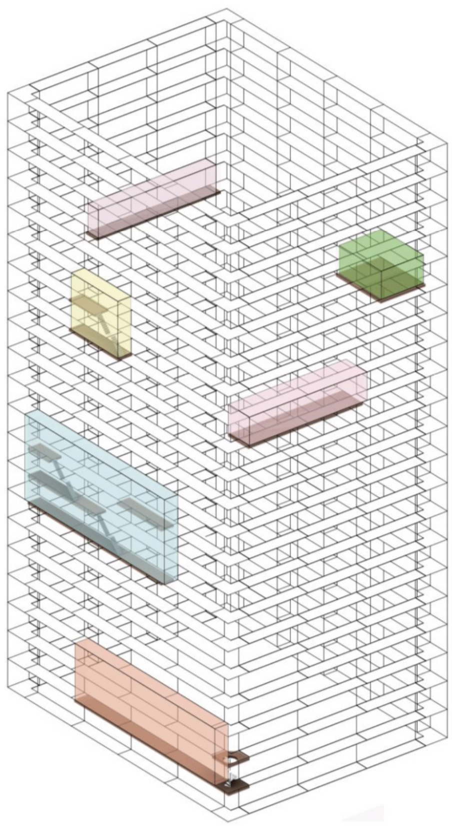


Figure 65. Different Types of Space (Axion View)

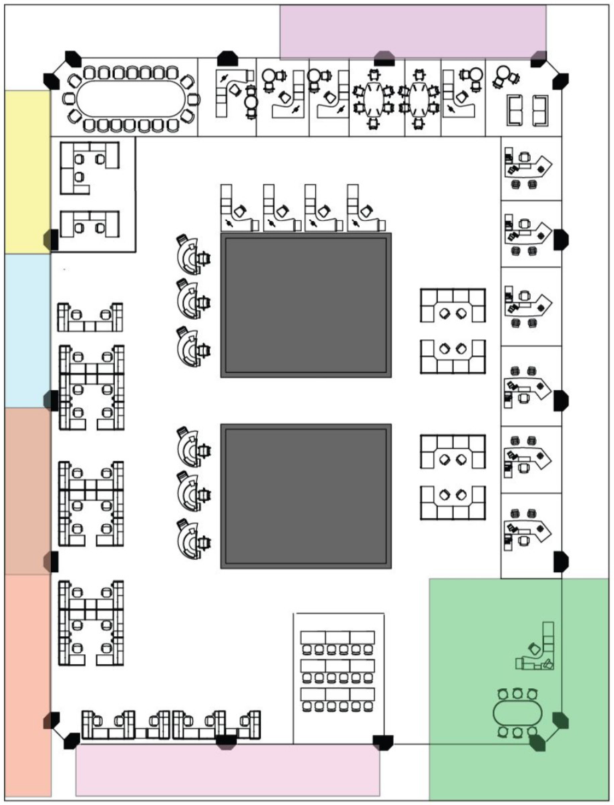


Figure 66. Different Types of Space (Plan View)

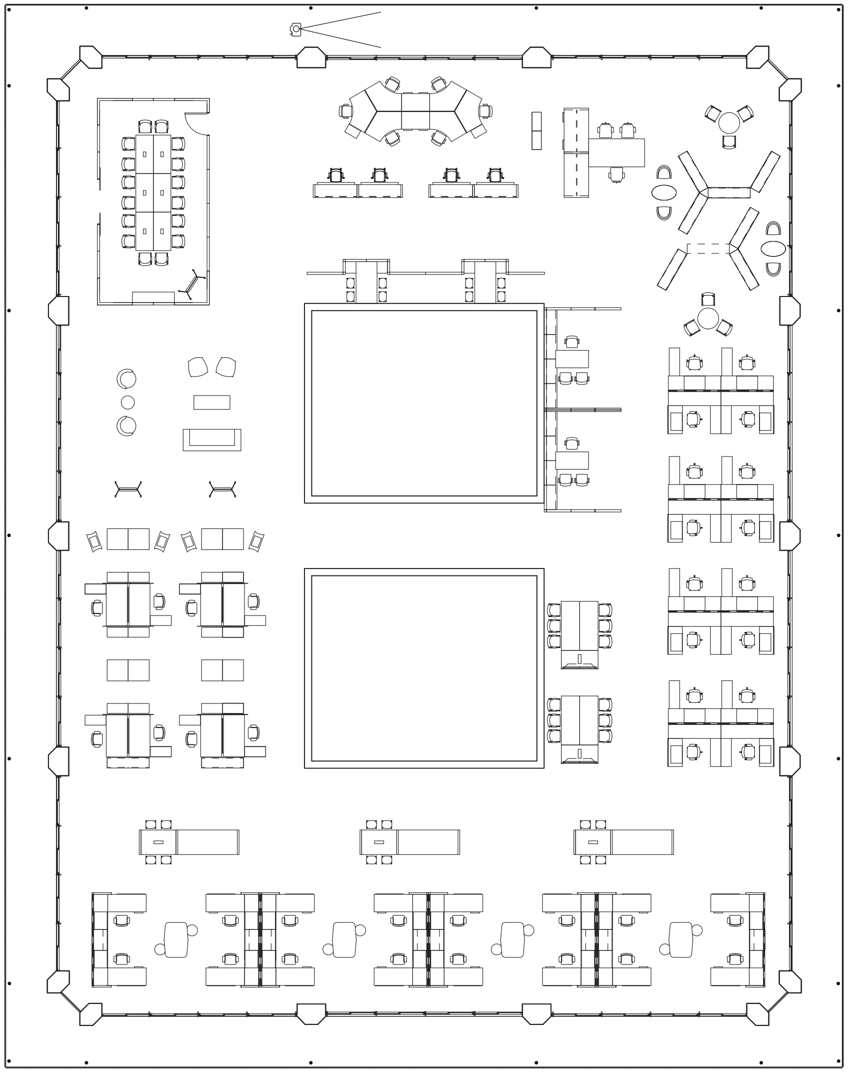
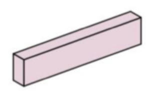


Figure 67. Base Case (Plan View)

Figure 68. Base Case (Perspective View)



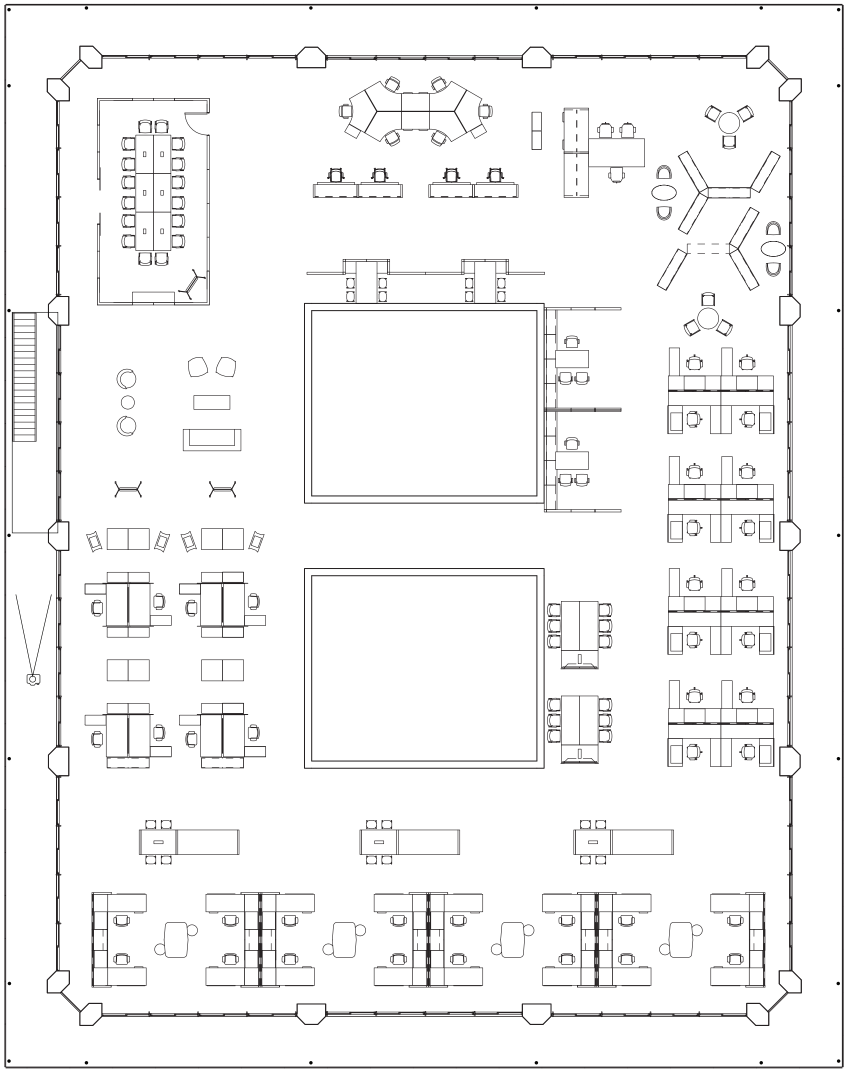
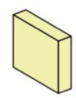


Figure 69. Double-Height Space (Plan View)

Figure 70. Double-Height Space (Perspective View)



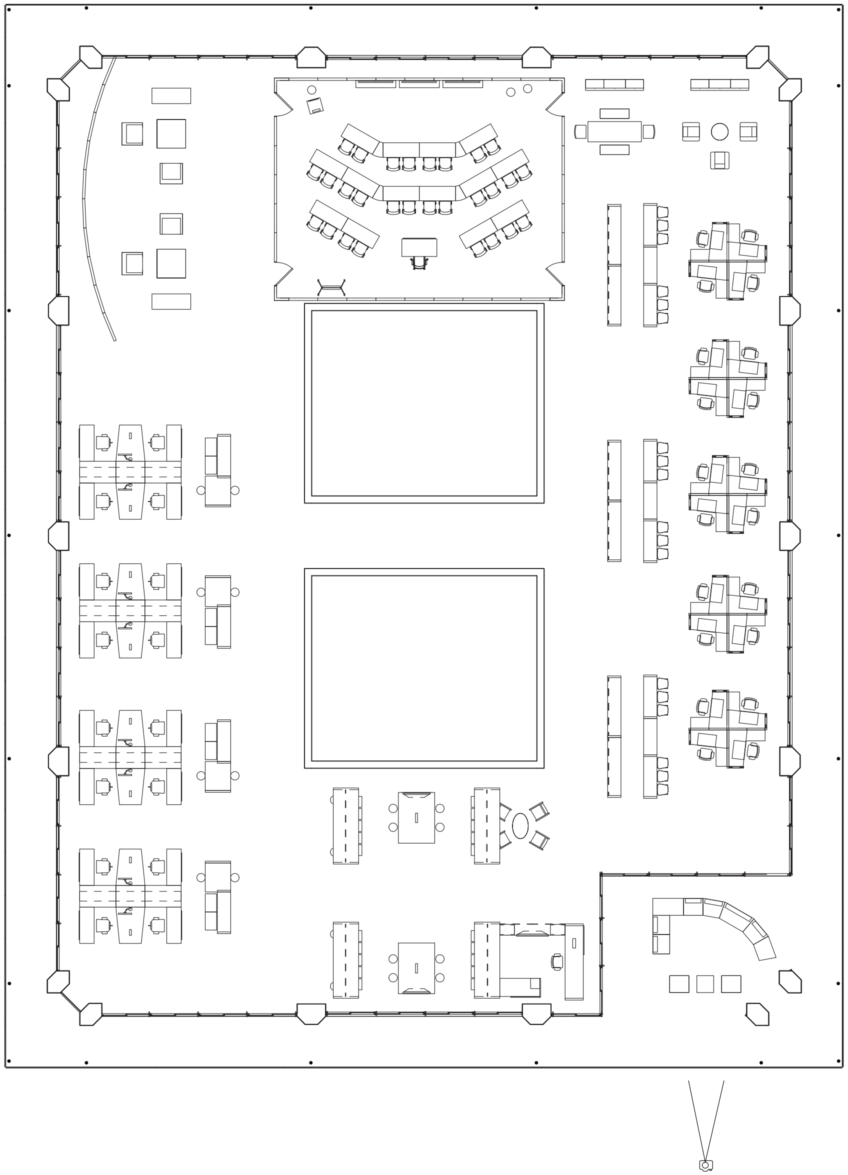


Figure 71. Expanded Space (Large) (Plan View)

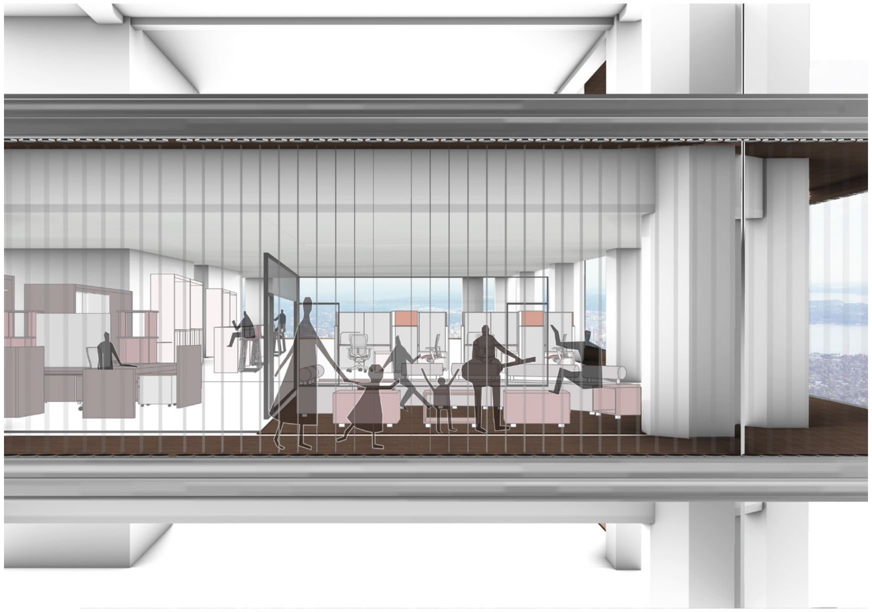
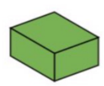


Figure 72. Expanded Space (Large) (Perspective View)



When the “space in between” is expanded, it brings the wood texture inside the original building. The extra space might act as dining and cafe areas for relaxation and gathering.

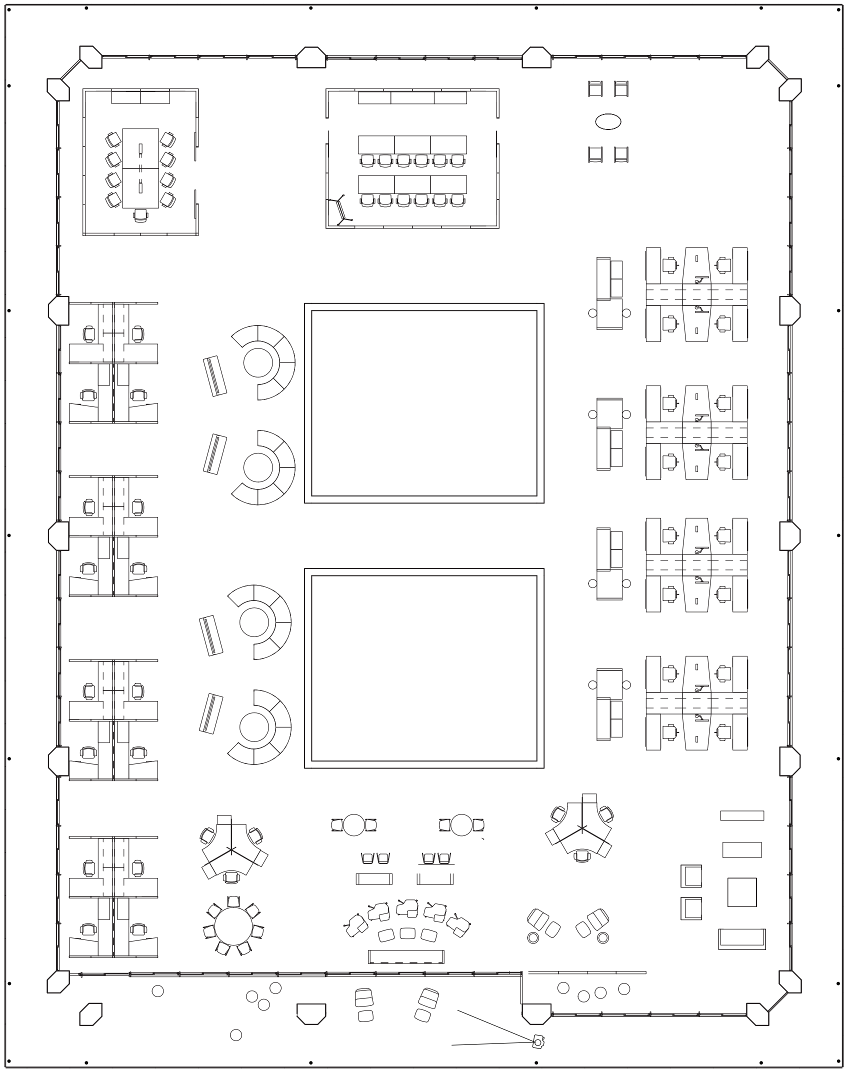
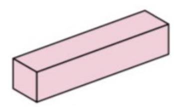


Figure 73. Expanded Space (Small) (Plan View)

Figure 74. Expanded Space (Small) (Perspective View)



Some of the spaces are enlarged to provide additional sitting areas.

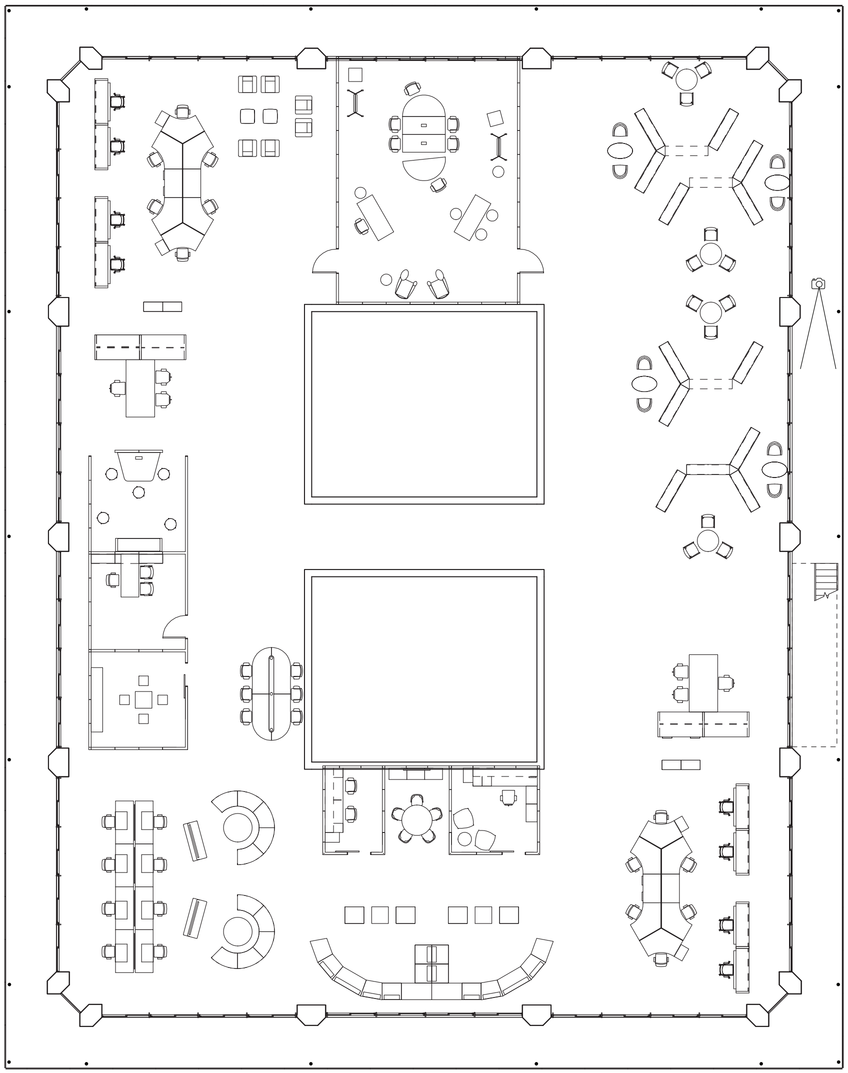
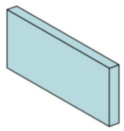


Figure 76. Triple-Height Space (Perspective View)



Some spaces are triple-height with stairs. This might occur beside the open offices, where the openness of the “space in between” meets the openness of the office, providing a more dynamic working environment.

Figure 75. Triple-Height Space (Plan View)

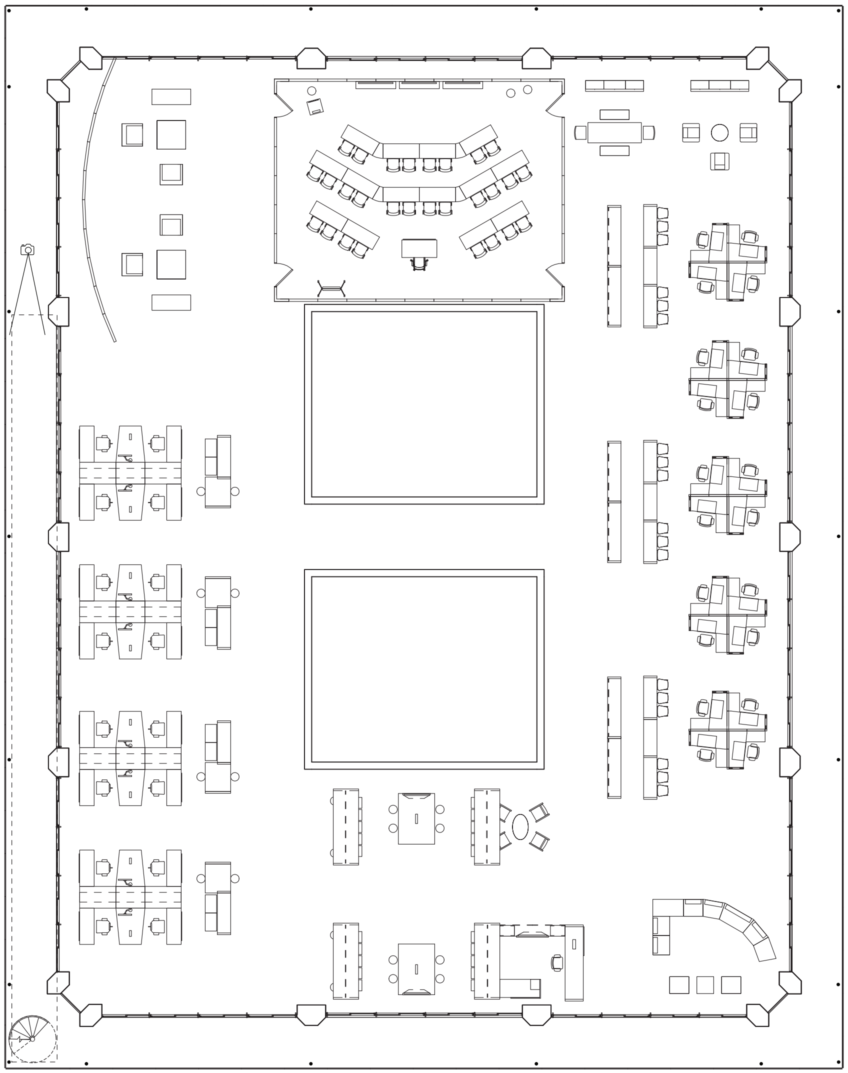
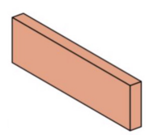


Figure 78. Double-Height Space with Spiral Stairs (Perspective View)



Some spaces are double height with spiral stairs. This might occur beside the closed offices, with the vertical circulation in the corner, providing a quieter environment inside.

Figure 77. Double-Height Space with Spiral Stairs (Plan View)

BUILDING SECTION

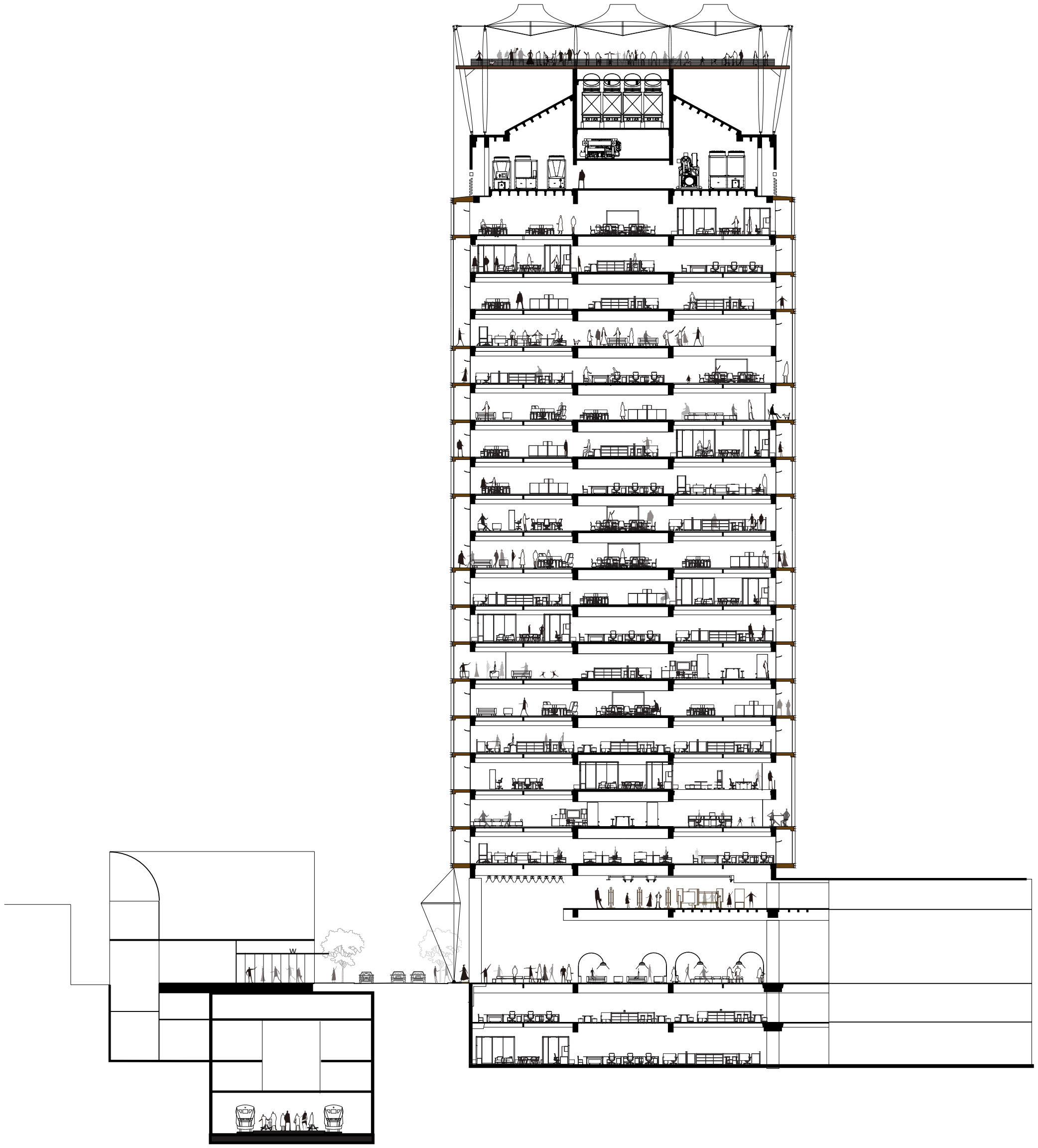


Figure 79. Building Section

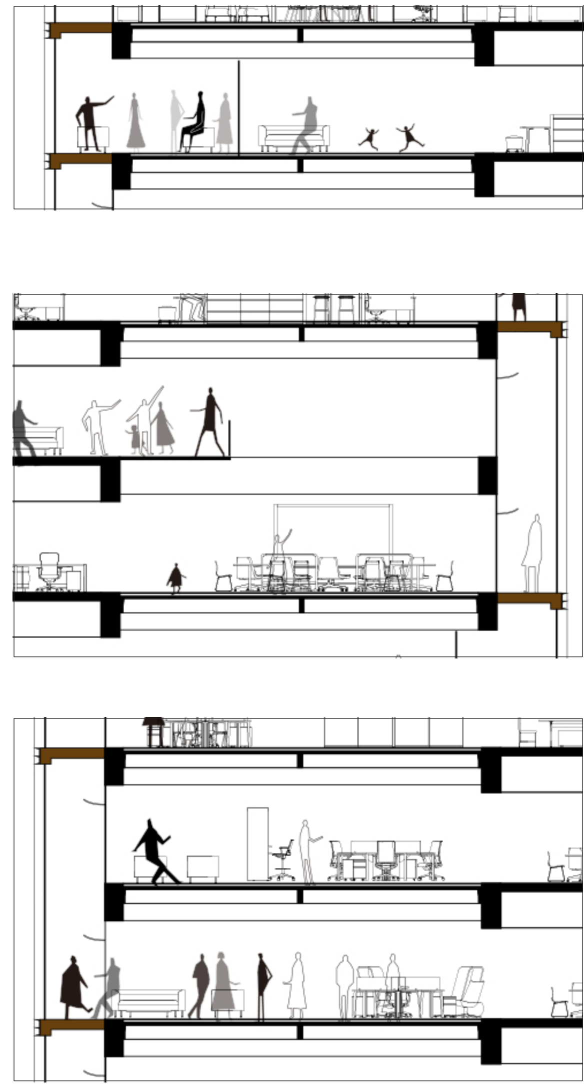


Figure 80. Building Sections(Enlarged)

4.2 Roof

The roof consists of tensile fabric attached to a steel frame, providing shade for the roof deck. The new steel columns are attached to the core of the original building, using steel rods to form a space frame to stiffen the structure.

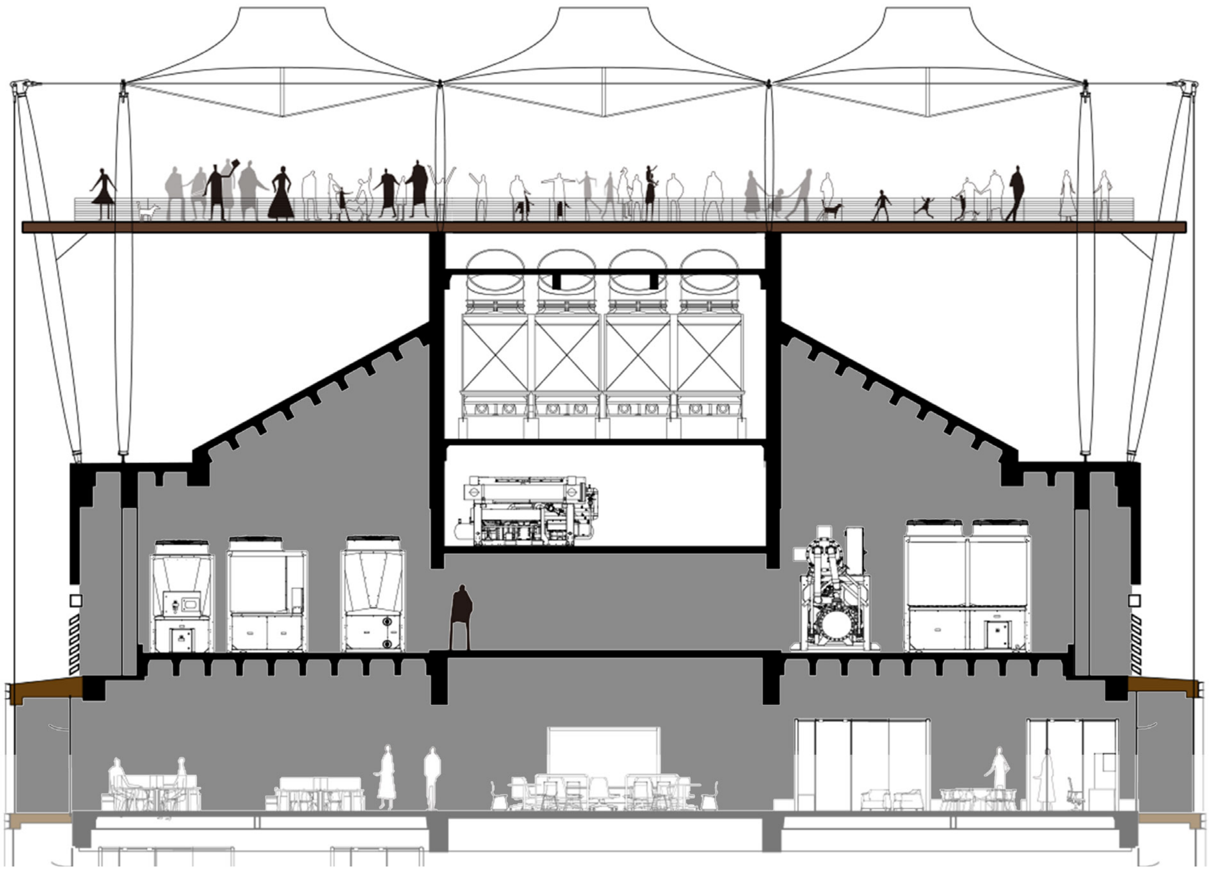


Figure 81. Roof Section

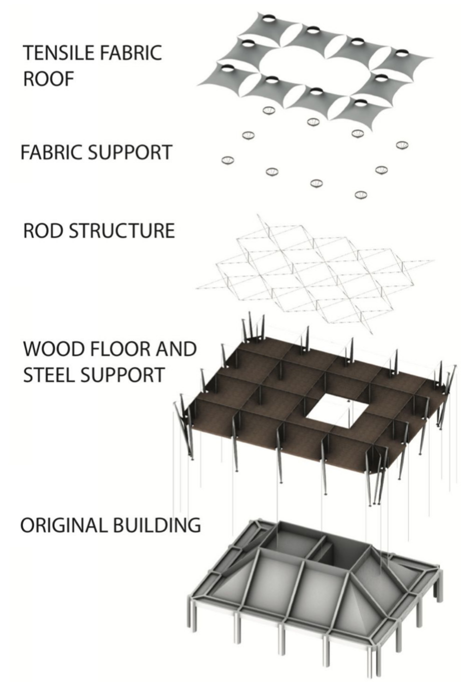


Figure 82. Roof Diagram

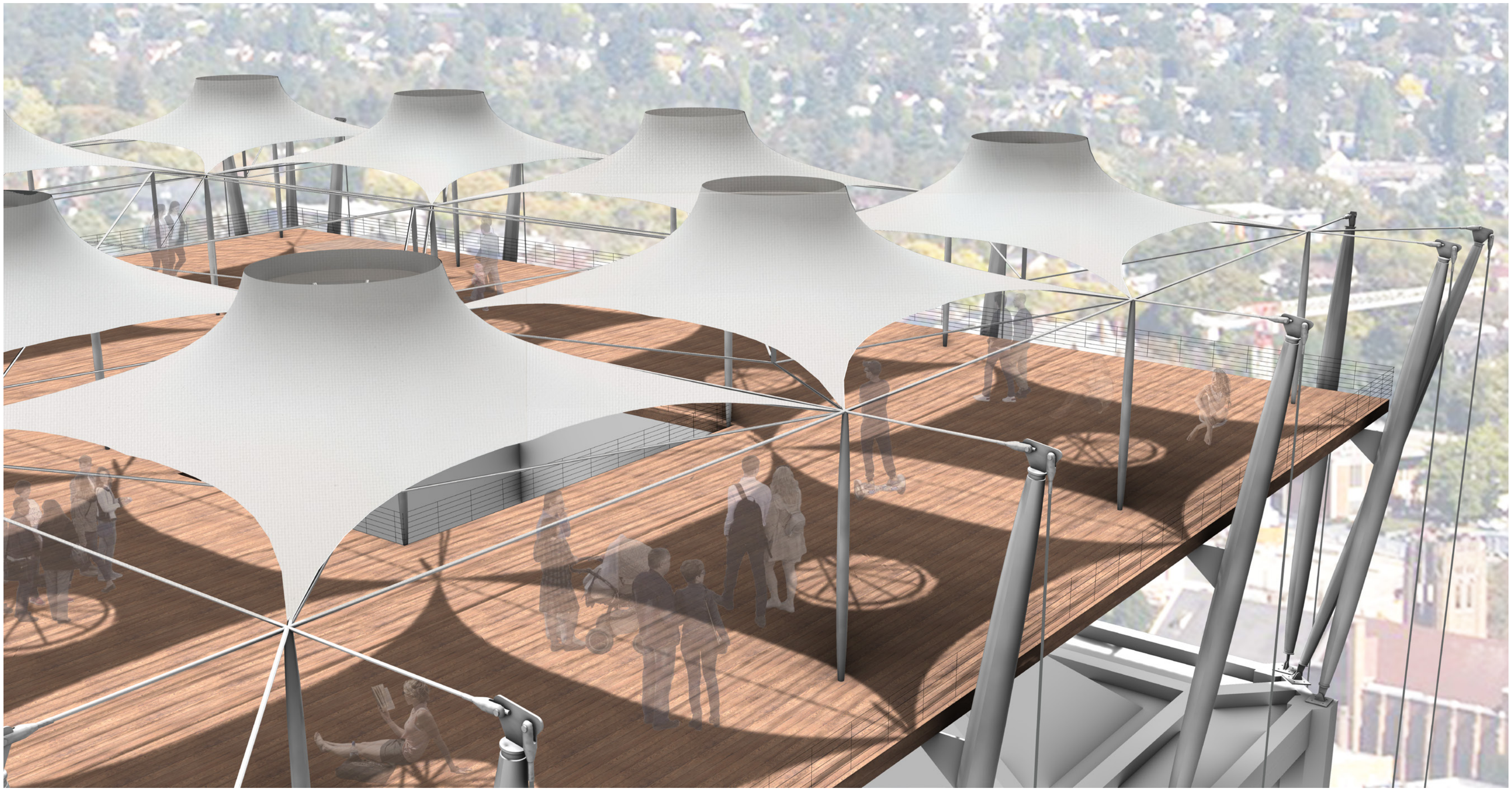


Figure 83. Roof View

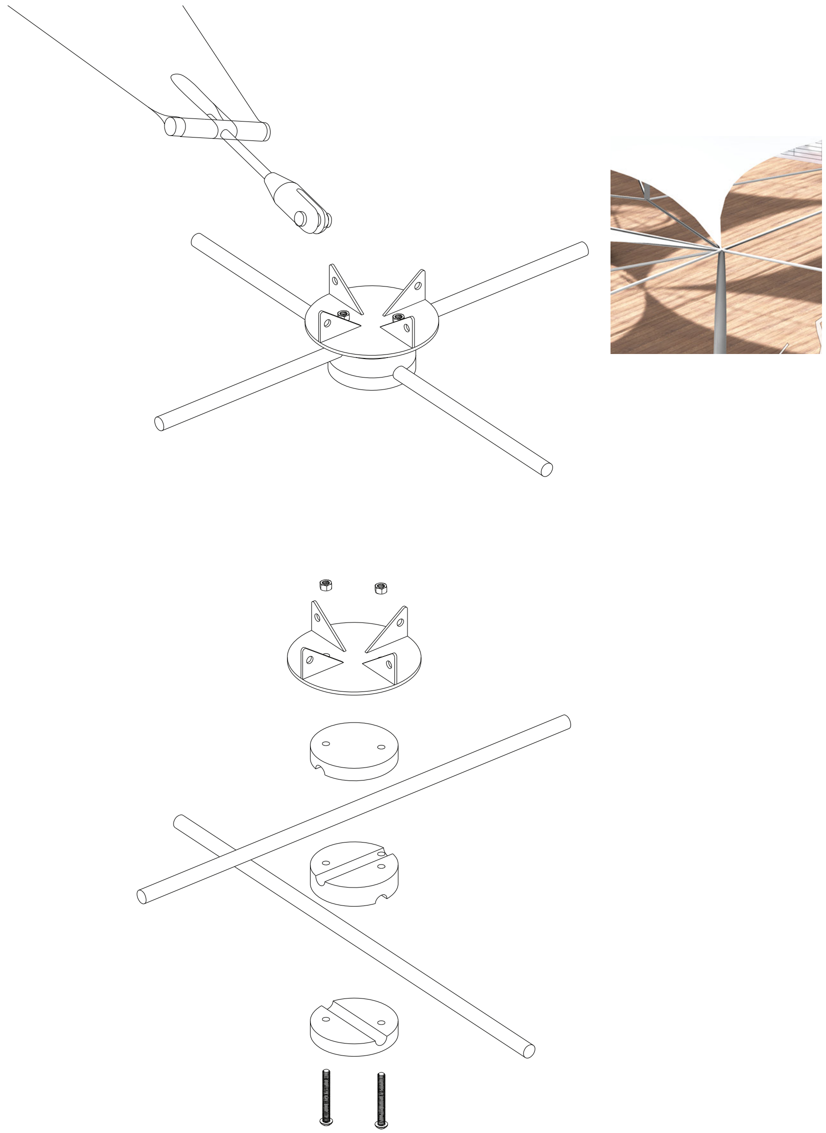


Figure 84. Cross Clamp Assembly

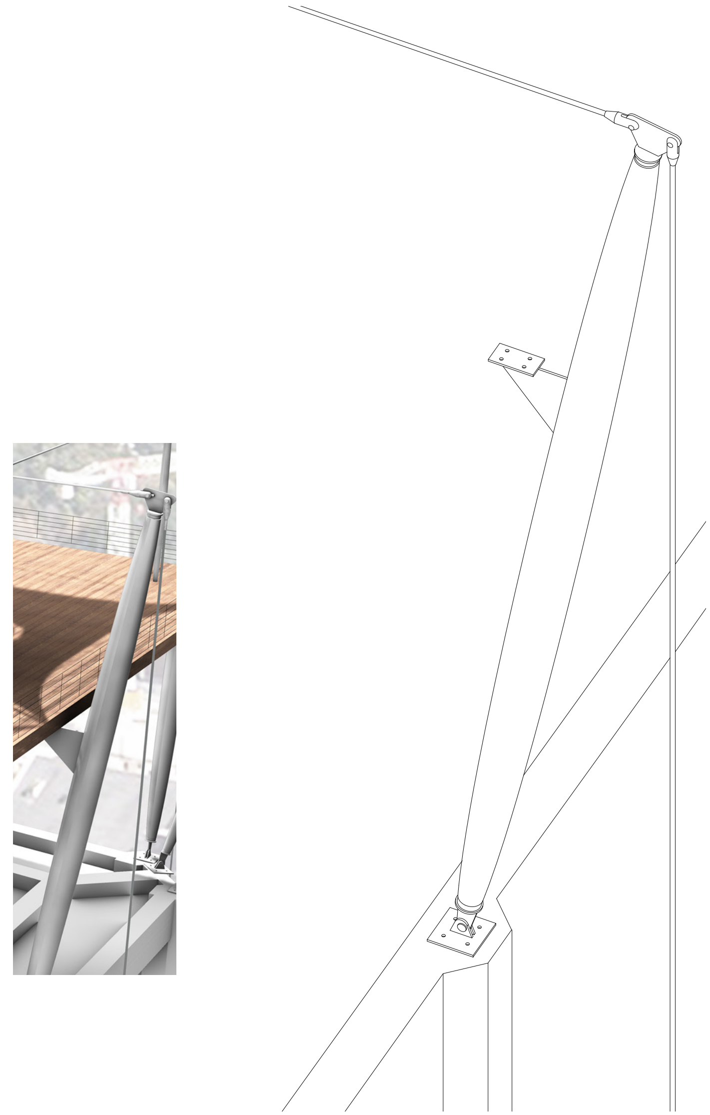


Figure 85. Steel Column Detail

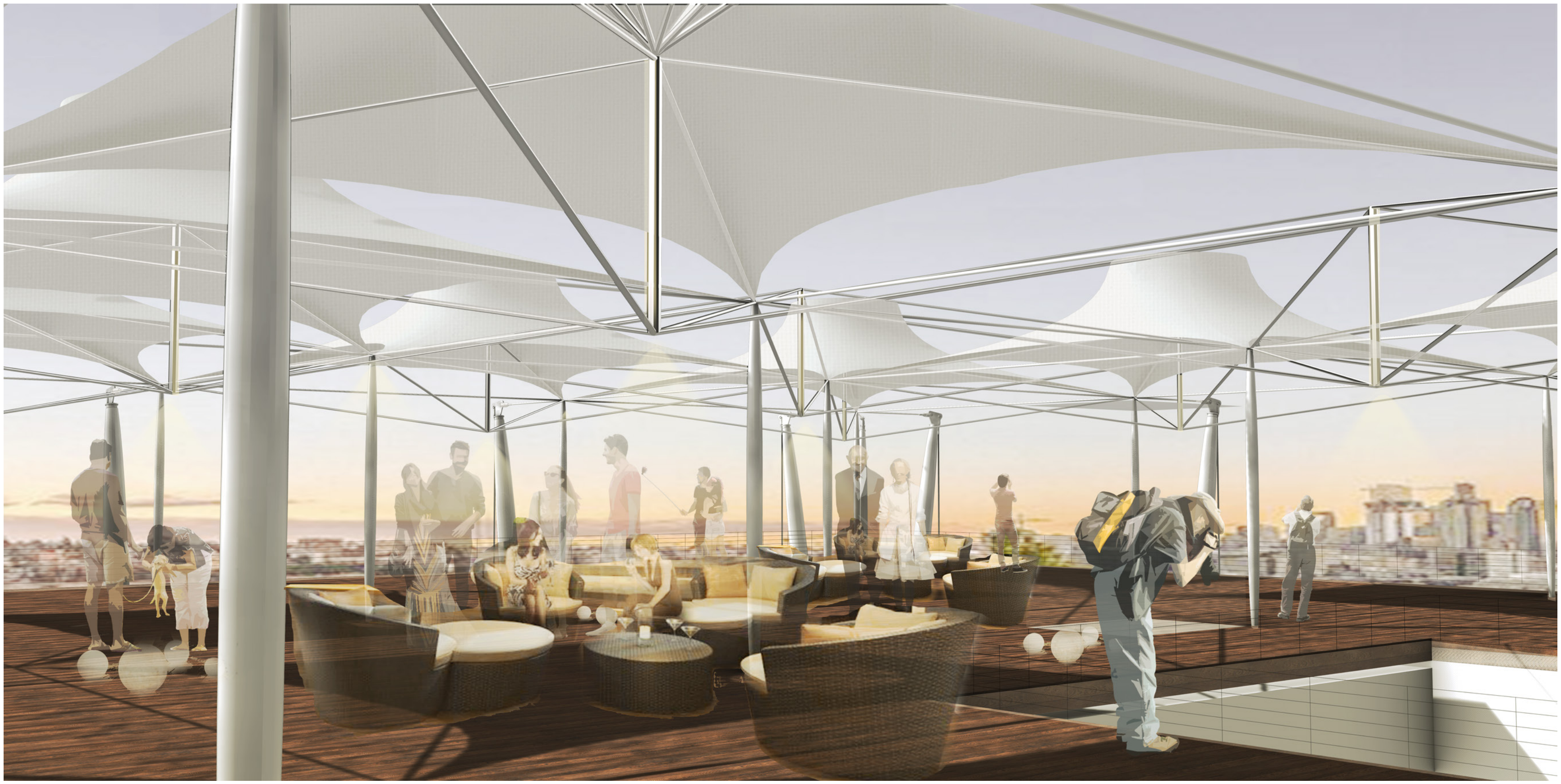


Figure 86. Roof View

4.3 Canopy

The wood floor continues at the ground floor level. This threshold suggests the space above and welcomes people walking by to enter the newly renovated UW tower.

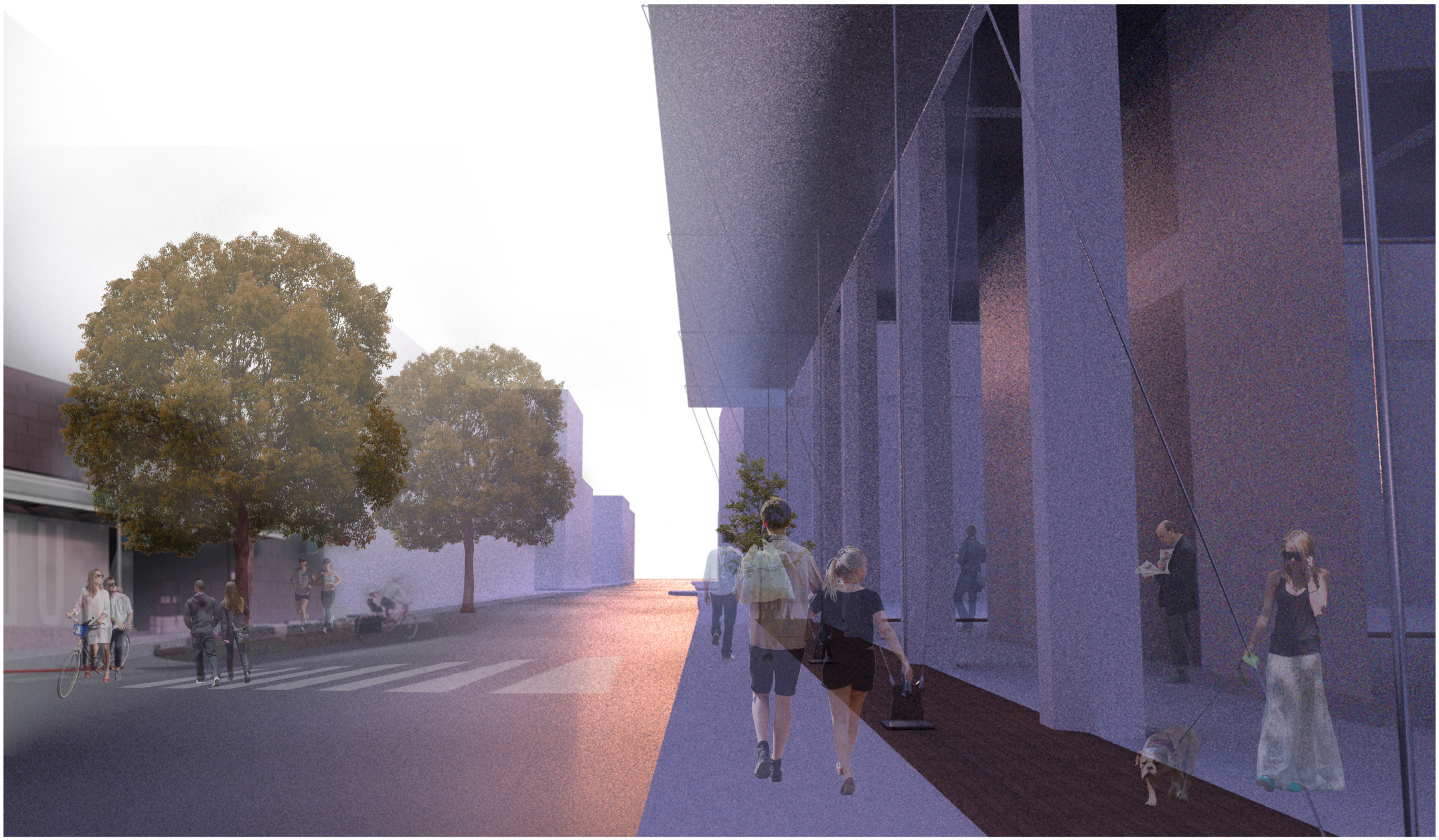


Figure 87. Canopy

5. Conclusion

This thesis began with the idea of using kinetics to reimagine a building envelope, transforming it from static to kinetic. After the site - UW Tower - was chosen, several explorations about structure, materials and kinetic components were made and discussed before the choice was made for a specific proposal. By adding new layers to the facade, the building gained a "space in between" its outside and interior environments, solving the insulation and shading problems of the original building, while improving natural ventilation and daylighting. Each of the layers has its function and they work together to control the interior environment.

Several changes were made during the design-development process. The structure of the additional floors changed from cantilevered to hanging, resulting in dramatically reduced depth of structure. In addition, early ideas about ETFE cushions evolved to become more conventional glass to better accommodate the development of the light-control louvers. Finally, the development of the structure of the floor affected the light shelf, which doesn't function well as it was first intended to. This might be changed to a solution using light-redirecting glass or solar tubes in the future.

In addition to the development of the skin of the building, the interior of the building also changed to provide a more open working environment by rearranging the office furniture. Depending on the use, the "space in between" can adapt to a variety of different spatial needs. Bolder changes could be made to the original building to create spaces of greater interest and utility.

The roof and entrance are also fully renovated, with additions, adding to the design integrity of the whole building. A roof deck is created, supported by both a new steel structure and the existing concrete structure. This proposes a large, new event space for the building and the University. Tensile fabric is used to provide shading on the roof deck, which closely fits the hanging structure. A glass canopy is attached to the bottom of the hanging structure, where the steel rod meets the ground. The wood floor also continues on the ground floor, which suggests the renovation of the building facade above. More development could happen on the entrance sequence to make the building more welcoming to the public.

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