

SPORTS CENTER

Relationship between architectural space and exercise performance

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Institute and State University in partial fulfillment of the
requirements for the degree of

Master of Architecture

In

School of Architecture + Design

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ABSTRACT

Function is the first priority of designing architecture. Function lets architectural space serve human body movement properly.

Today, there are many sport centers (gyms) for people to choose. Most of the gyms are simply rooms with machines. Although their spaces can fulfill the basic demands of a workout gym (function), the function of gym design is not only to give people space to work out, but also to use the architectural space to improve exercise performance.

As a bodybuilder and powerlifter for seven years, I have competed in bodybuilding. I am also planning to compete in powerlifting. So, I want to use my knowledge and experience of training to improve the exercise performance through design of the architectural space.

ACKNOWLEDGEMENT

I deeply appreciate my thesis chairman, Prof. Davis, and committee members, Prof. Gartner and Prof. Dugas in guiding my thesis. This would not have been possible without all of their support and guidance.

I would like to thank my parents, because they gave endless care and support. I could not have these achievements without all of their love and support.

Both powerlifting and bodybuilding give support for this study and work, and add the importance of discipline and persistence.

I would like to thank my friends, and everyone else who helped and inspired me in my study of architecture.

--- YUAN GAO

May 2019

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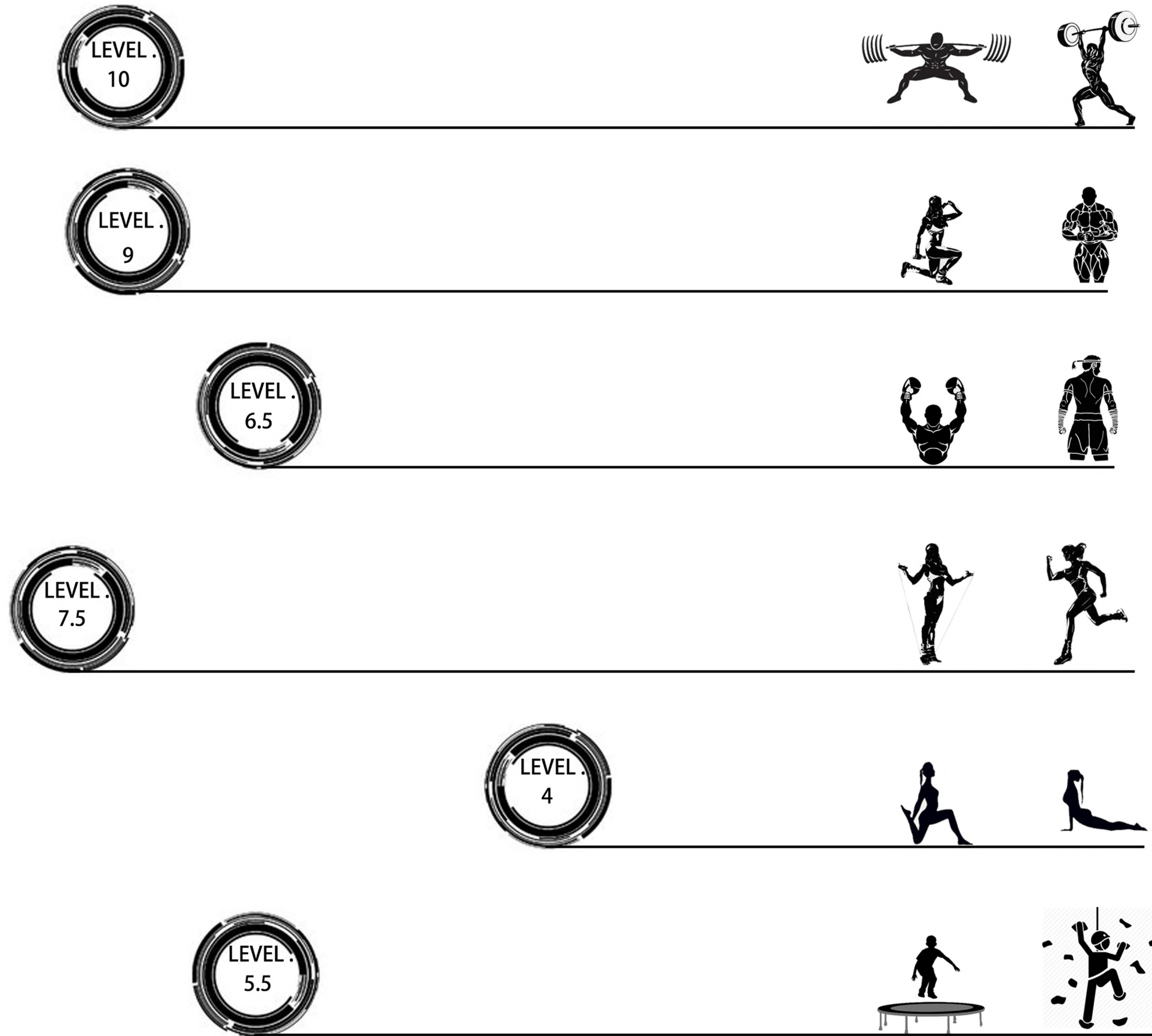
CONCLUSION

CHAPTER 1 : RESEARCH

Relationship between architectural space and exercise performance

In the book, "*Body, Memory, and Architecture*," the authors state that all architecture functions as a potential stimulus for body movements. The book further discuss an experiment where the great choreographer, "*Martha Graham...asked her students to train their haptic experience of space. A natural outcome of this kind of training is that the entire body gradually is mobilized to touch and feel space, so that movement becomes not a vague indescribable set of reflex actions, but an articulately felt interaction with the positive stuff of space.*" Consequently, I believe putting people who are exercising in a fan-shaped space, will stimulate their aesthesia (the normal ability to experience sensation, perception, or sensitivity) to encourage better performance in their training.

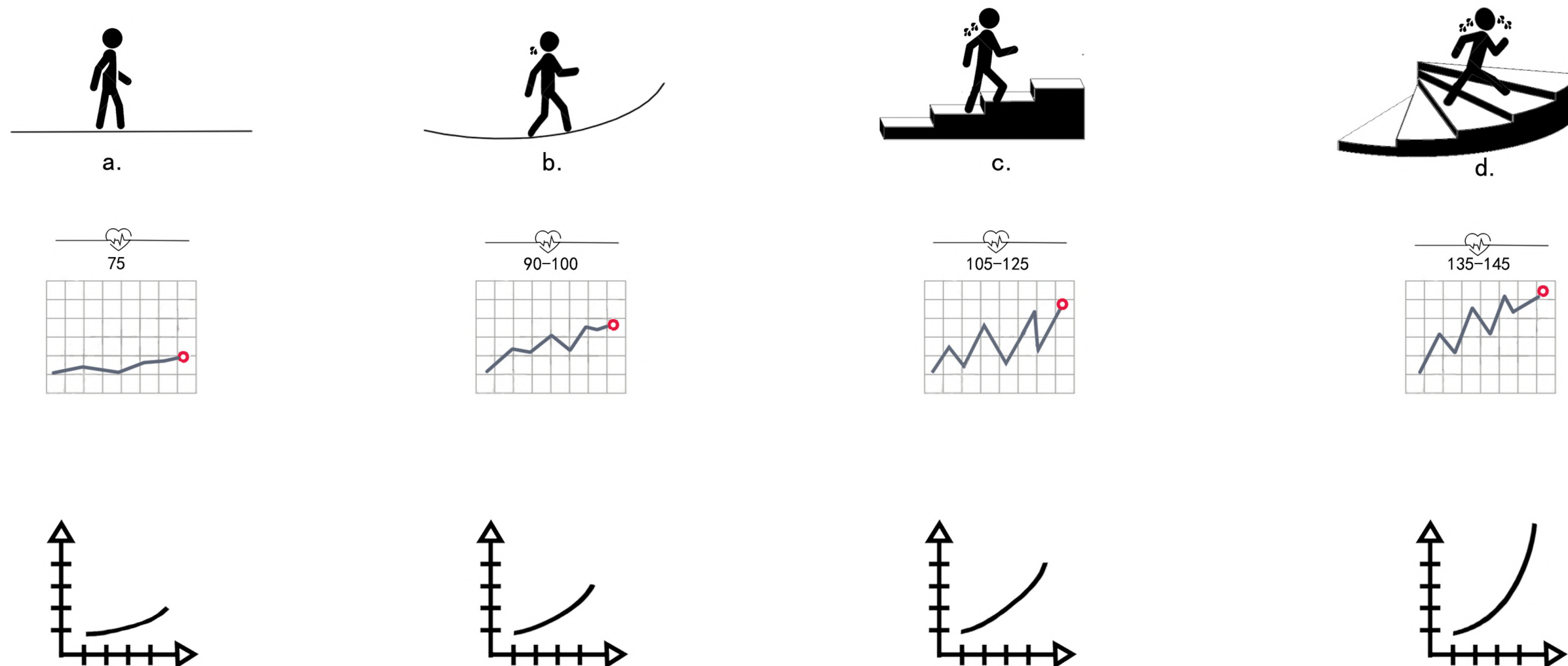
[Kent C. Bloomer and Charles W. Moore. *Body Memory and Architecture*. Yale University Press, Ltd., London publishing, 1977]



My thesis is about the relationship between different types of exercise performance and architectural space. This diagram shows the impact that architectural space has on exercise performance and the requirements of spatial design to accommodate them.

I divide the impact degrees into 10 levels. From the diagram, I find anaerobic exercise (lifting) spaces to have a high impact on the person training. Yoga, stretching, trampoline activity and climbing exercises all have much lower impact. This phenomenon, is due in part to the human's central nervous system. Lifting exercises like powerlifting and weight lifting, need the nervous system to get into a high activity level for better results. Bodybuilding requires a greater muscle to brain relationship than other exercises. Powerlifting requires a higher level of activity from the nervous system than most workouts.

The complication of designing architectural space depends on specific workout functions. Thus, I used the length of a line to indicate the impact people will have on the space, based on particular exercises. When designing an exercise space from this perspective, dimension, materials, structure and circulation, will become more important. Therefore, some lower impact exercises will have a different effect on dimension of the architectural space.

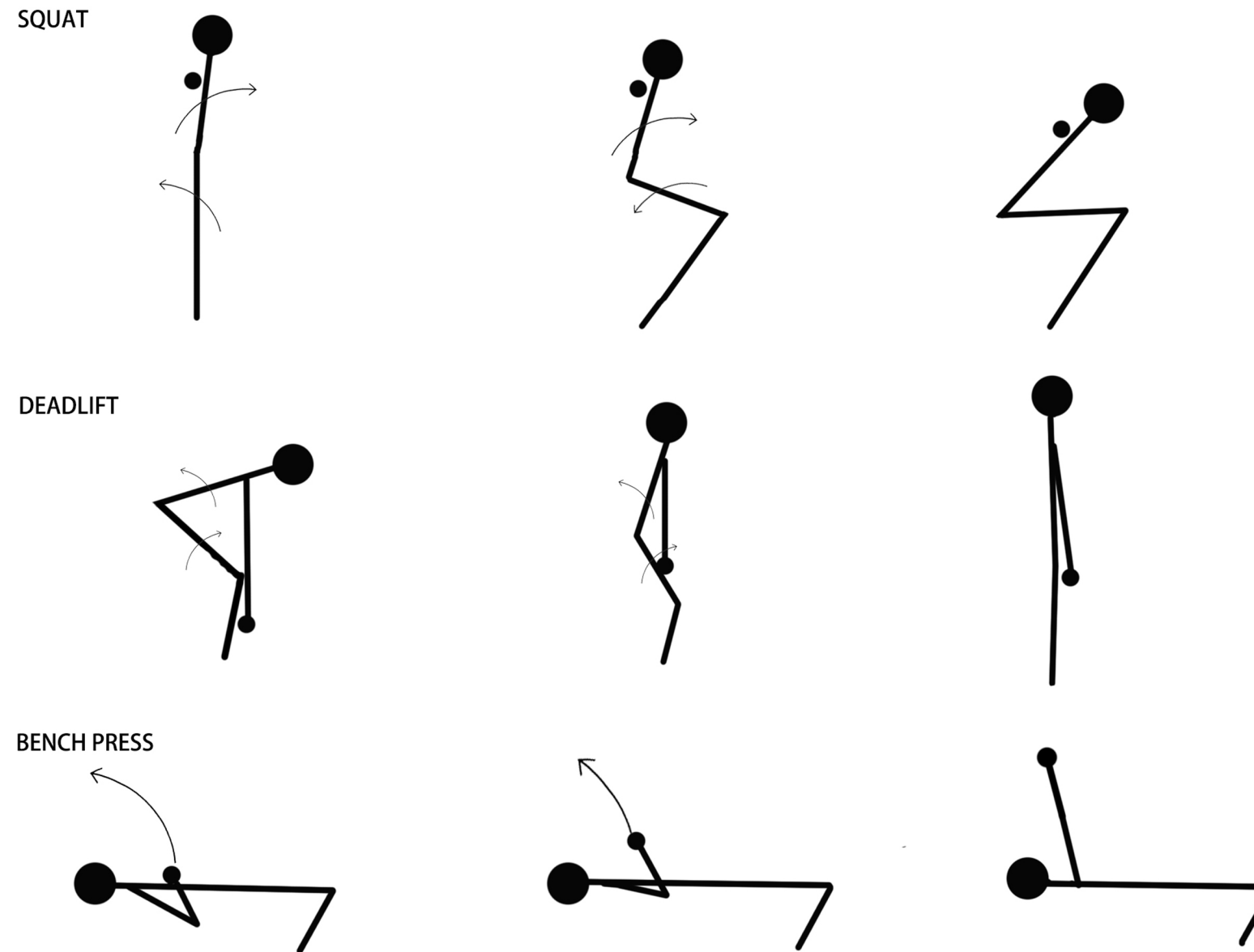


“Anaerobic exercise consists of brief intense bursts of physical activity, such as weightlifting and sprints, where oxygen demand surpasses oxygen supply. While aerobic exercise relies on oxygen, anaerobic exercise is fueled by energy stored in your muscles ...”¹ Cardio exercise is influenced by curved elements in the exercise space. Diagrams a-d above, compare people doing cardio on a level surface, curved surface, stairs and spiral stairs. Different levels of energy expenditure are required in each circumstance. The second line of graphs, moving from left to right, indicate an increase in the heart rate based on the level of difficulty.

A primary reason to do cardio workouts is to burn off excess calories. The third set of graph-based diagrams show approximate increases in calorie consumption from left to right. The ideal heart rate for cardio is 133- 152 Beats per minute (BPM).² In testing my own heart rate doing cardio exercises, I find my heart to beat about 135-145 during running on spiral stairs. Consequently I have designed a running track similar to diagram d above, using different height steps in a curved form.

¹ [<https://study.com/academy/lesson/anaerobic-exercise-definition-benefits-examples.html>]

² [<https://www.lifespanfitness.com/fitness/resources/target-heart-rate-calculator>]

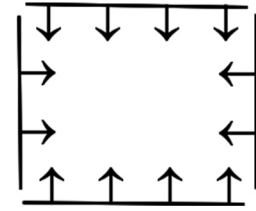
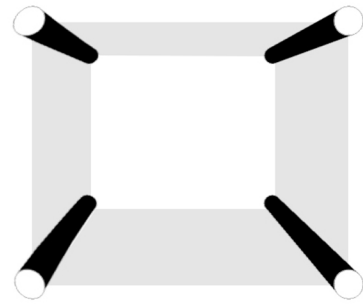


The primary reason for a person to gain muscle is to gain strength over their lifespan. This strength is necessary for all human endeavors. This requires both vertical and horizontal compound movements for positive muscle strength gain. These motions tend to generate a curved or fan like path for different parts of the body.

The most common representative compound movement training motions are squat, bench press and deadlift. The figures above diagram these motions. The upper body tends to move in a fan-shaped path from the hip joint. The lower body follows a similar pattern from the knee joints. This is shown above in the bench press movement, where the shoulders and arms and bar for weights, all take on a quarter circle curved path.

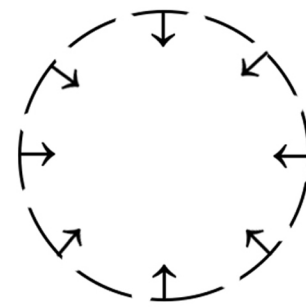
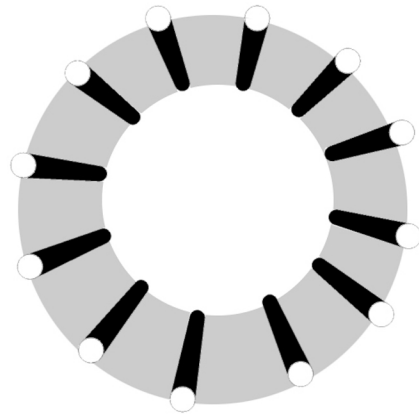
In the book, *“Body, Memory, and Architecture,”* the authors state that all architecture functions as a potential stimulus for body movements.³ The book further discuss an experiment where the great choreographer, *“Martha Graham...asked her students to train their haptic experience of space. A natural outcome of this kind of training is that the entire body gradually is mobilized to touch and feel space, so that movement becomes not a vague indescribable set of reflex actions, but an articulately felt interaction with the positive stuff of space.”* Consequently, I believe putting people who are exercising in a fan-shaped space, will stimulate their aesthesia (the normal ability to experience sensation, perception, or sensitivity) to encourage better performance in their training.

³[Kent C. Bloomer and Charles W. Moore. *Body Memory and Architecture*, Yale University Press, Ltd., London publishing, 1977]

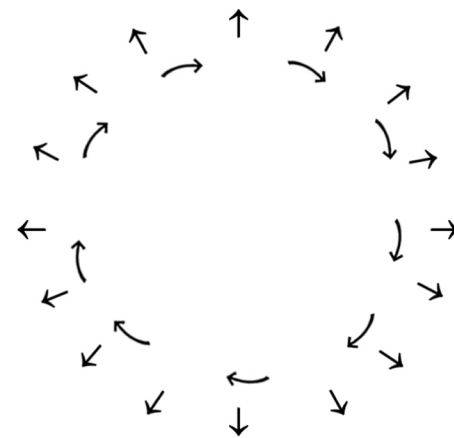
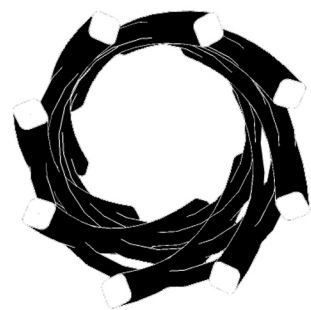


After analyzing the structure in elevations, plans of the structure also need to be analyzed. Columns are a fundamental component of a building's structural system.

Four columns placed as the diagram to the left indicates, will form a square or rectangular space. The boundary of the created space may be seen as restraining action. This would not be an ideal space for that reason.

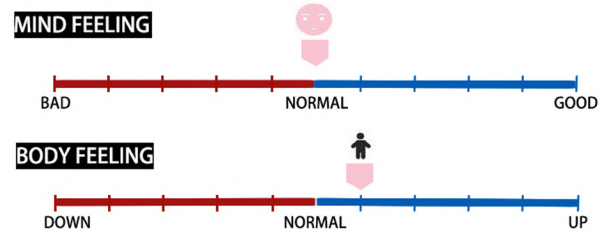


Another typical column relationship might create a circular shaped space. This form creates a round boundary. Rounded space implies much more pressure than a polygonal space, because it has the sense of a centripetal force.

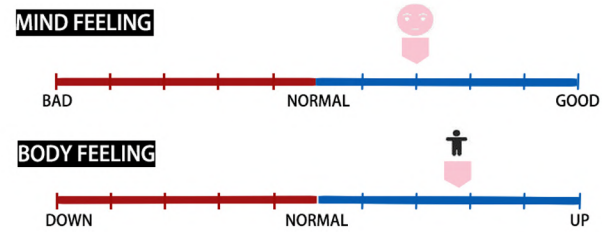


An exercise environment is best addressed with a fluid like element. Consequently, I used curved lines to represent motion. I then combined them to create a form similar to twisting a towel, torquing the structural form.

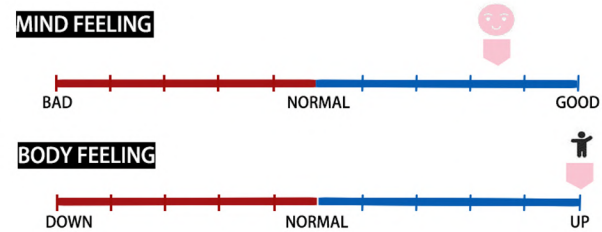
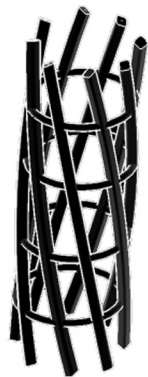
The left figures show how the torqued force implies a rotation. This rotation generates a fluid sense, which makes the space feel as if expanding.



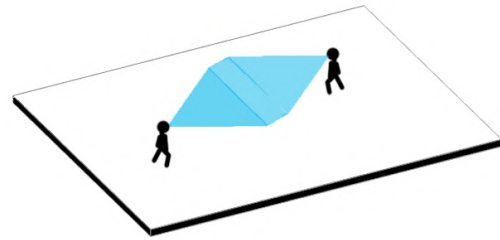
My assumption is that conventional single and straight columns do not activate the mind. The diagrams to the left provide a comparison of column shape responses.



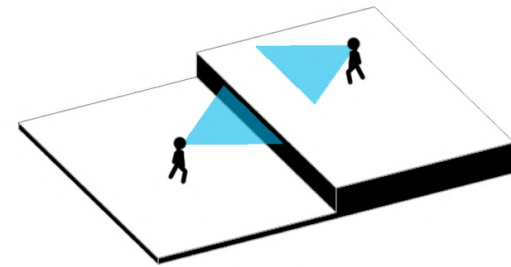
I propose that a curved column implies strength and energy. Consequently, this column design may stimulate the mind and body of those exercising.



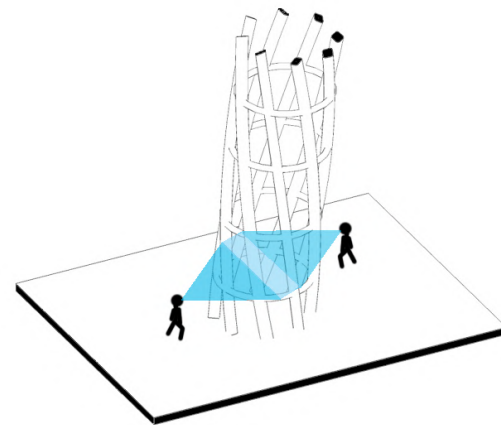
When a composite of columns come together in a twisted form, even more strength and energy is stimulated. This is why I designed the bundled and torqued structural columns in the primary bodybuilding and powerlifting training spaces. Where the column meets the roof, a skylight is formed. Thus, the space between the elements act as a light shaft to the floors below.



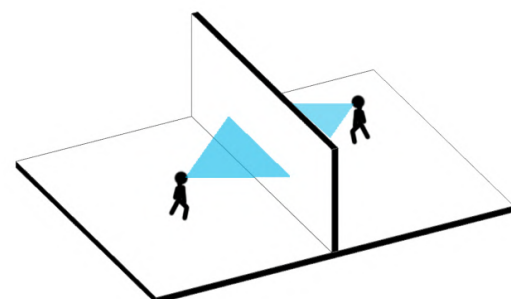
The left figure shows people's view connection in no privacy space. People can know others behavior clearly. This space can create more connections between people, However, it is not helpful for concentration in workout.



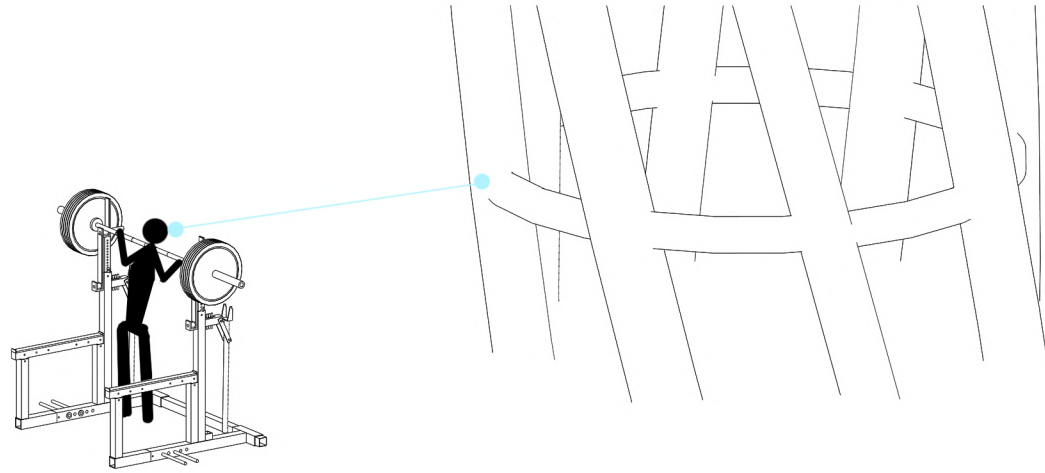
As the second figure shows, people are not able to see each other directly, but they still can have view connections in this space. Thus, having small different height in space can make the space to be slightly semi-private.



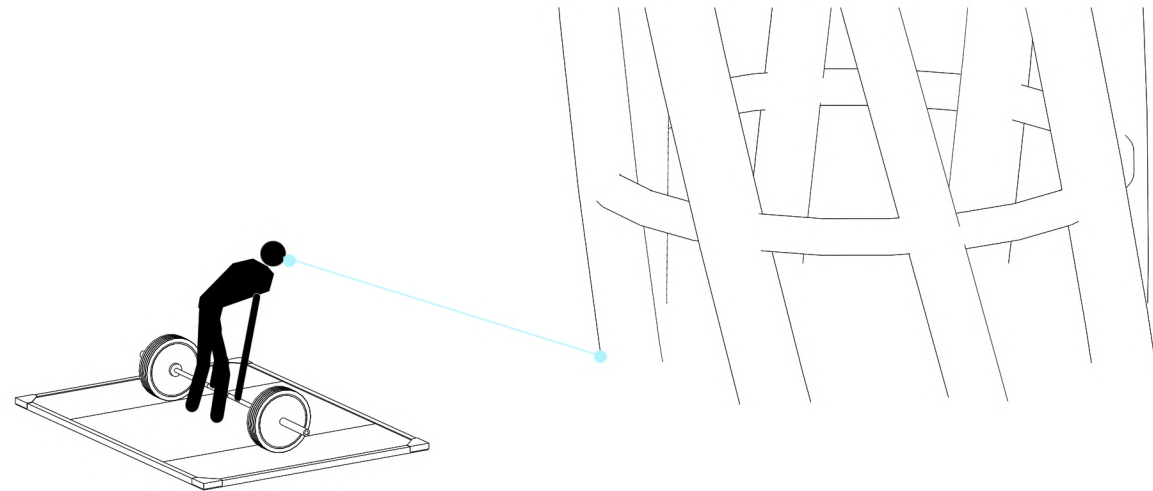
It is also a good choice to use some horizontal elements to make a semi-private space. The structure I used in my building fulfills this requirement. The vertical curved columns and horizontal circle beams form a grid between people, which triggers the space to become a semi-private. The thickness of these columns and beams make the view connection lower again. In conclusion, this structure fits the requirements of semi-private very well. Thus, a different height space with this elements can create a space which will let people have connections with each other, but the connections will not bother each other in workout.



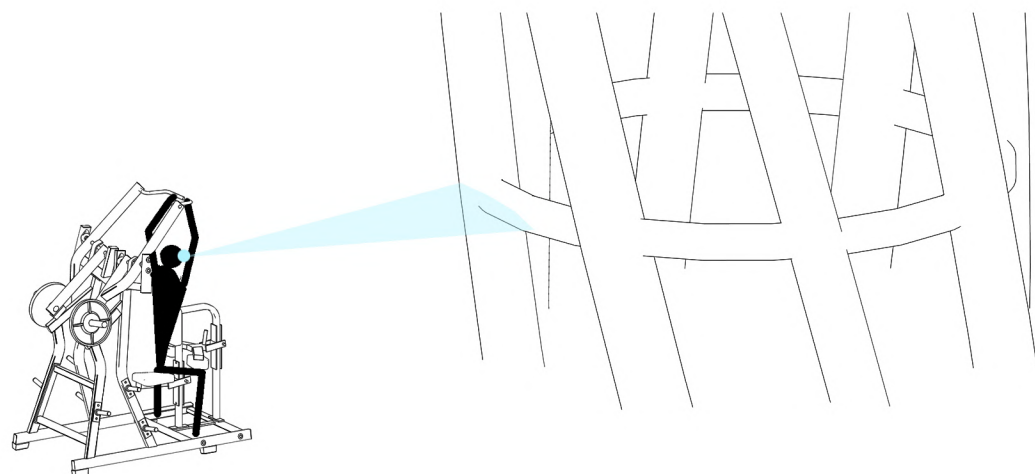
The wall is the most common elements in a building. Wall can separate one space to more and without connections. Although we still need some connections in training place, but using the wall to separate different training is rational. So I use wall to divide different training spaces in the same height level.



In the book, "*Starting Strength*,"⁴ the book suggests people are advised to let their eyes focus on a point when they squat. This point should be same height as their normal eye level. Thus, the squat racks are arranged around the twisted structure to maintain this requirement. The left figure indicates that there are mutiple of points which are combined by curved columns and circle beams.

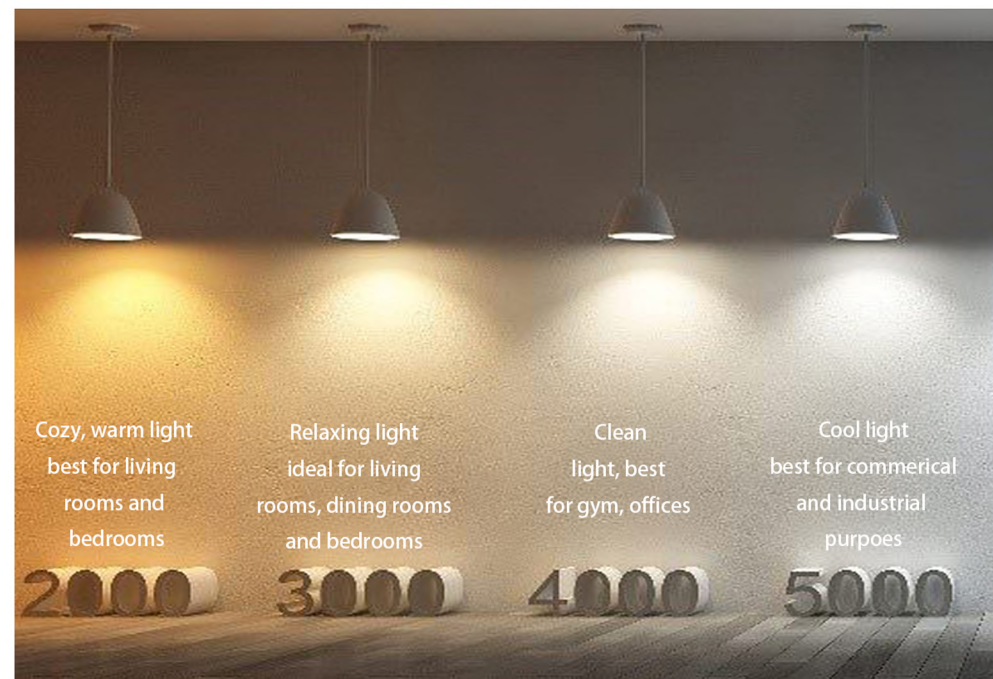
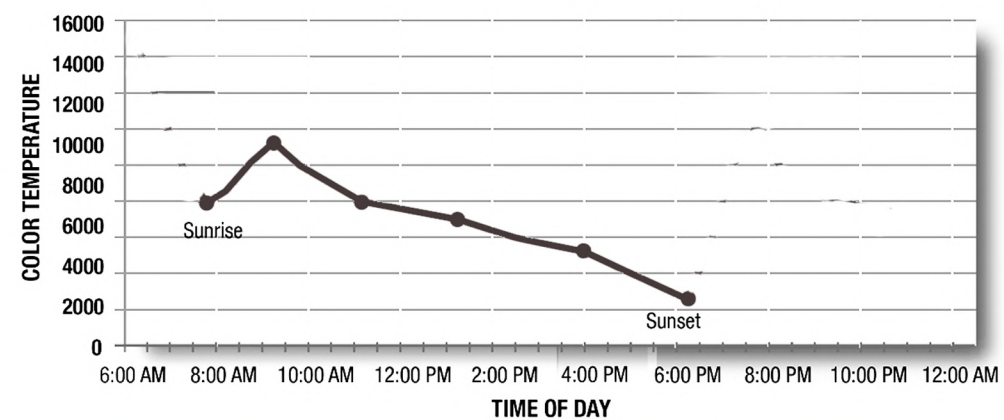
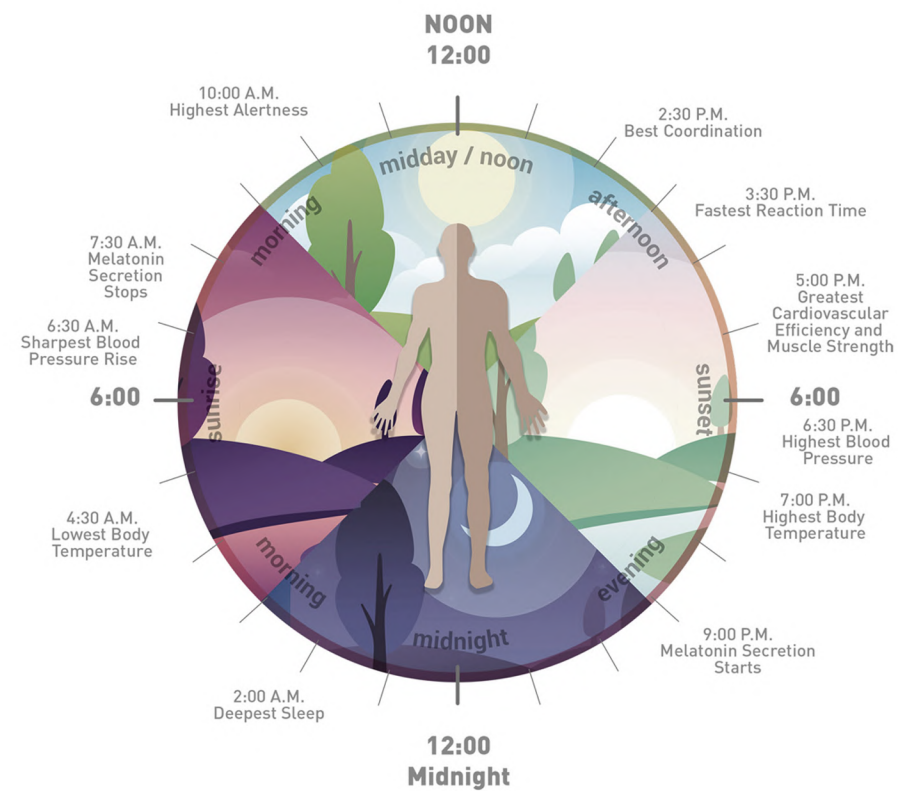


In the book, "*Starting Strength*," the book suggests people should let their eyes focus on a ground point when they deadlift. This ground point is people's eye's view when they set up with their spine in a natural position. Arranging deadlift platforms around the twisted structure can fulfill this. The left figure indicates that there are mutiple ground points which are combined by curved columns and the ground.



As I mentioned before, the twisted structures are conducive to active people's central nerve systems. Therefore, arranging the training machines in a place where these structures can be seen has benefit for trainer.

⁴ [Mark Rippetoe, *Starting Strength*, Aasgaard Company publishing, 2013]



Natural light is one of the most important elements in spatial design. Artificial lights can improve exercise performance as well. Light quality, color temperature and type can affect activities in positive and negative ways.

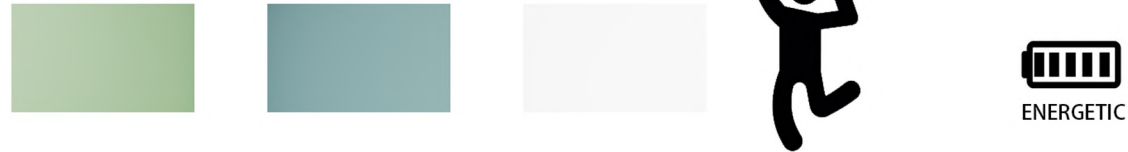
The top figure on the left indicates the best time for humans to workout is 5pm.⁵ The color temperature of natural light can improve exercise performance.⁶

The second graph shows the 5pm color temperature at around 4000 K. Assuming what was stated before, the general light color temperature in the gym should then be maintained around 4000 k. In nature, light varies between 2100 and 9500 K. The middle range is then between 7000 K and 4500 K. I found that a stainless-steel mesh on the west façade is best to reduce the strong natural light for powerlifting and body building. This material will help the interior color temperature maintain 4000 K. The skylights in the roof of the primary training spaces will scatter the light throughout the spaces and the light will not be too strong, consequently no filtering will be necessary.

⁵ [Chronobiology- Is There A Best Time to Exercise? - Alexander Sandalis]

⁶ [Why LEDs are the ideal choice for gym lighting? - Eaton]

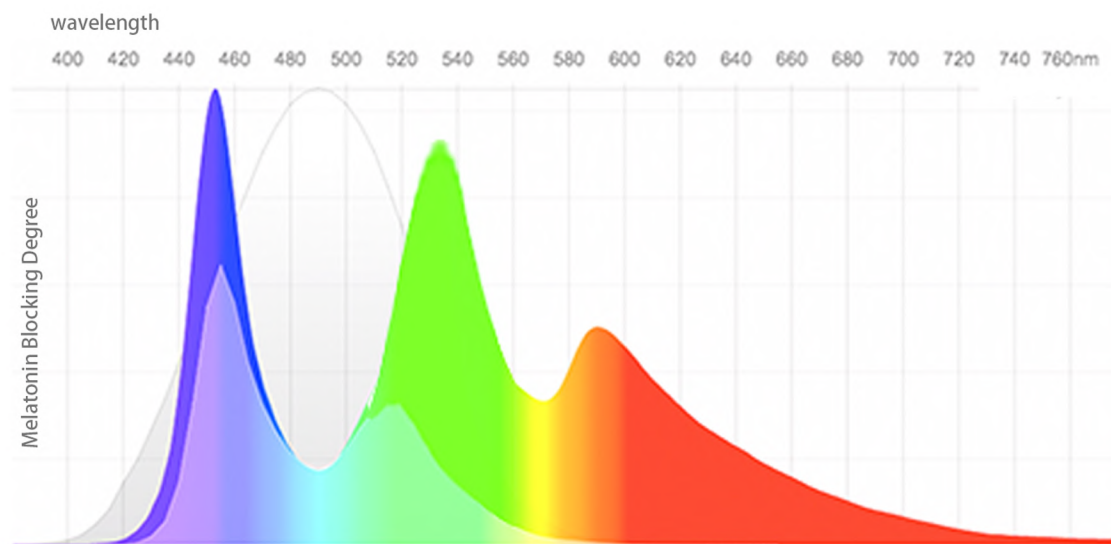
LIGHTS IN COOL COLOR ENVIRONMENTS



LIGHTS IN MILD COLOR ENVIRONMENTS



LIGHTS IN WARM COLOR ENVIRONMENTS



There are many different factors that influence human exercise performance. These include but are not limited to, melatonin, insulin, and blood glucose. These factors also influence appetite and sleep. Melatonin is most responsive to the environment.

When melatonin is released into the body, sleep is induced. The reverse is true when it is restricted. The body is more energetic when melatonin is low and fatigued when it is high. Consequently, the exercise environment should be designed to lower melatonin.

Melatonin is affected by the wavelength (color) of light.⁷ The human eye does not automatically detect the wavelength color of lights. It is perceived through reflection off of walls, floors and structural components. The diagrams to the left show the relationship between melatonin and wavelength color. Exercise conducted in a space of cool color lighting will be more energetic than by warm color affected environments. White, blue and green provide a good color balance for exercise spaces.

⁷ [<https://justgetflux.com/research.html>]



White
purity, innocence



95%



5%



Yellow
warmth, energy



85%



15%



Red
love, excitement



75%



25%



Orange
enthusiasm,
attention



80%



20%



Blue
calmness, sadness



40%



60%



Green
envy



55%



45%



Black
evil, unhappiness



25%



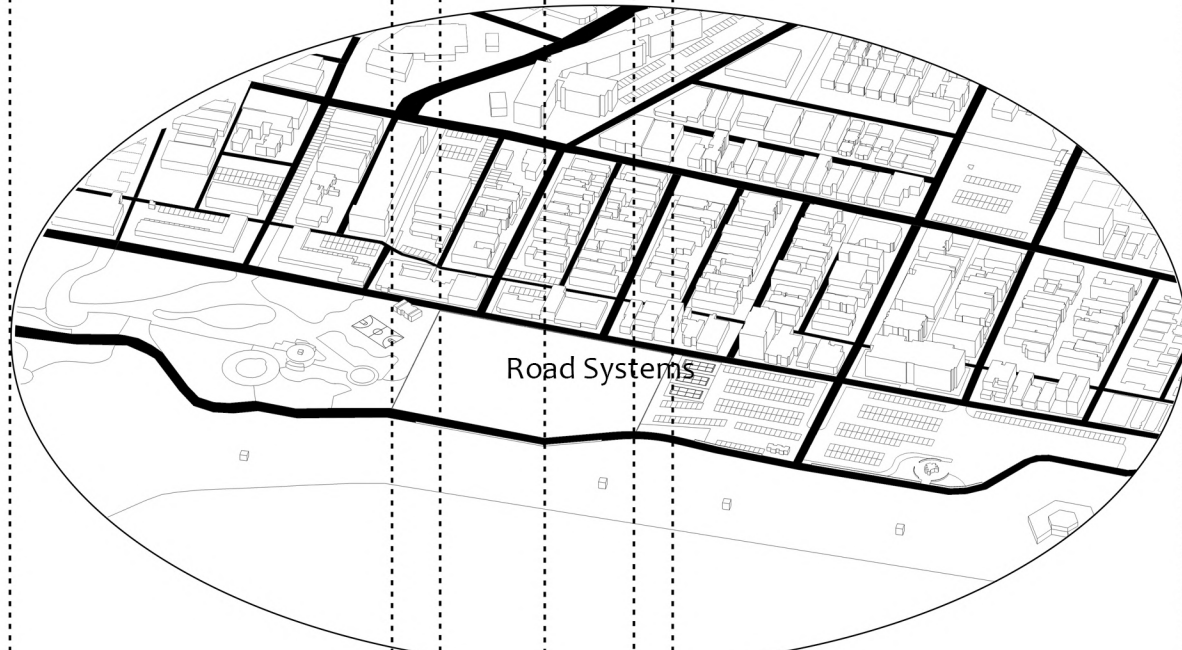
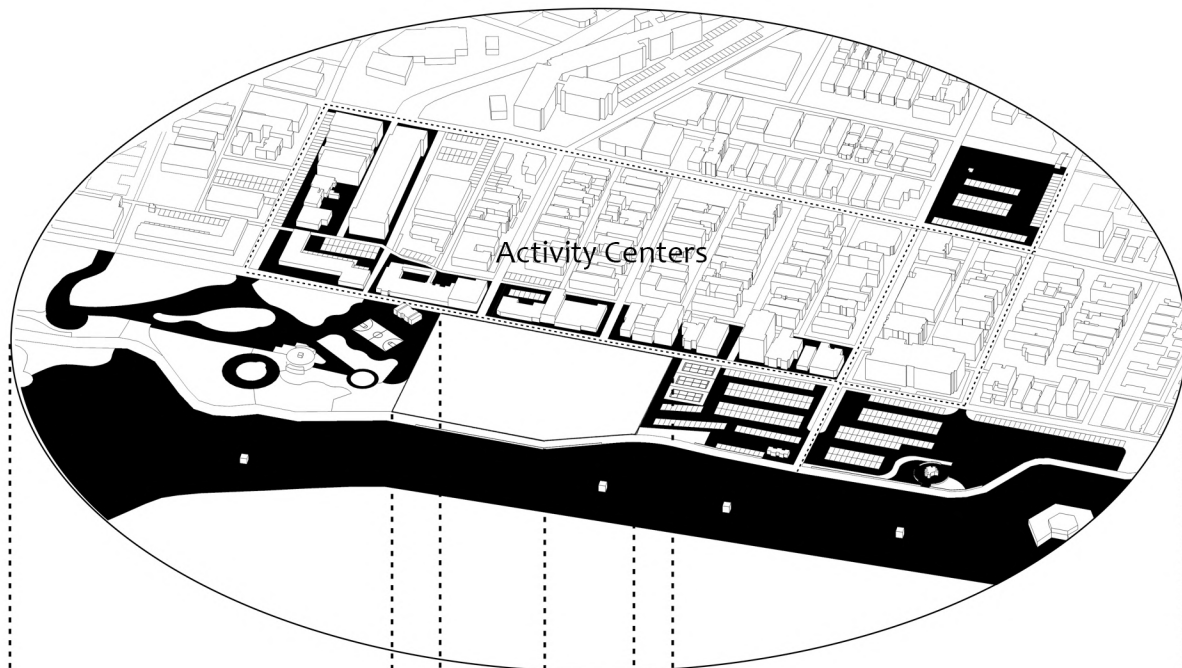
75%



The diagrams on the left show the relational effect of color balance on weightlifting. I have chosen white as the primary color of the gym's architectural space. White will encourage the body to be calm and stable. Red is shown where the color balance is likely to affect the performance of the exercise.

CHAPTER 2 : DIAGRAMS

Analytical graphics of site and building



Children's Playground



Basketball Courts



Tennis Courts



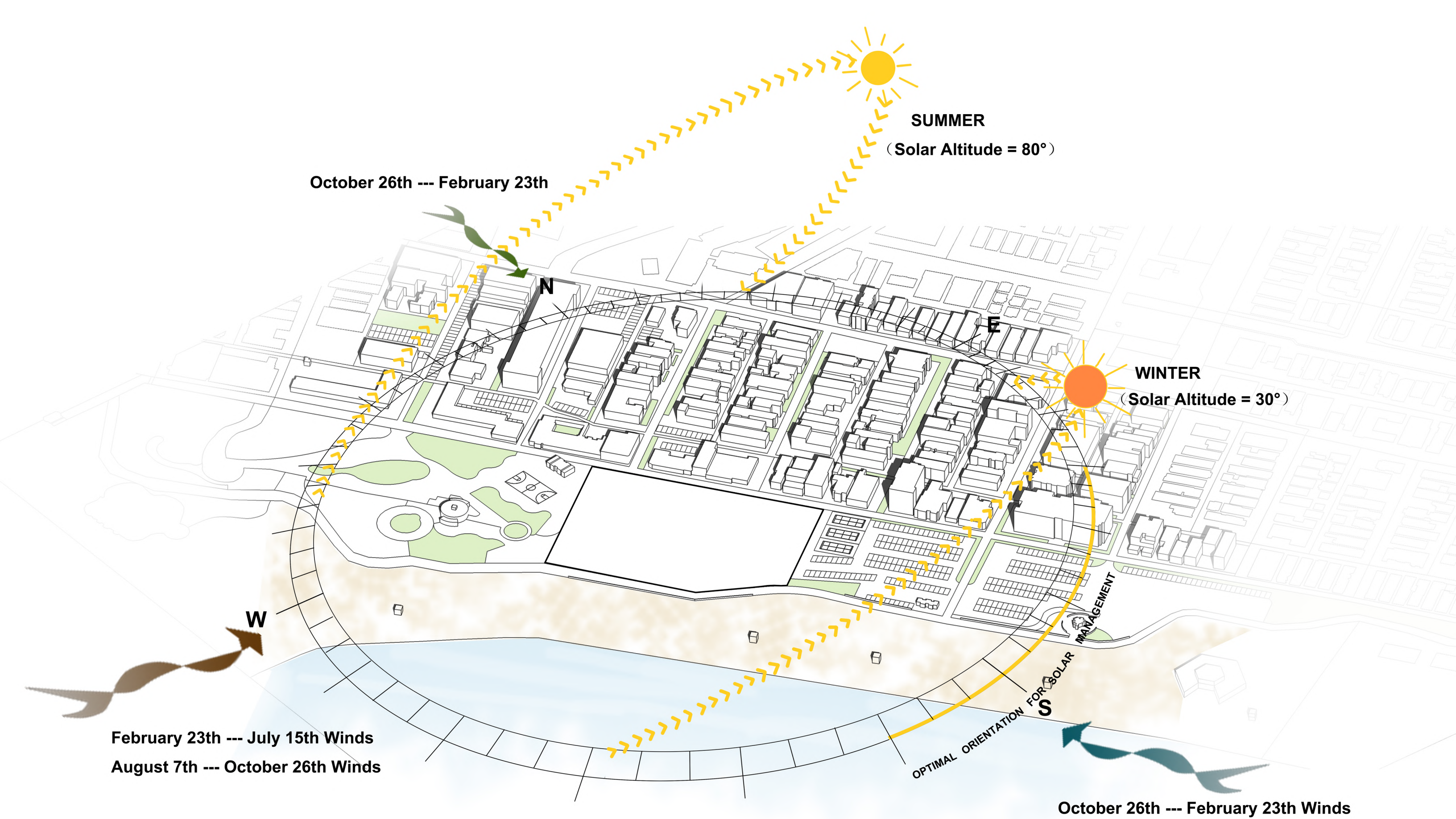
Art Wall

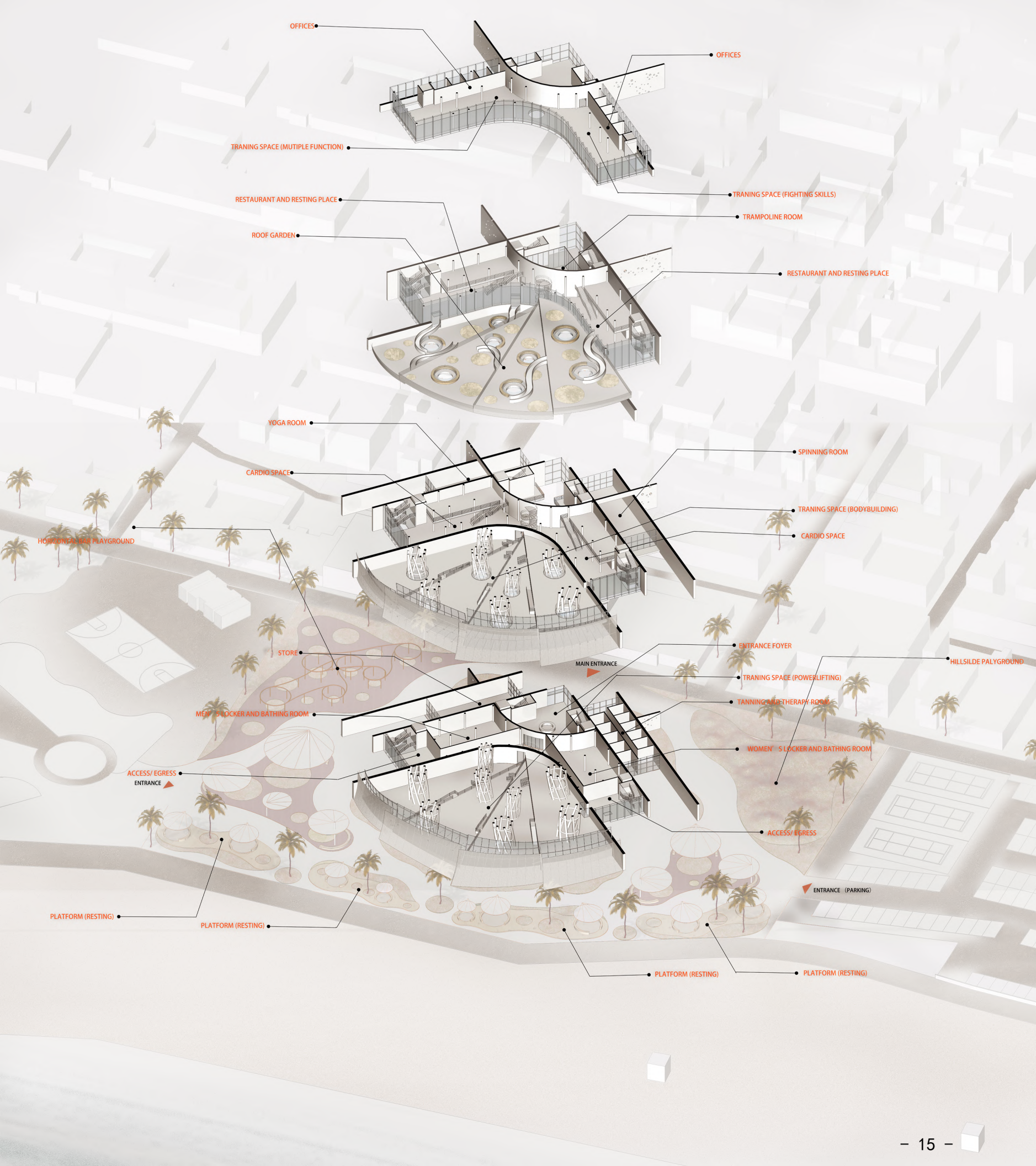


Skate Park

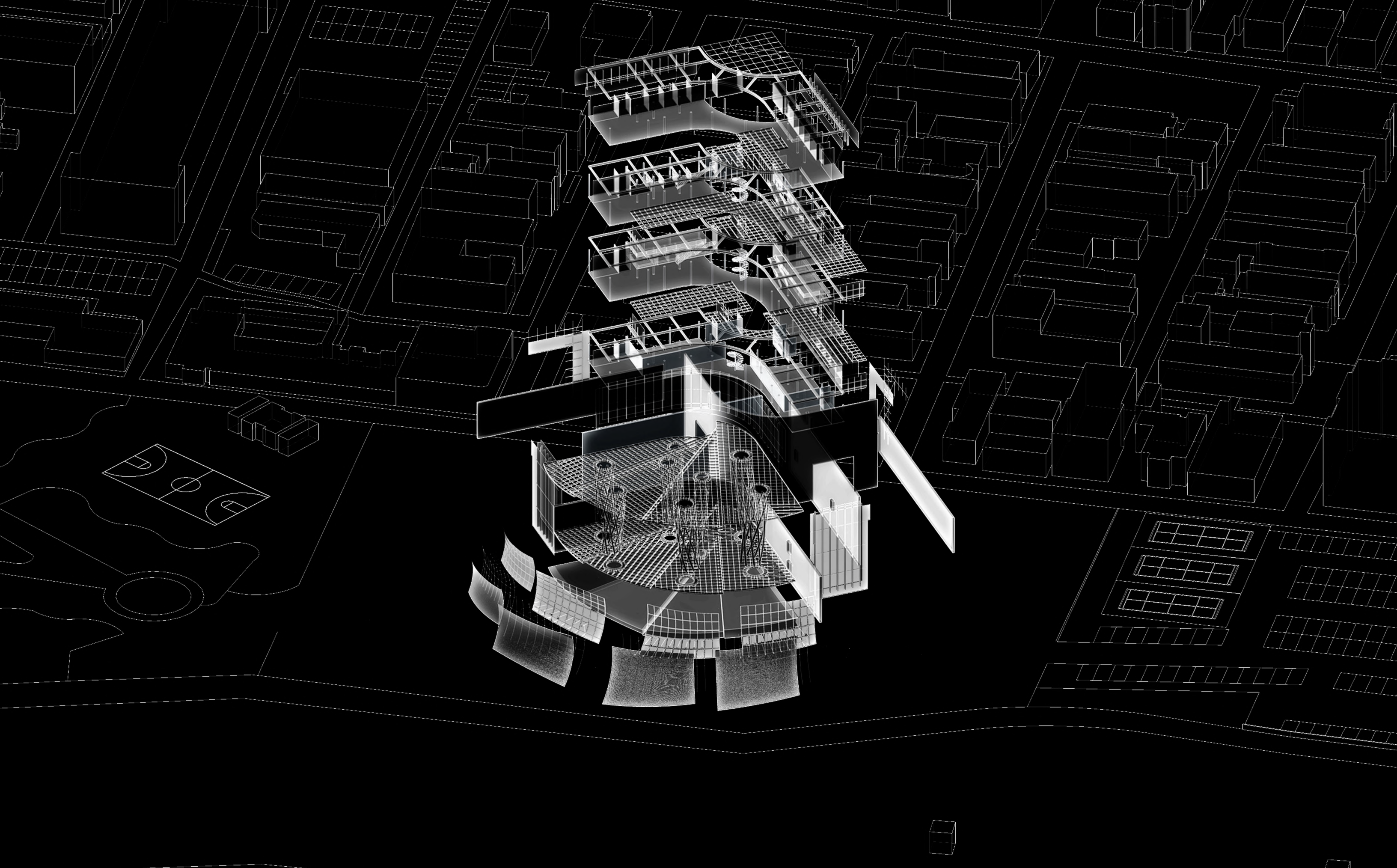


Outdoor Gym



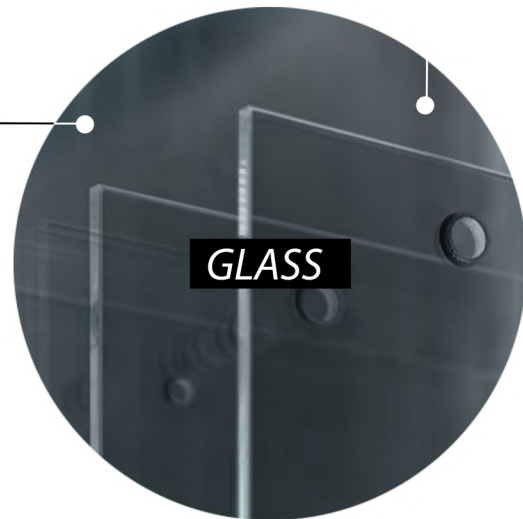
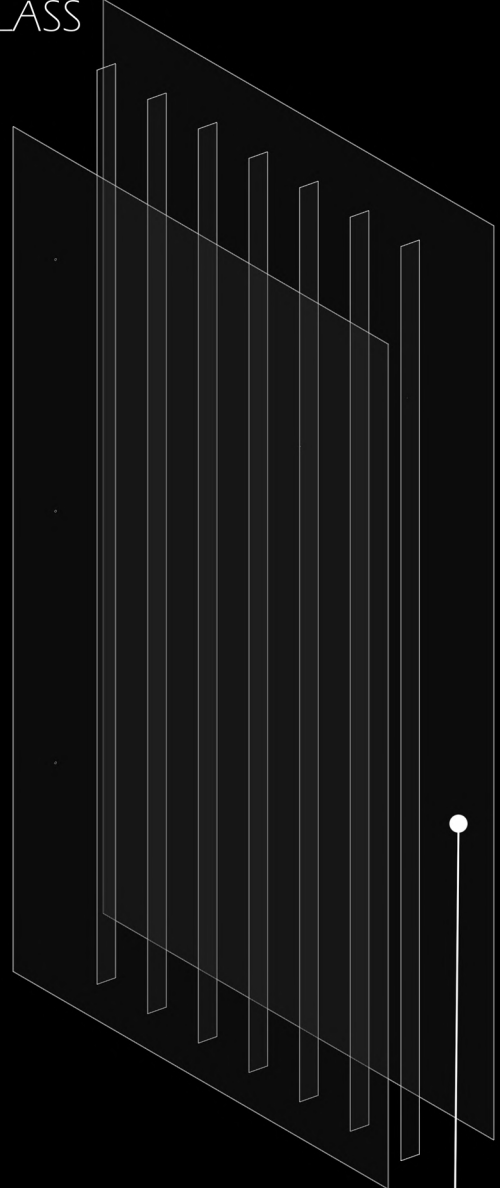
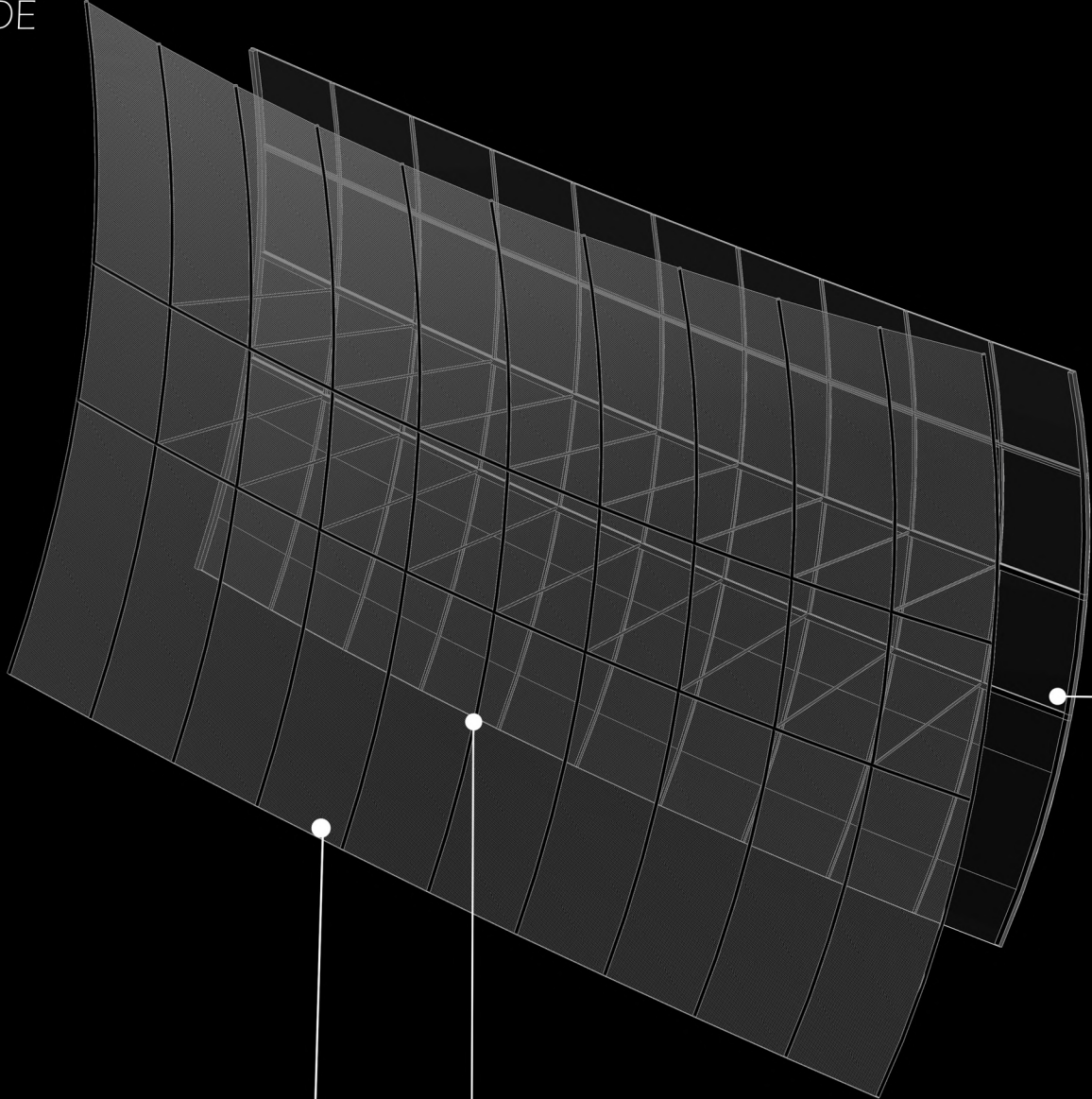


This diagram shows function of every space in the design. (building + site)

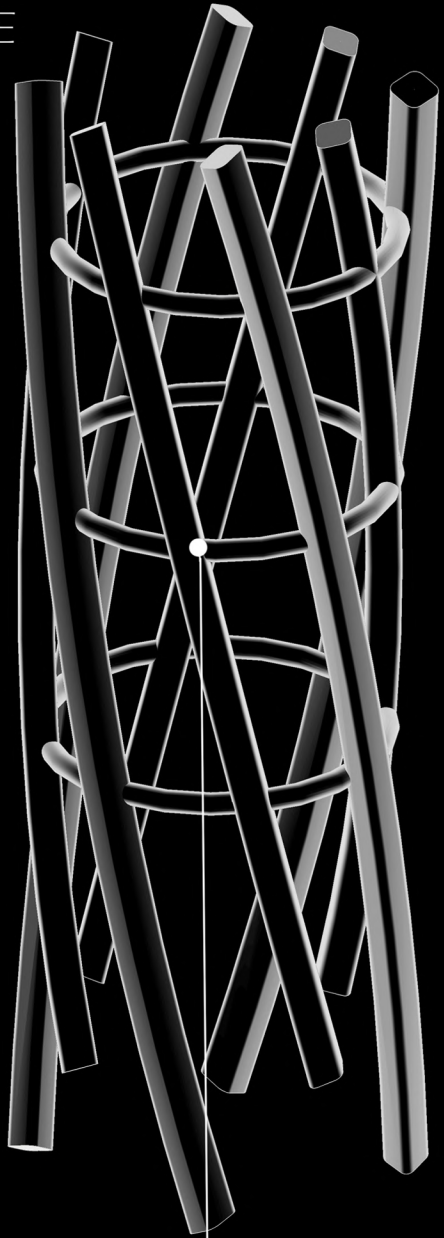


MESH FACADE

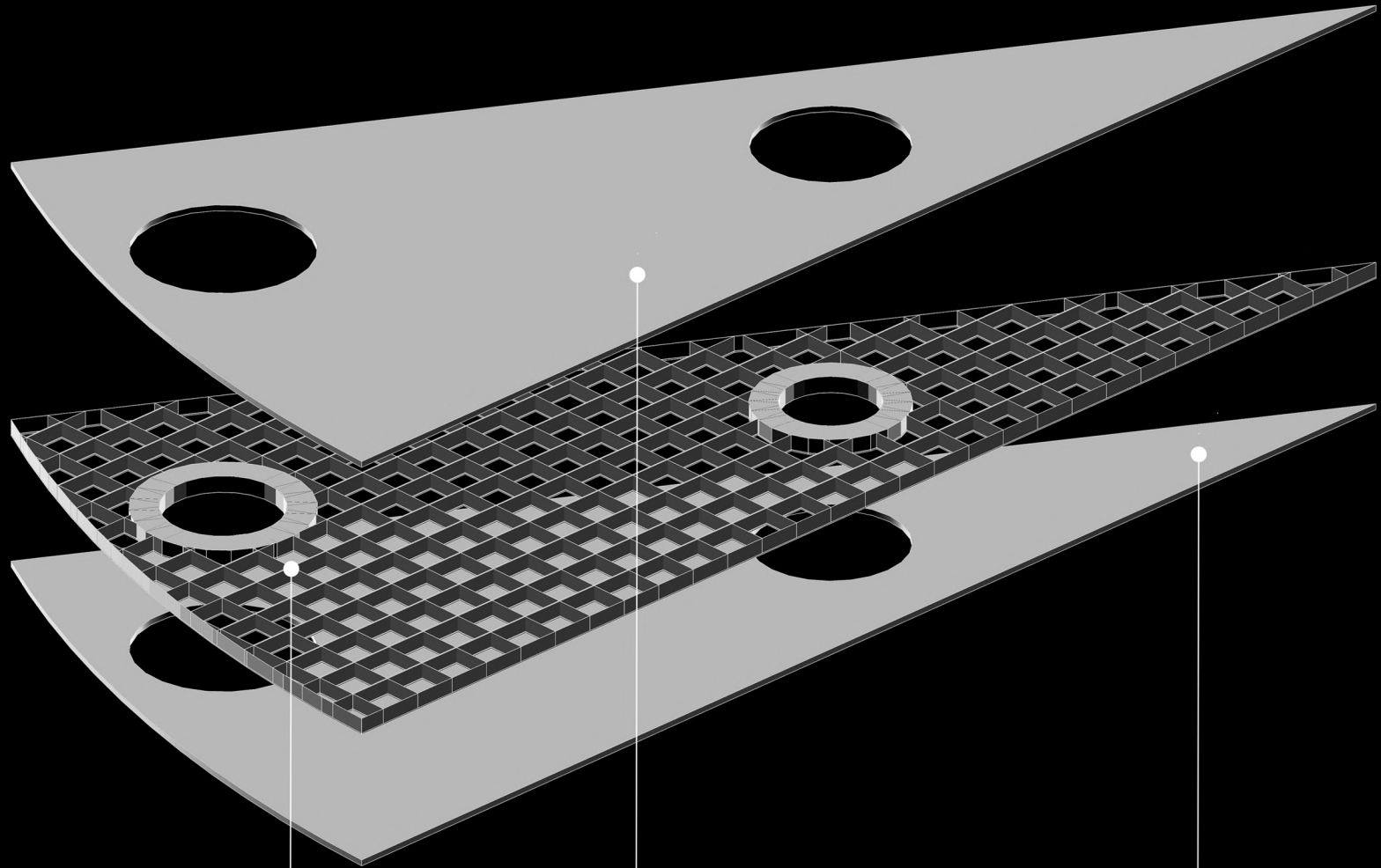
DOUBLE LAYERED STRUCTURAL GLASS



TWISTED STRUCTURE



WAFFLE SLAB STRUCTURE



STEEL



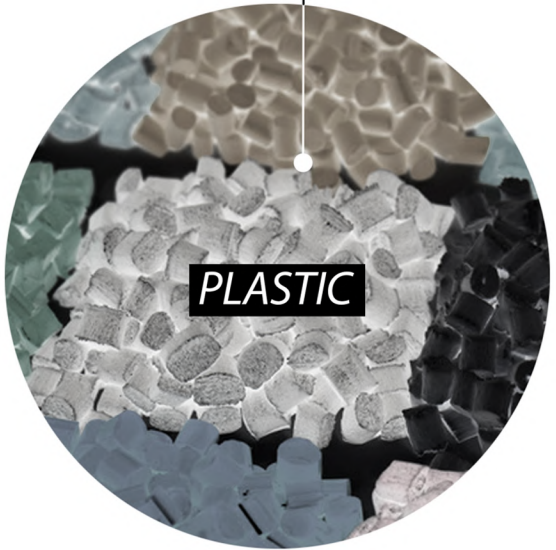
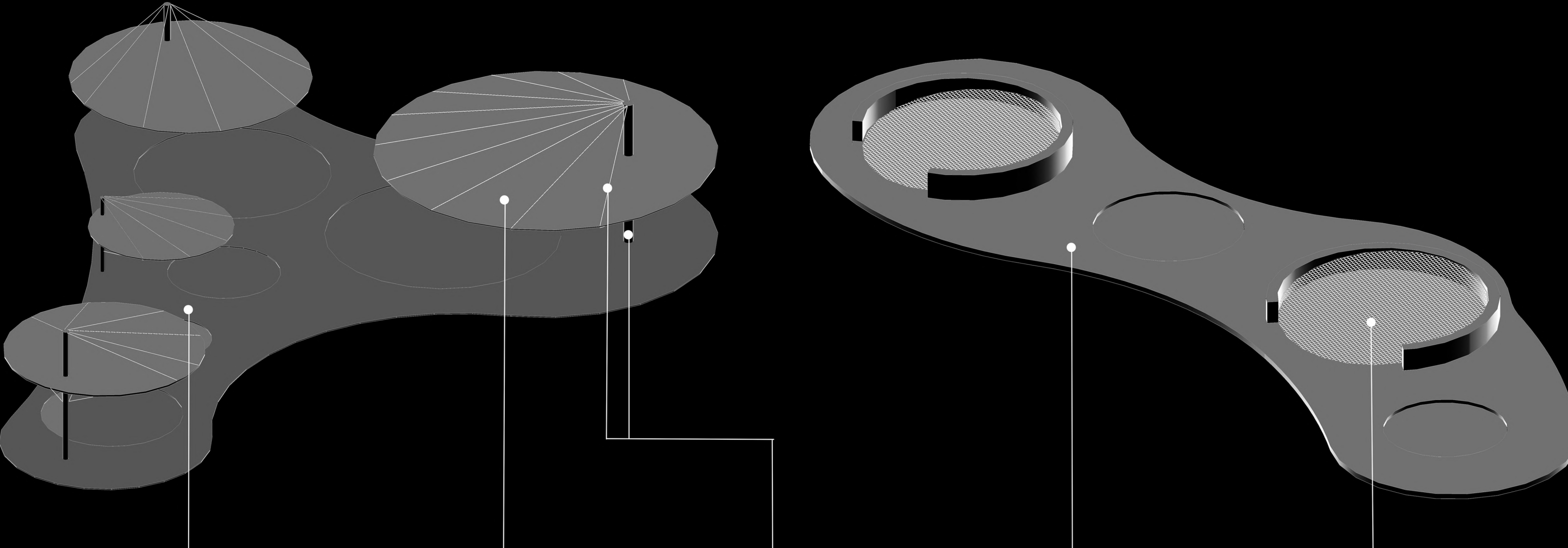
CONCRETE



ACOUSTIC PANEL

SHADING & PLAYGROUND

RESTING PLATFORM



PLASTIC



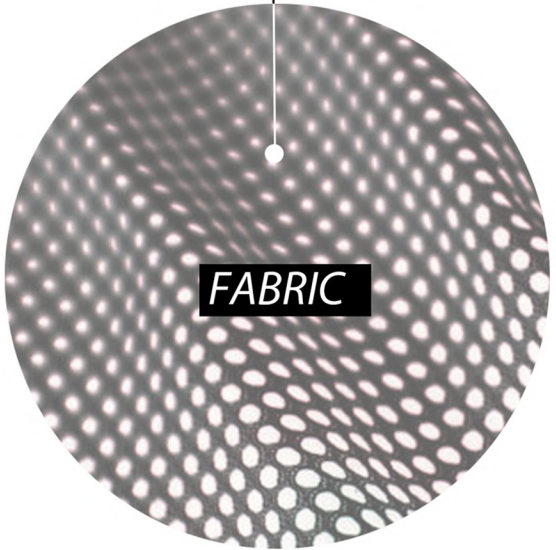
ACRYLIC



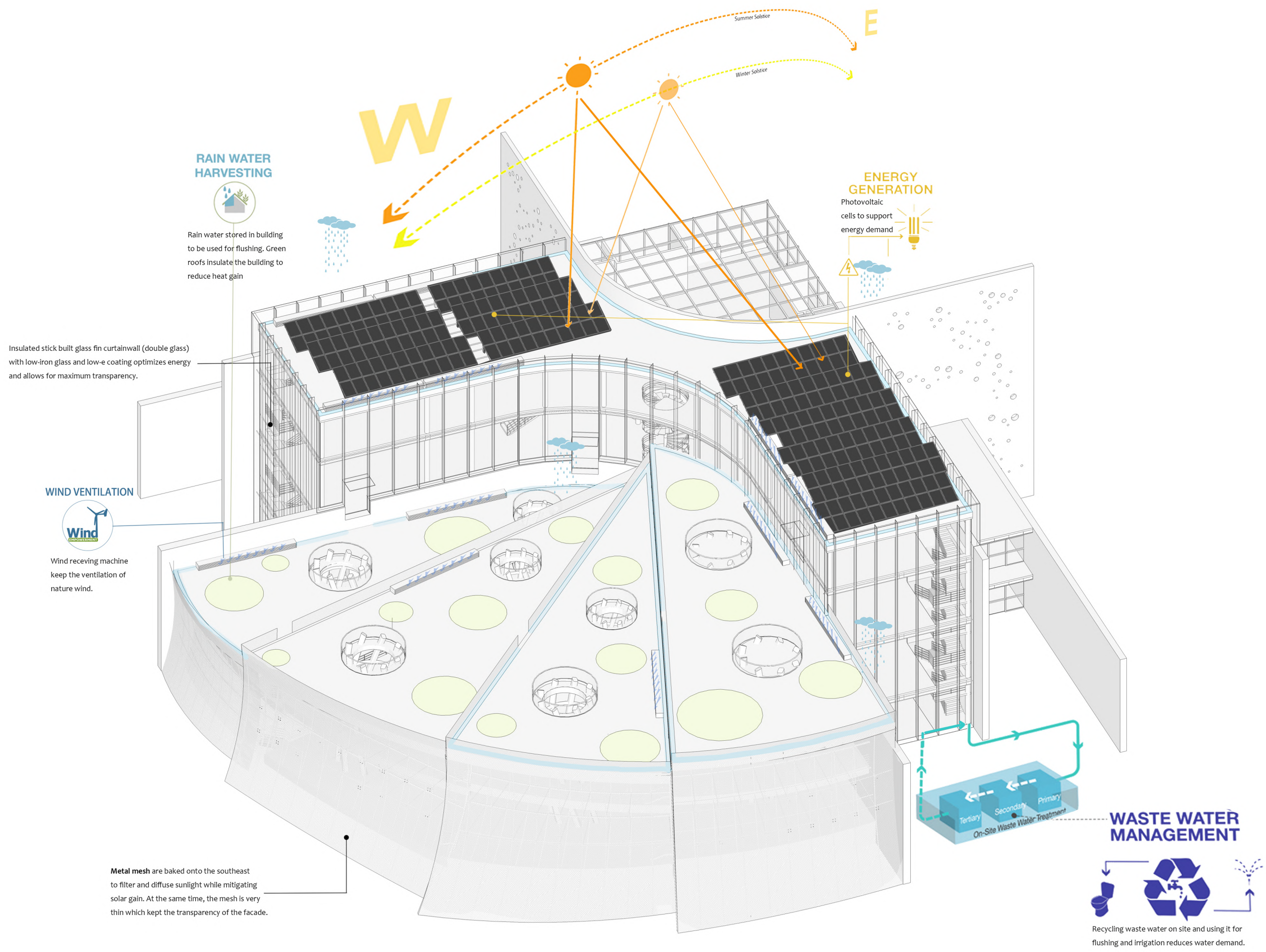
STEEL



WOOD



FABRIC



RAIN WATER HARVESTING

Rain water stored in building to be used for flushing. Green roofs insulate the building to reduce heat gain

ENERGY GENERATION

Photovoltaic cells to support energy demand

Insulated stick built glass fin curtainwall (double glass) with low-iron glass and low-e coating optimizes energy and allows for maximum transparency.

WIND VENTILATION



Wind receiving machine keep the ventilation of nature wind.

Metal mesh are baked onto the southeast to filter and diffuse sunlight while mitigating solar gain. At the same time, the mesh is very thin which kept the transparency of the facade.



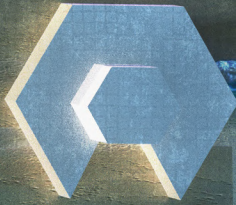
WASTE WATER MANAGEMENT

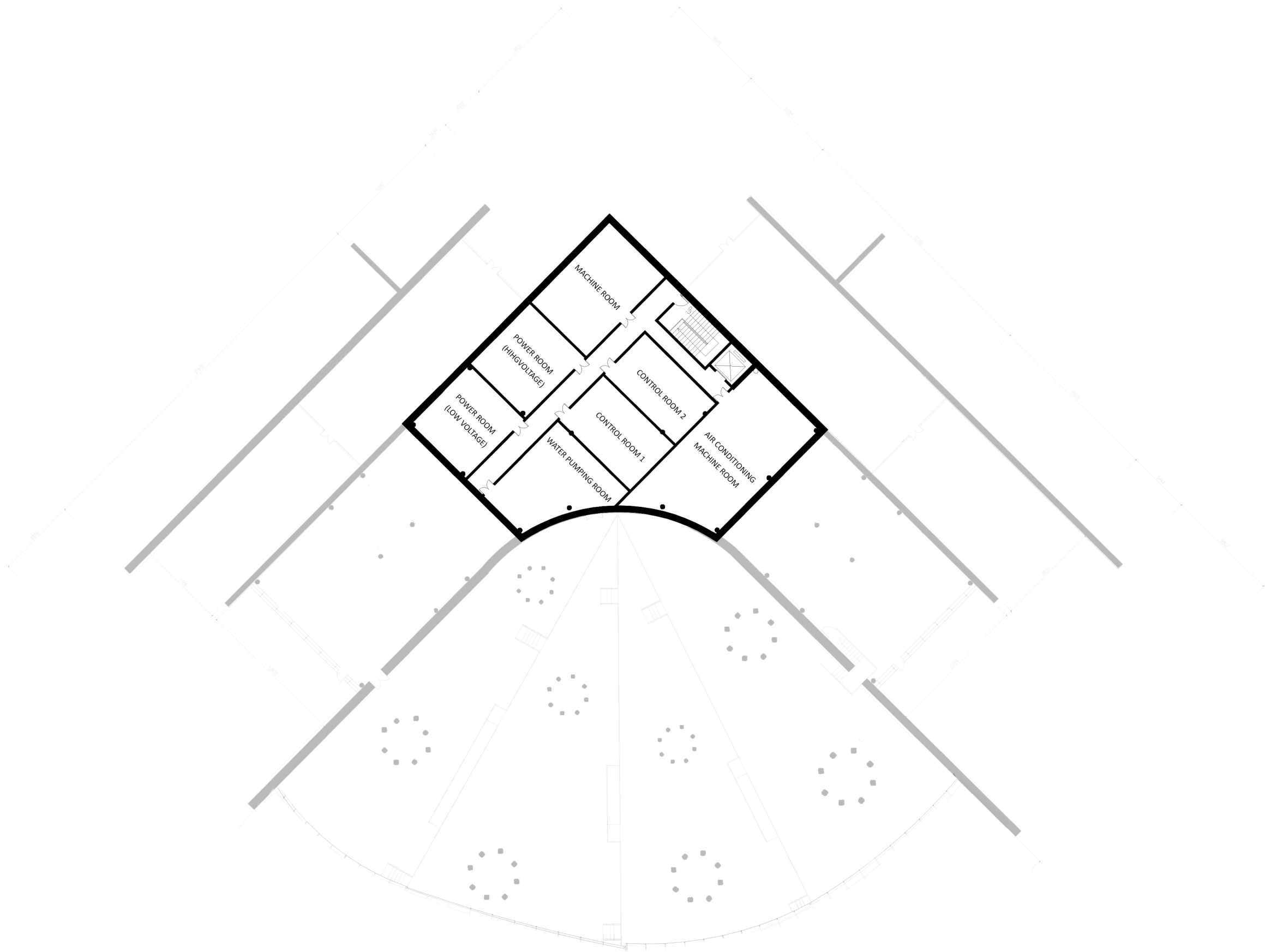


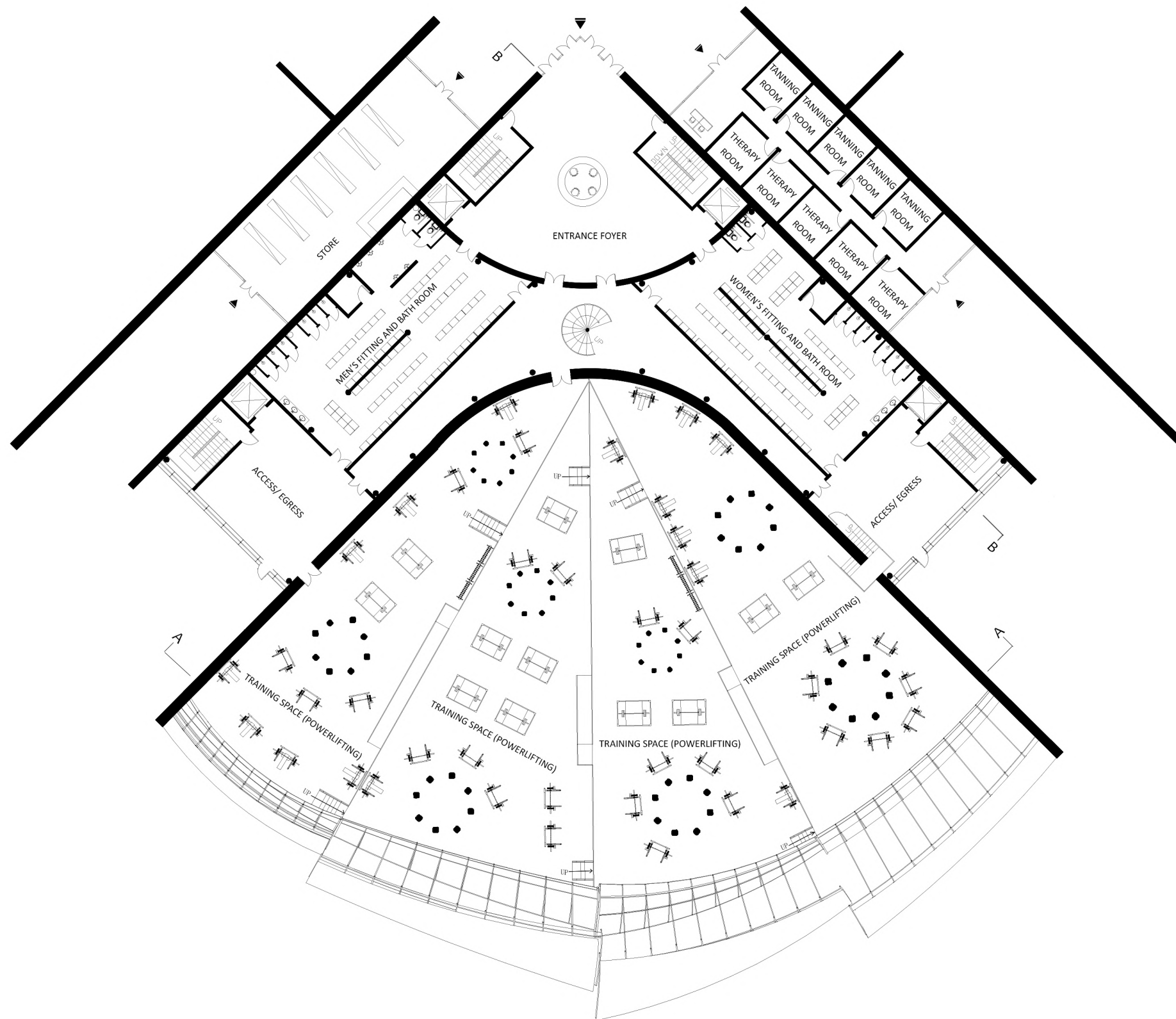
Recycling waste water on site and using it for flushing and irrigation reduces water demand.

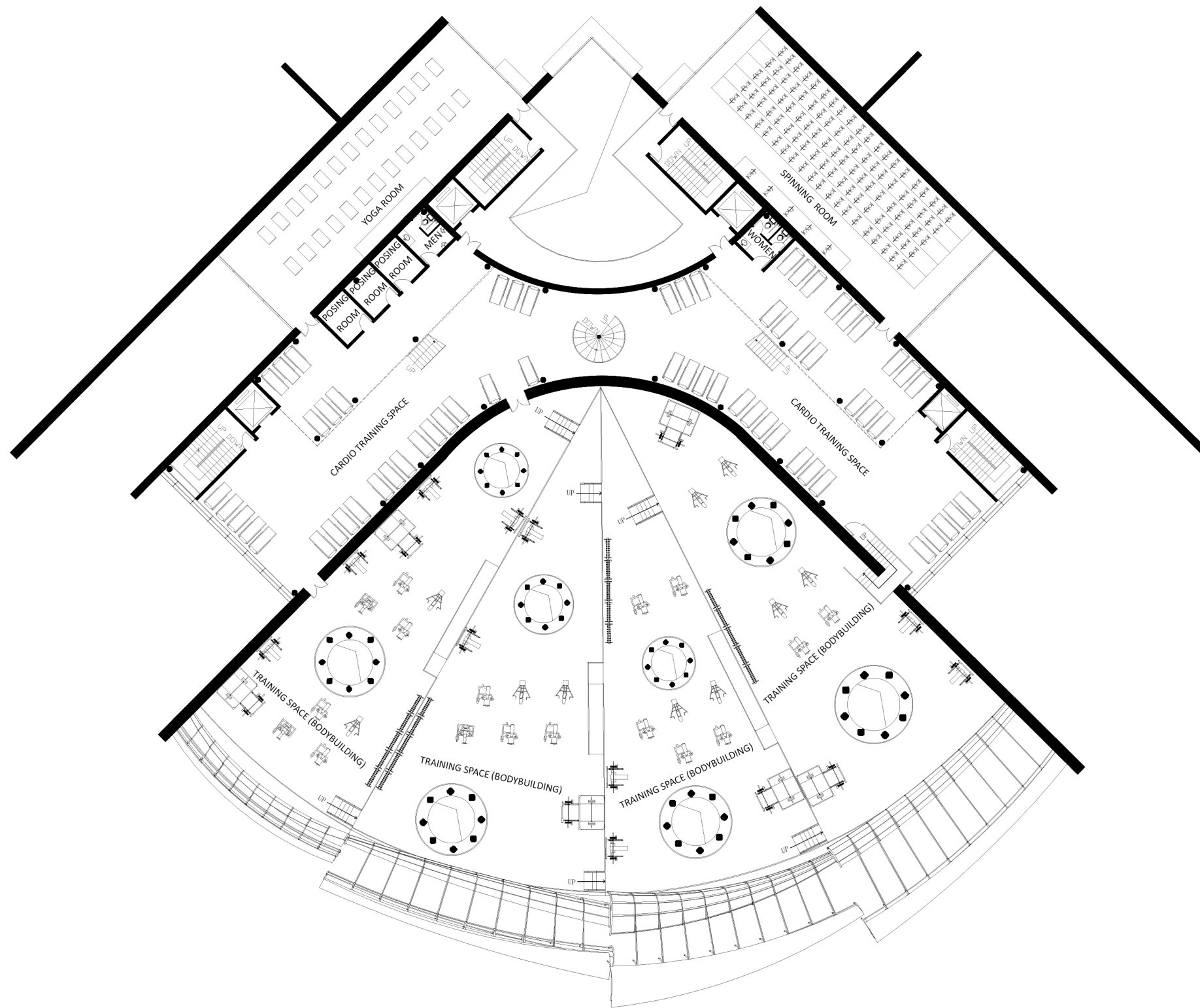
CHAPTER 3 : ARCHITECTURAL DRAWINGS

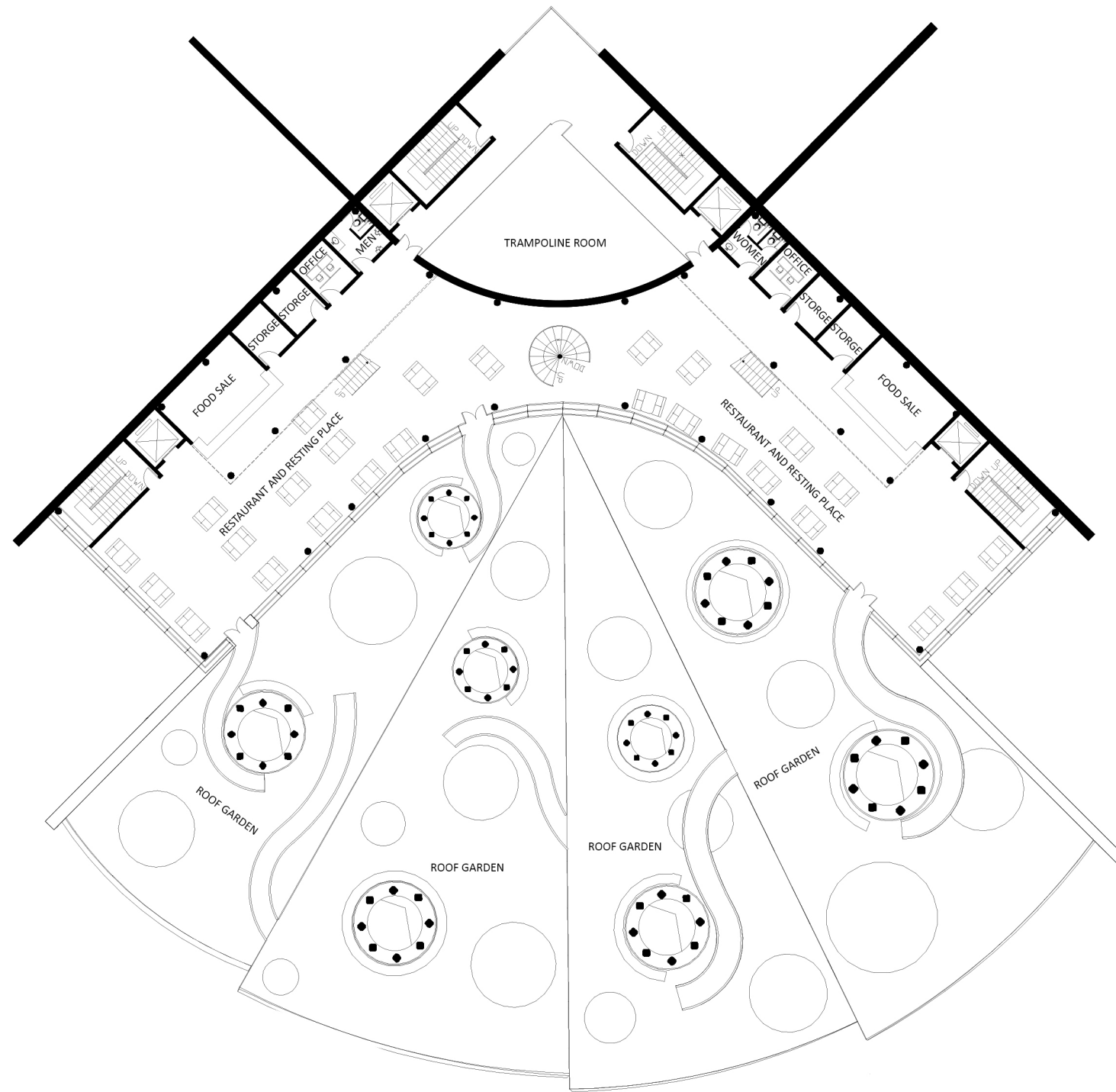
Site plan, floor plans, elevation and sections of the project

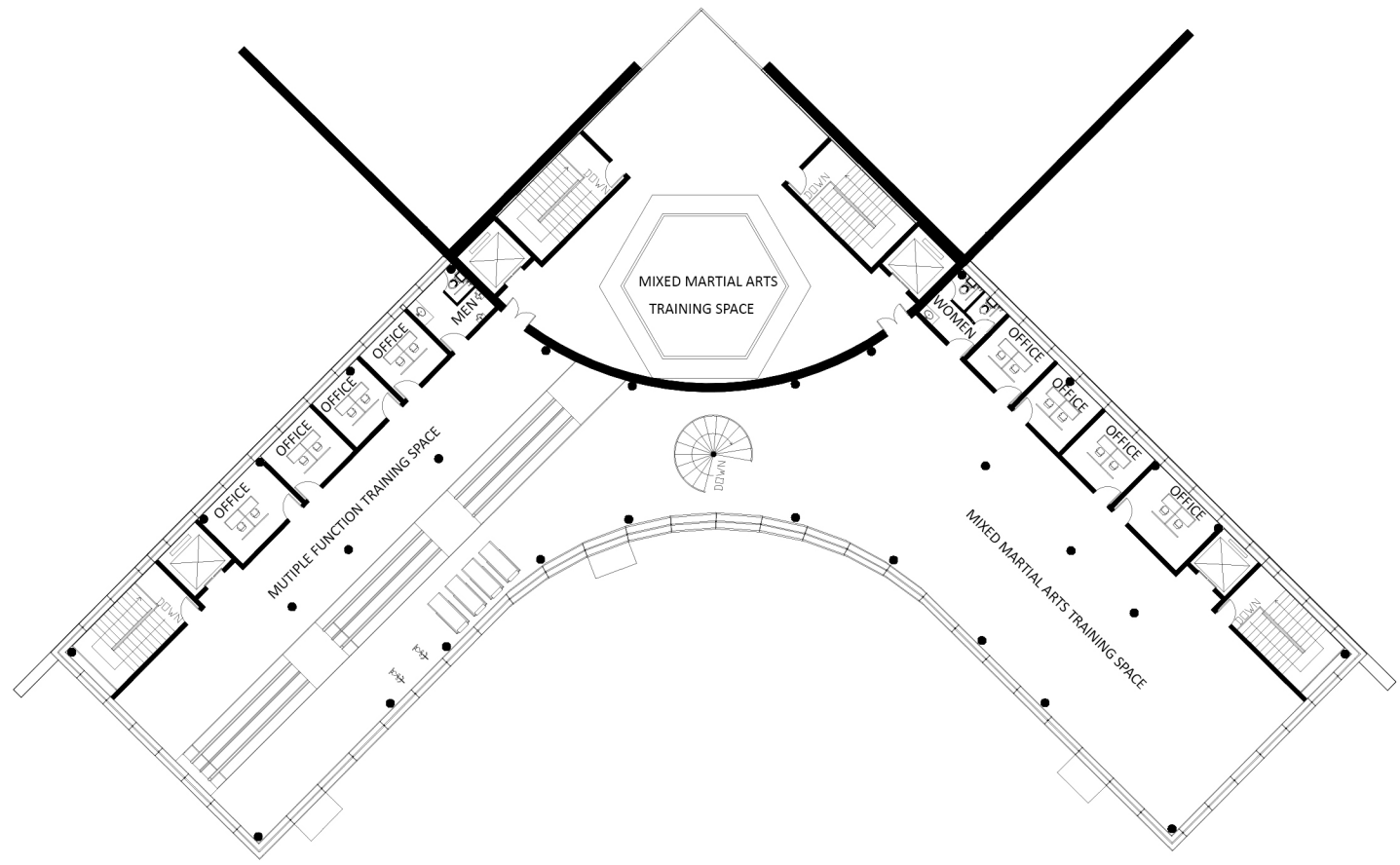


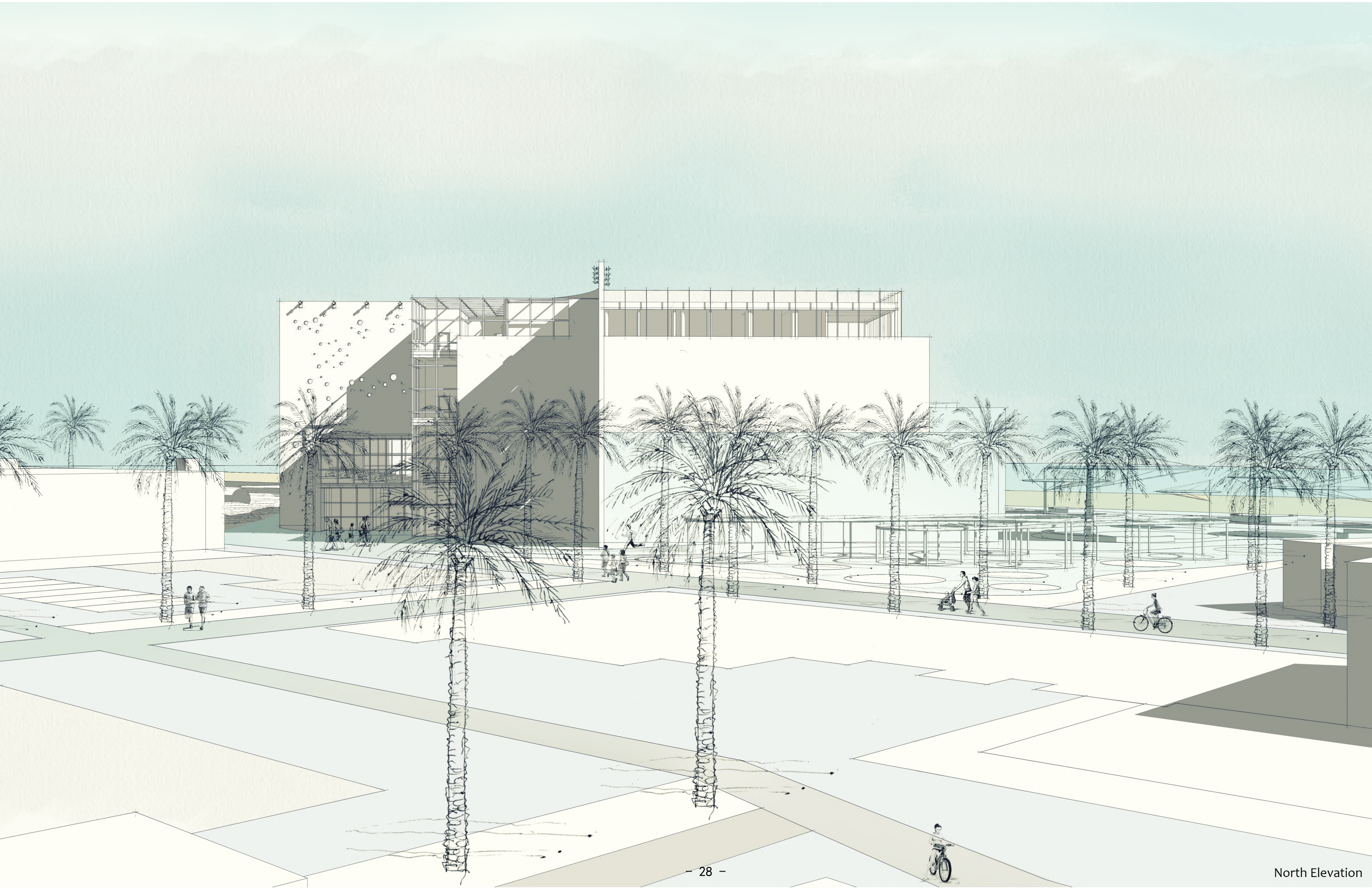


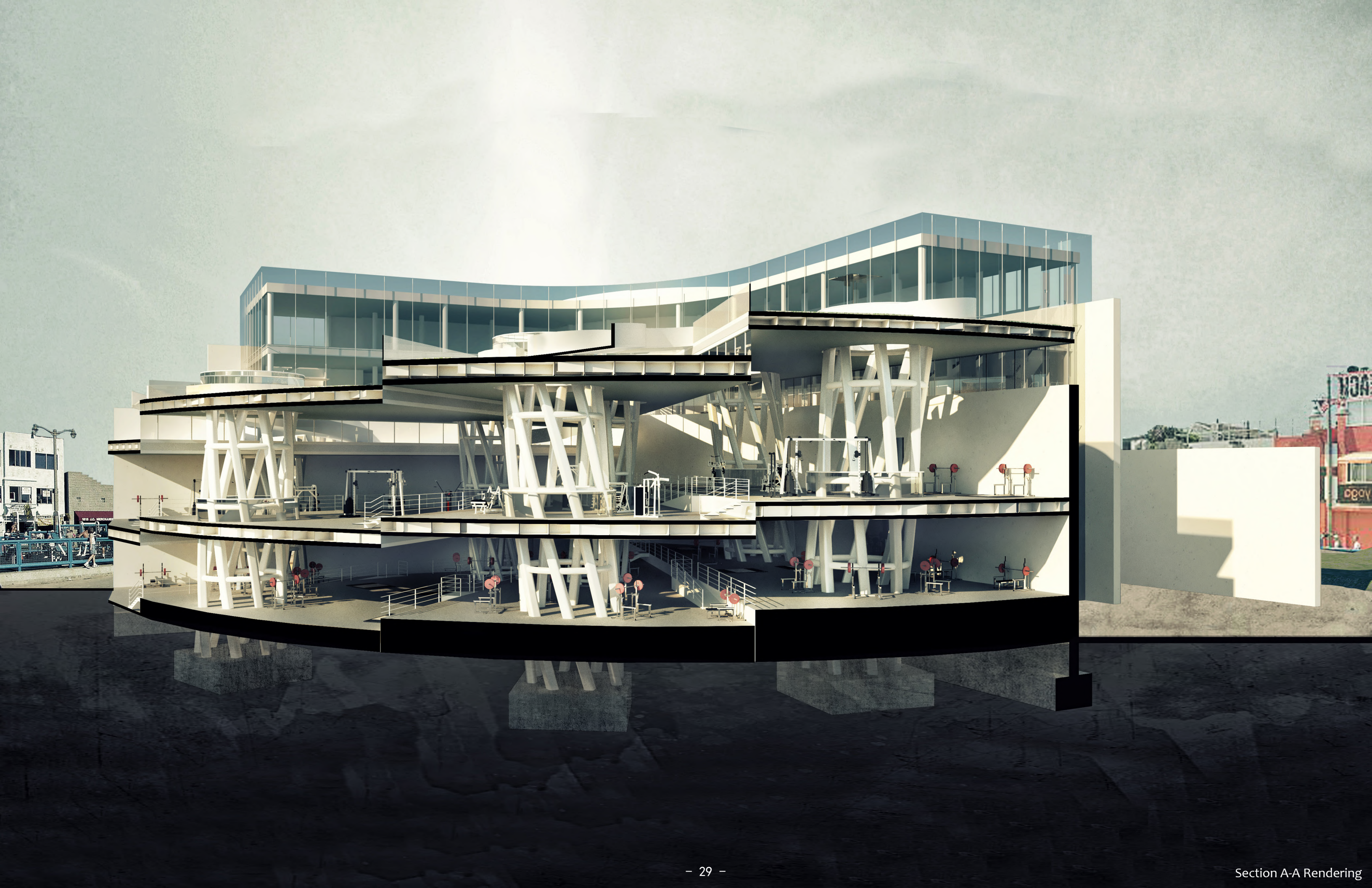


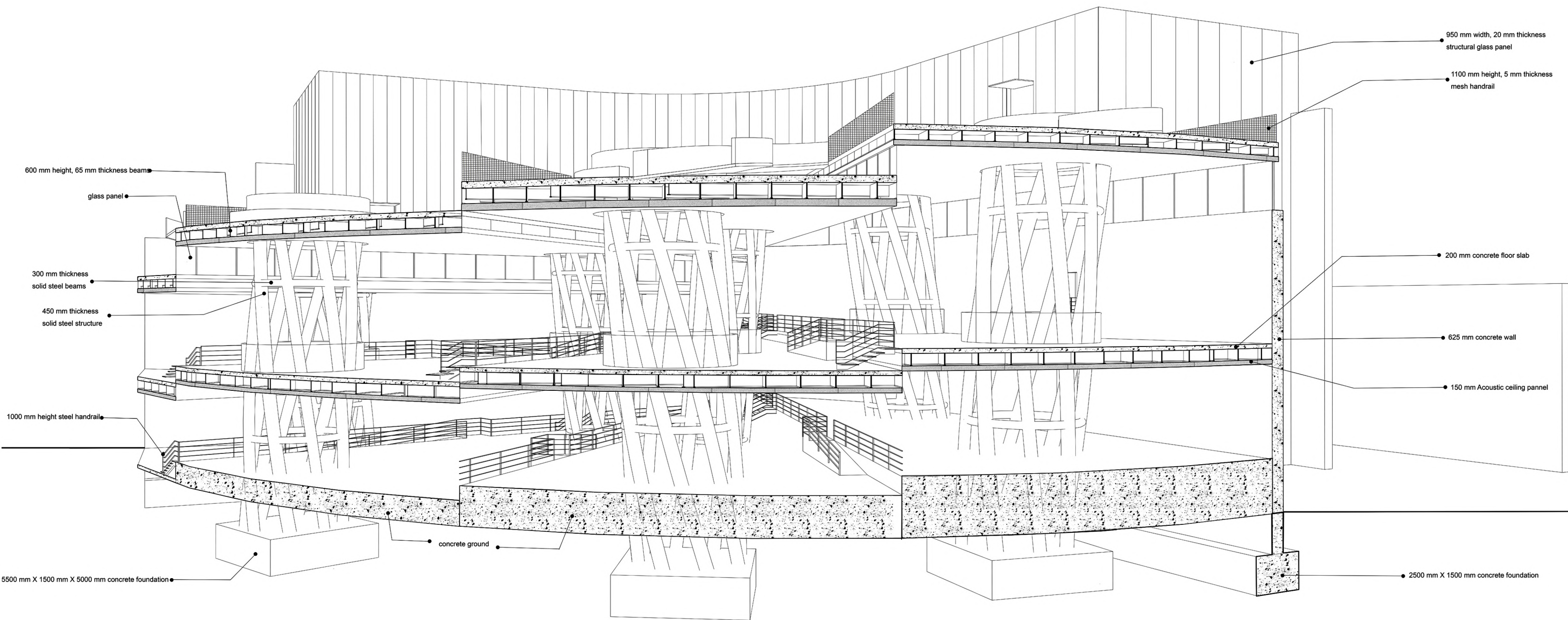












600 mm height, 65 mm thickness beams

glass panel

300 mm thickness solid steel beams

450 mm thickness solid steel structure

1000 mm height steel handrail

5500 mm X 1500 mm X 5000 mm concrete foundation

concrete ground

950 mm width, 20 mm thickness structural glass panel

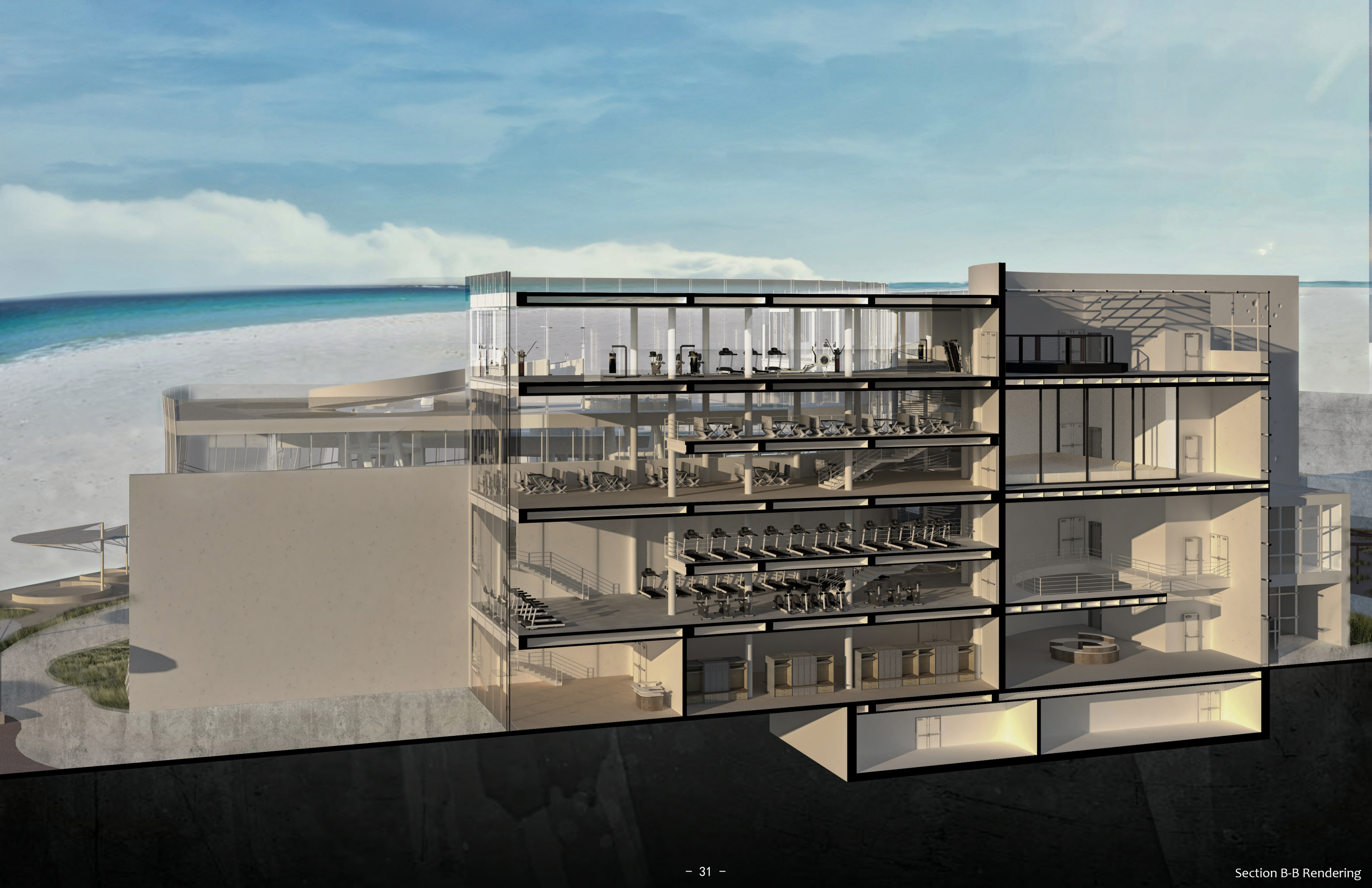
1100 mm height, 5 mm thickness mesh handrail

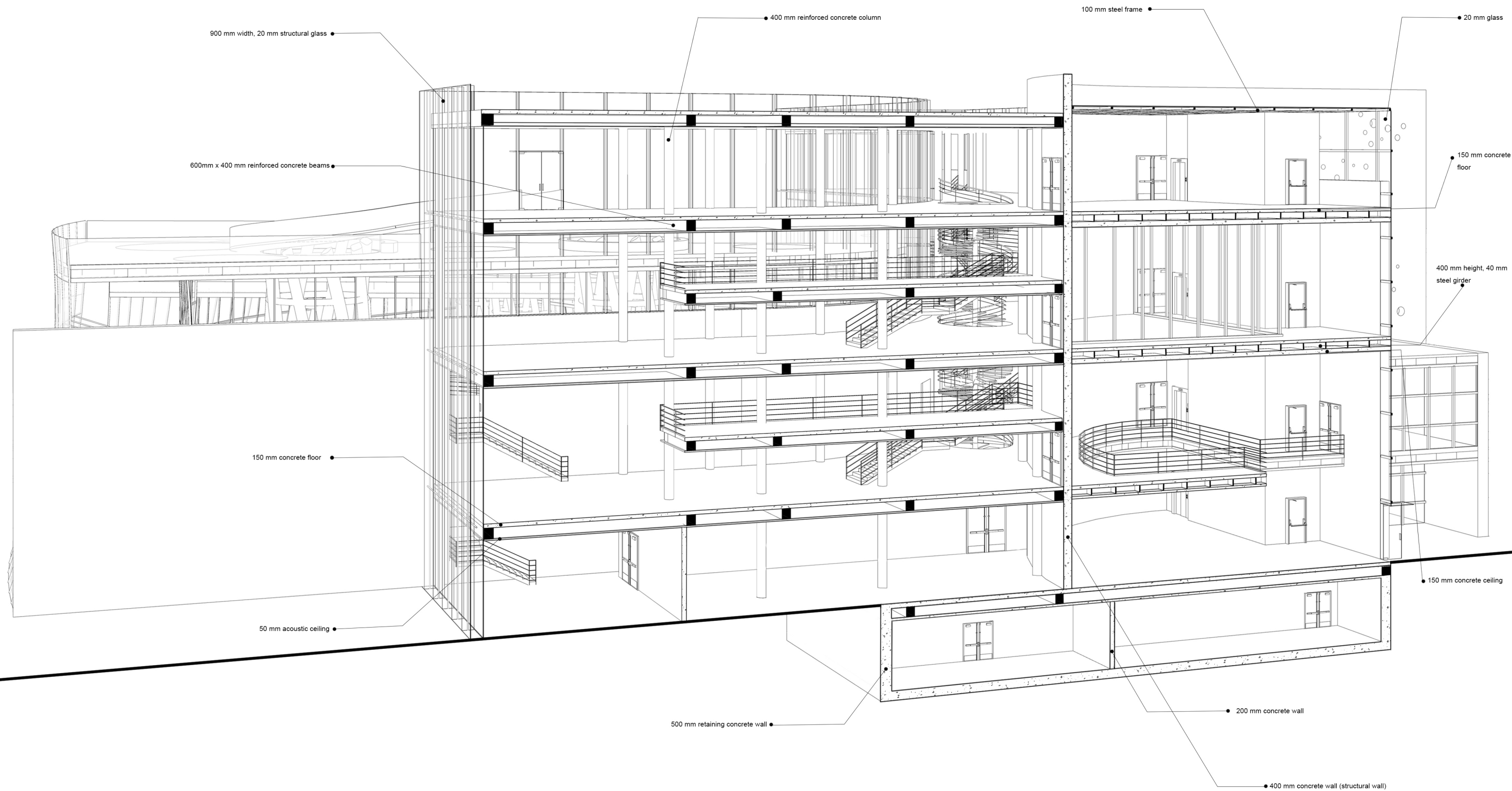
200 mm concrete floor slab

625 mm concrete wall

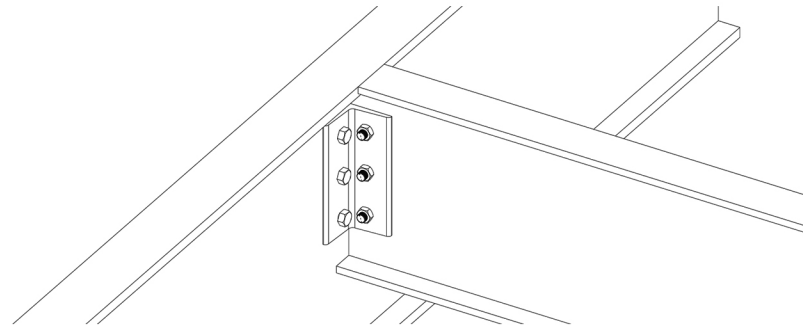
150 mm Acoustic ceiling pannel

2500 mm X 1500 mm concrete foundation



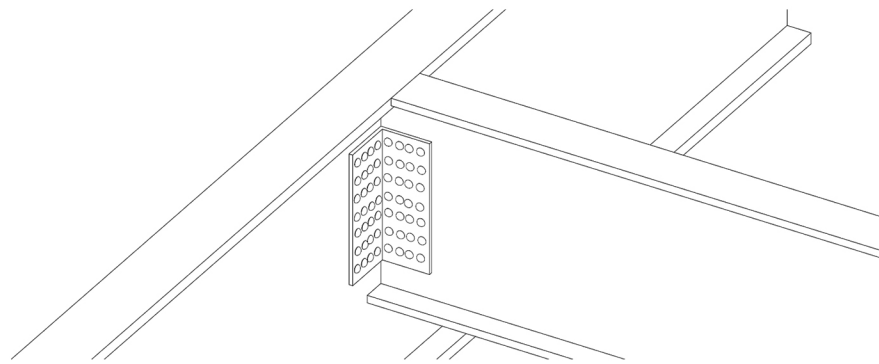


CHAPTER 4 : CONSTRUCTION DETAILS



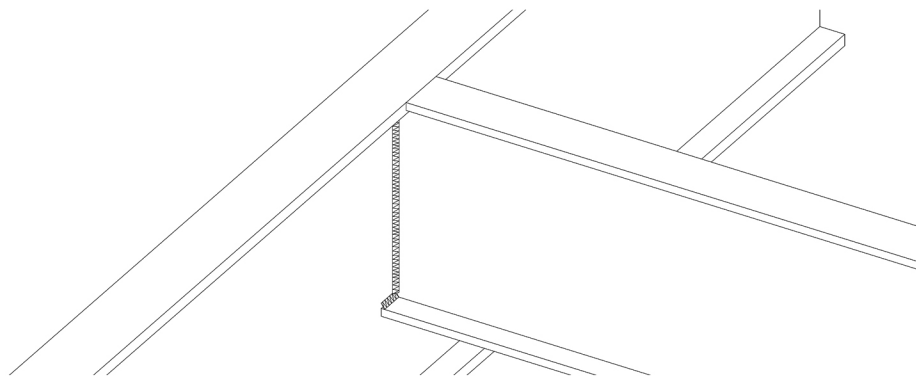
BOLTED

Bolted connections are mostly used in buildings and bridges. They have excellent mechanical properties under shearing forces and axial forces. From an aesthetic perspective, it is acceptable. They are the easiest connections to check for quality and replacement. Thus, they can be applied in steel beams and girder connections.



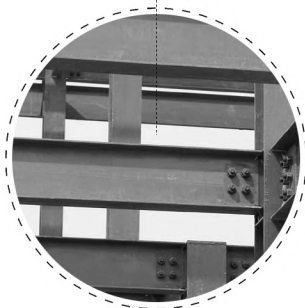
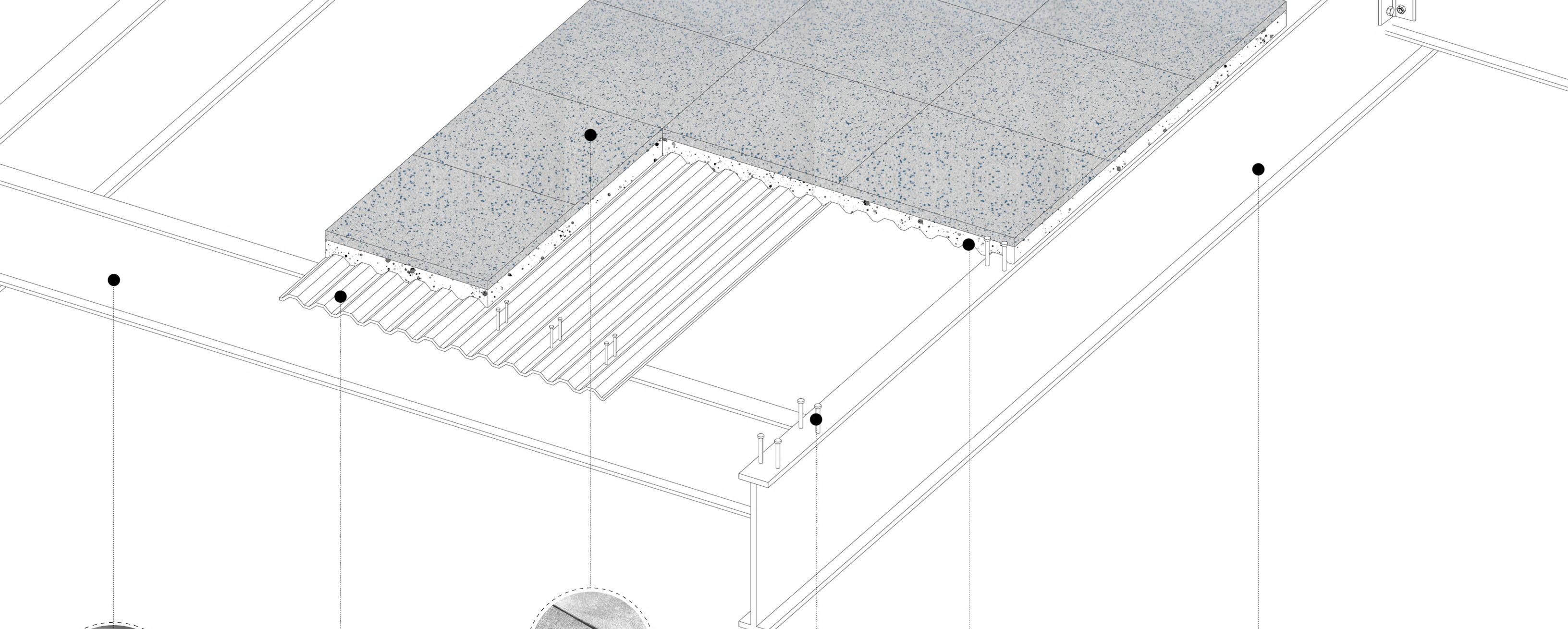
RIVETED

Riveted connections were popular in the period of World War 2. Their mechanical properties are positive under shearing force and axial force. However, they are not as good as bolted connections, because they are prone to stress fractures.

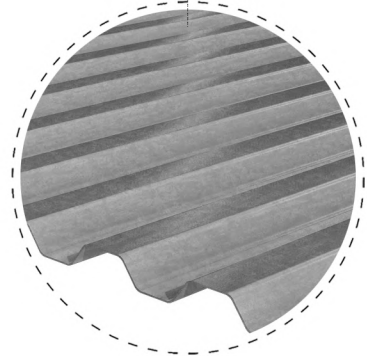


WELDED

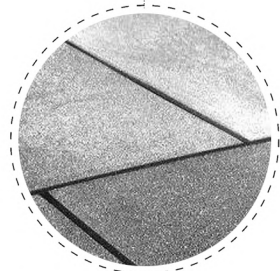
Welded connections are mostly applied in shipbuilding. They are also used in buildings. They are more aesthetically pleasing than steel connections. It is easy to change material properties under chemical transformations. This will lead to stress deformation. It is a serious problem in the connection of airplane surfaces. However, they can be acceptable in bridge and building construction. Thus, I decided to use this connection in the spinal structure.



Beam



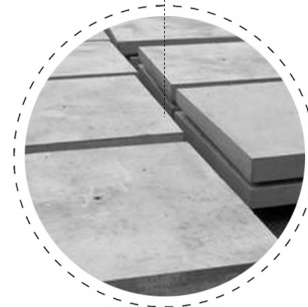
Steel Decking



Rubber Flooring



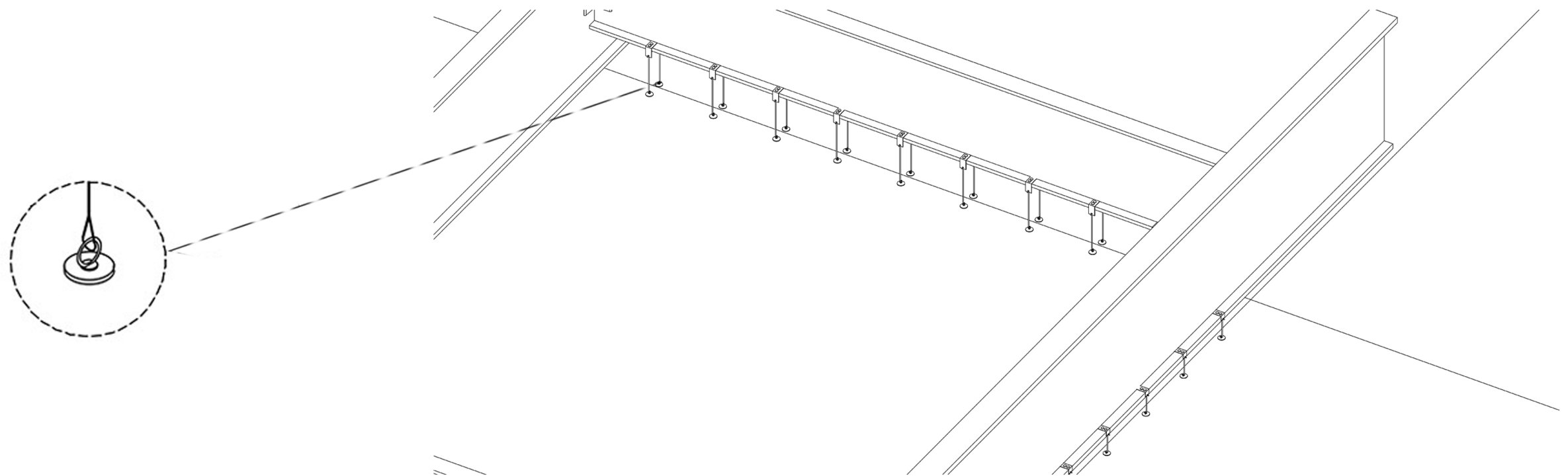
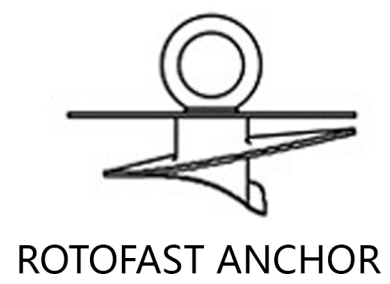
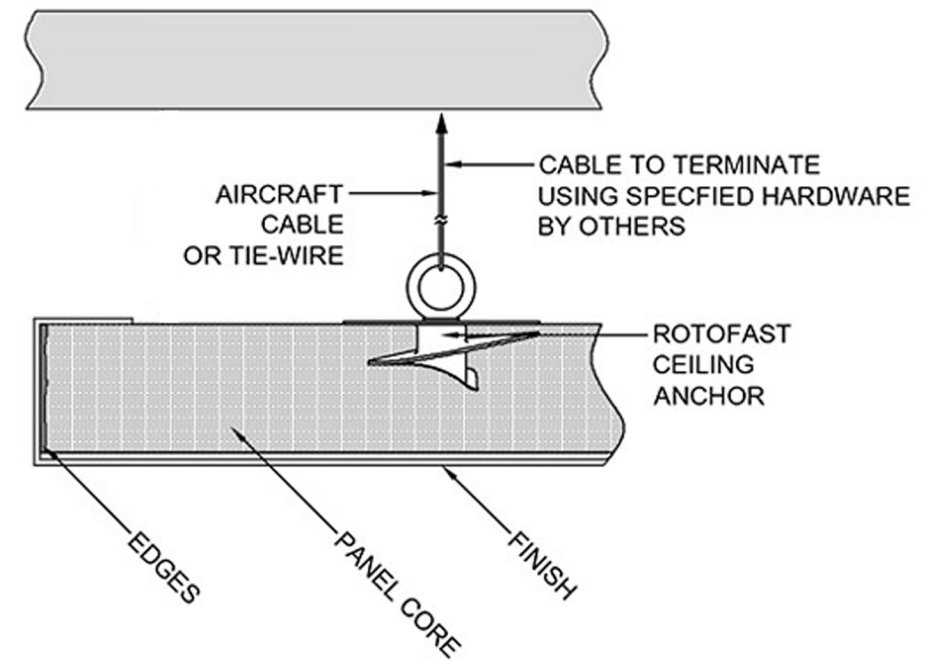
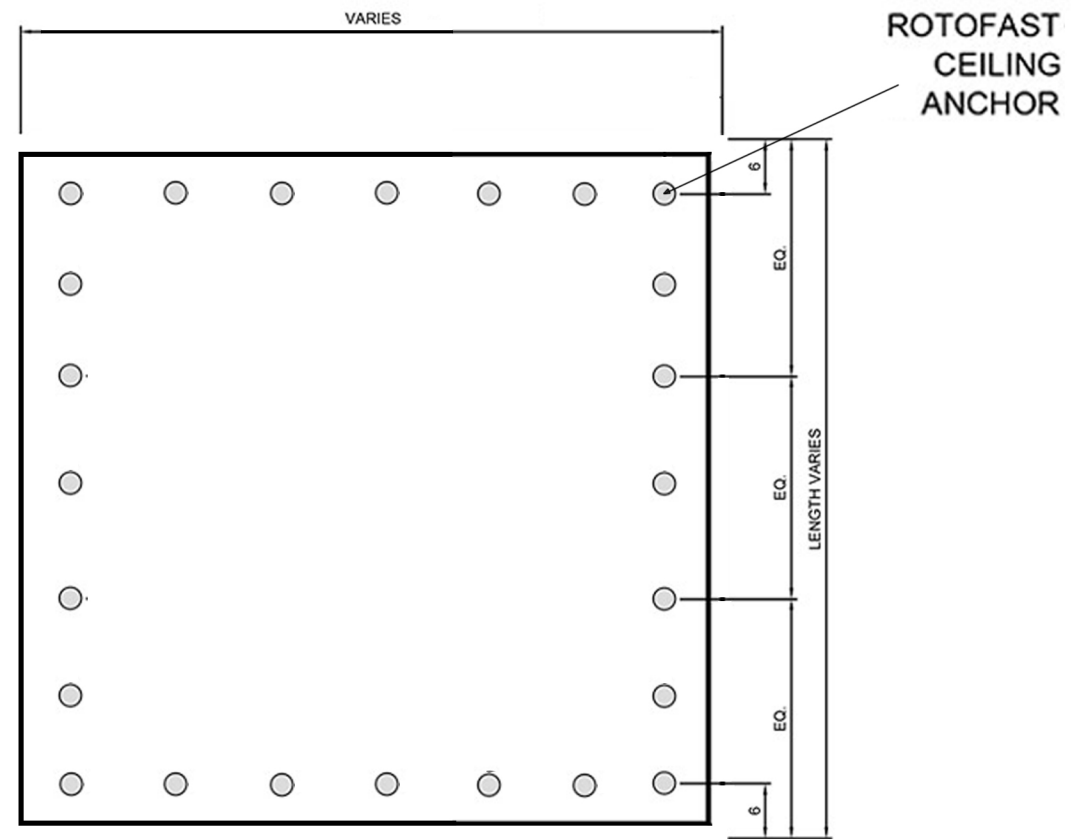
Stud Shear Connector

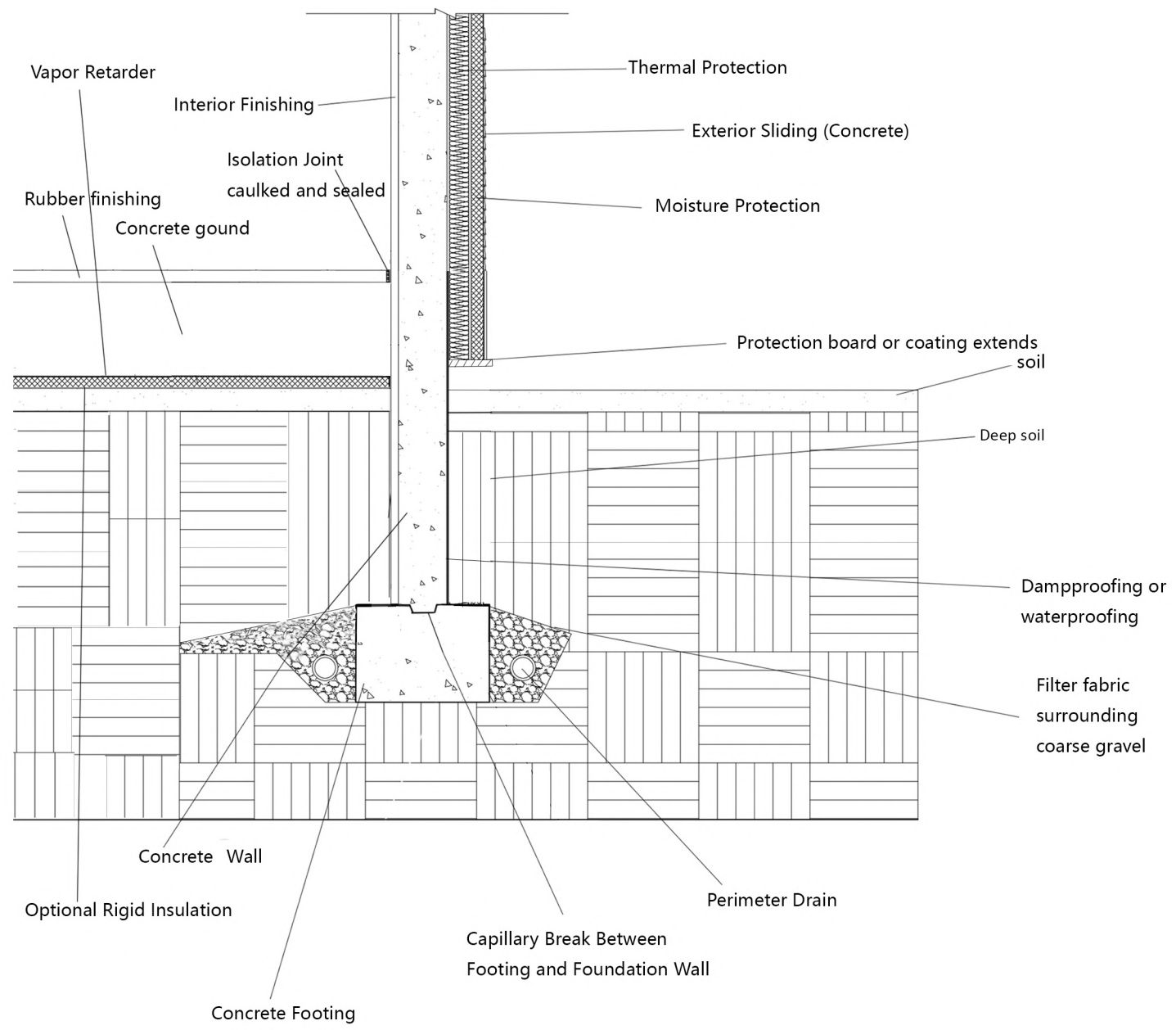


Concrete Slab

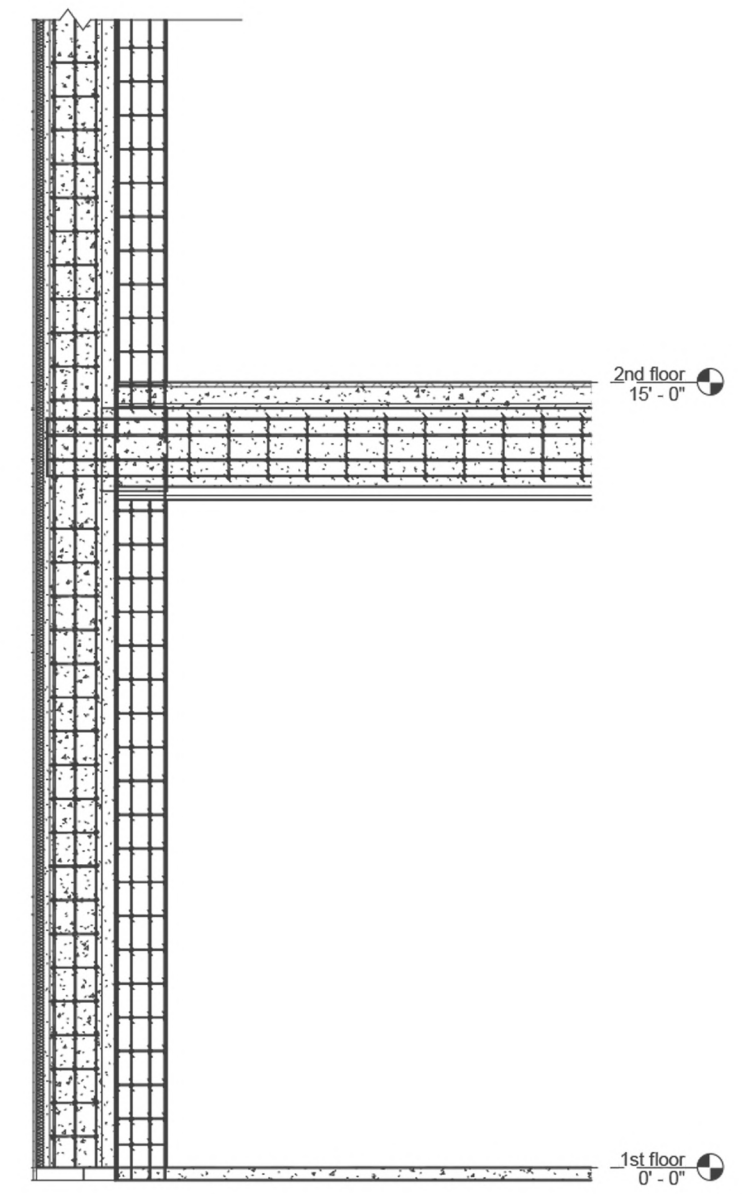


Girder

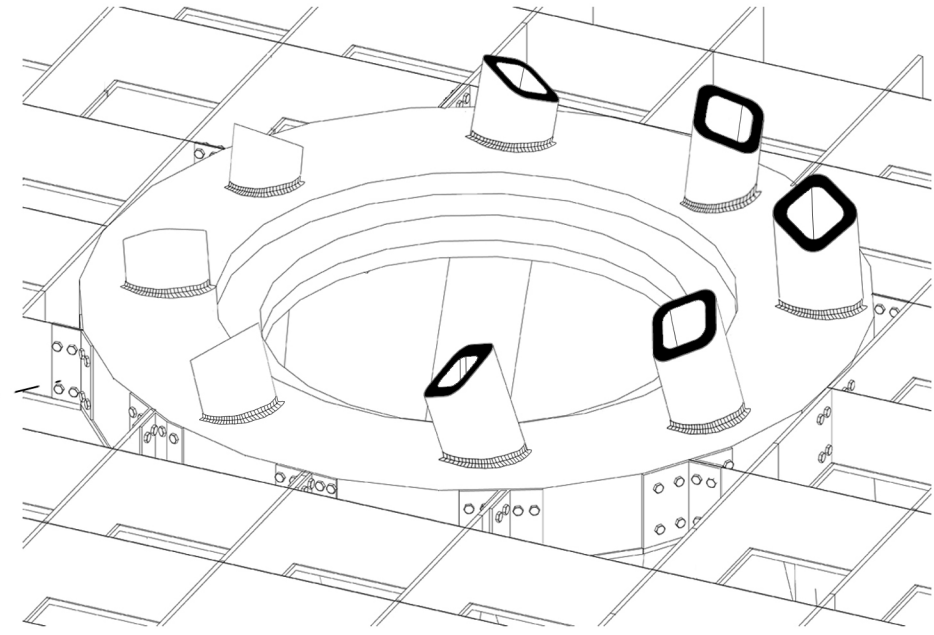
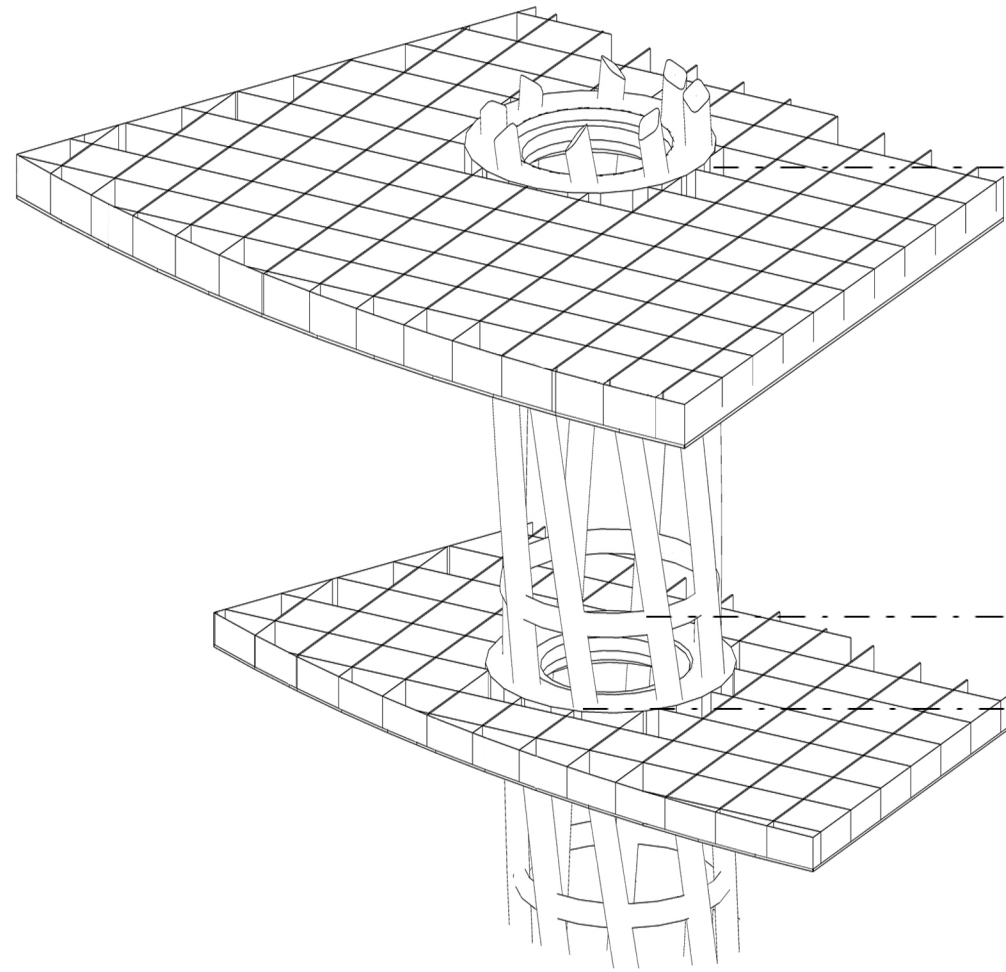




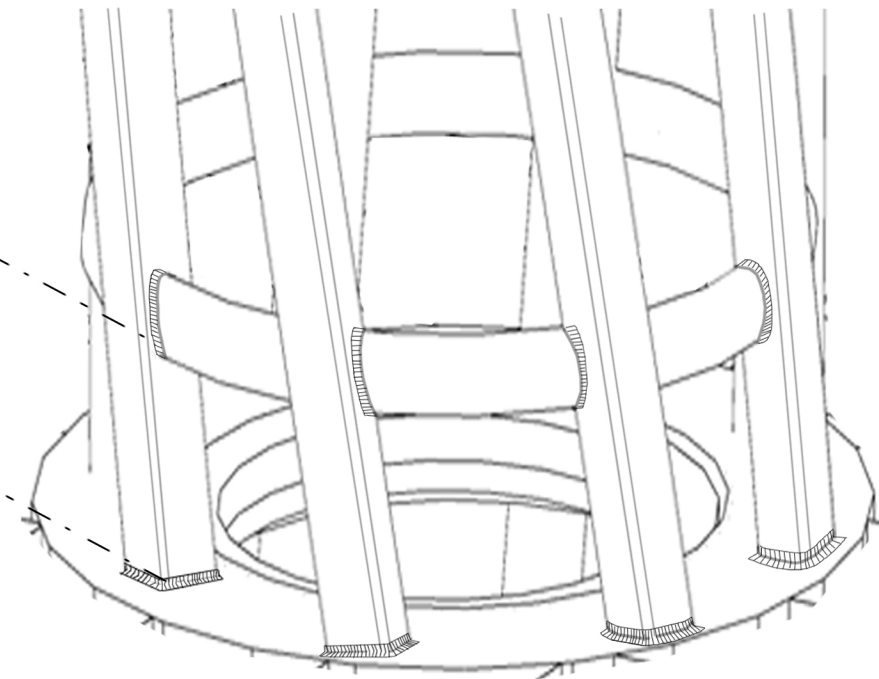
Wall foundation section



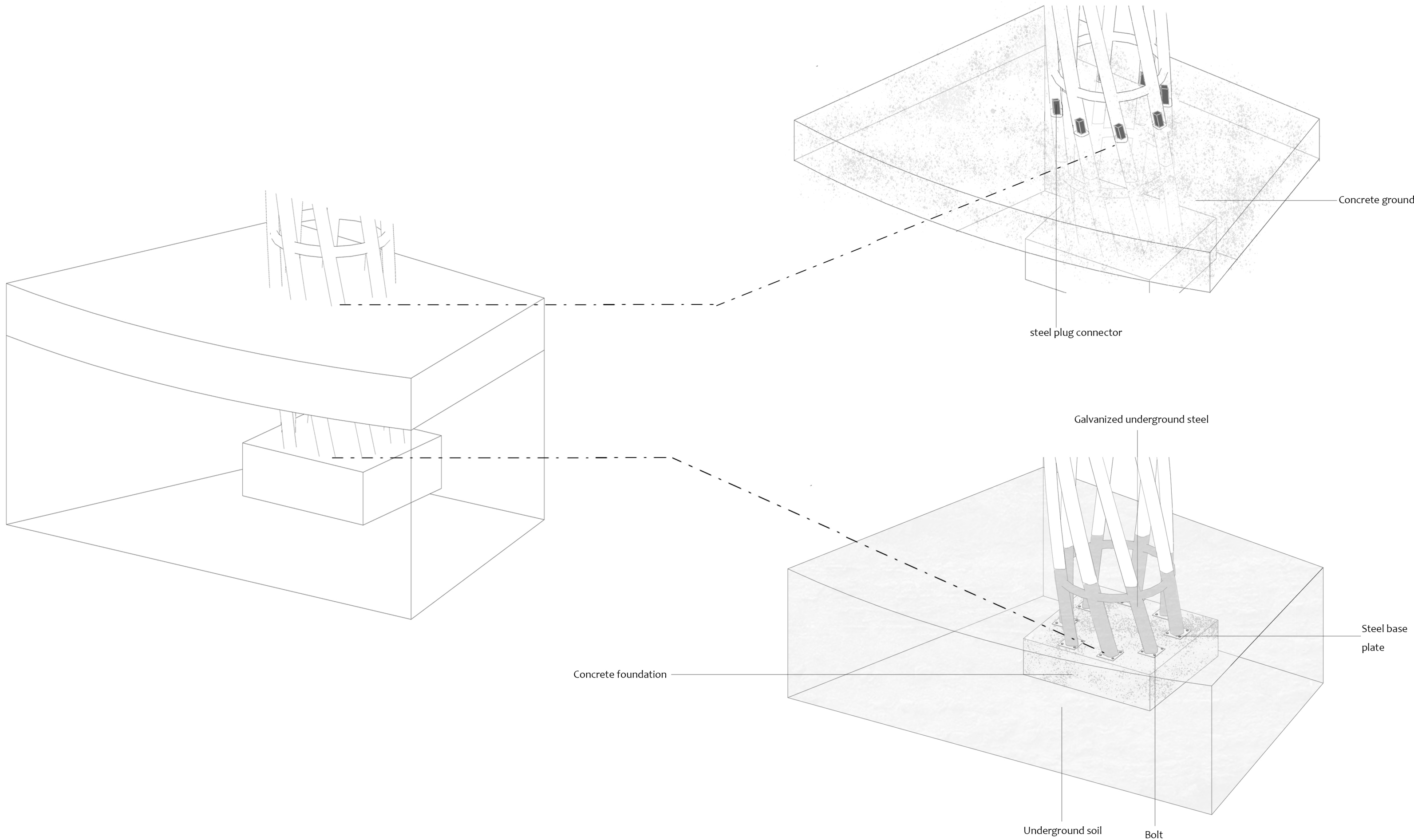
Reinforced concrete columns and slabs section

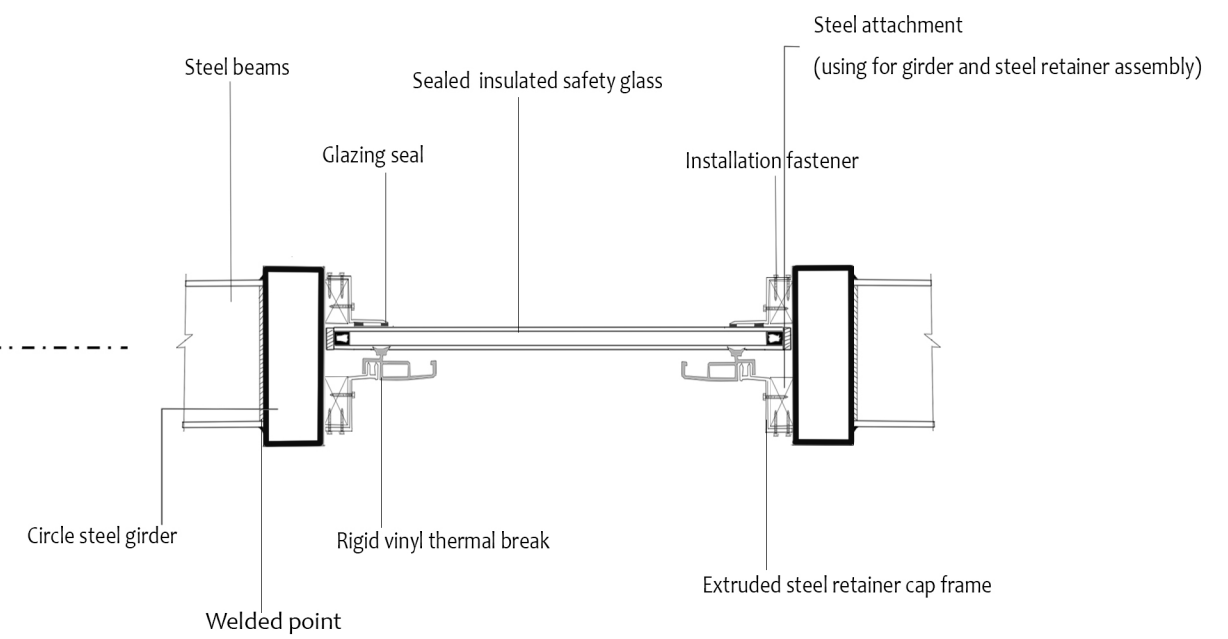
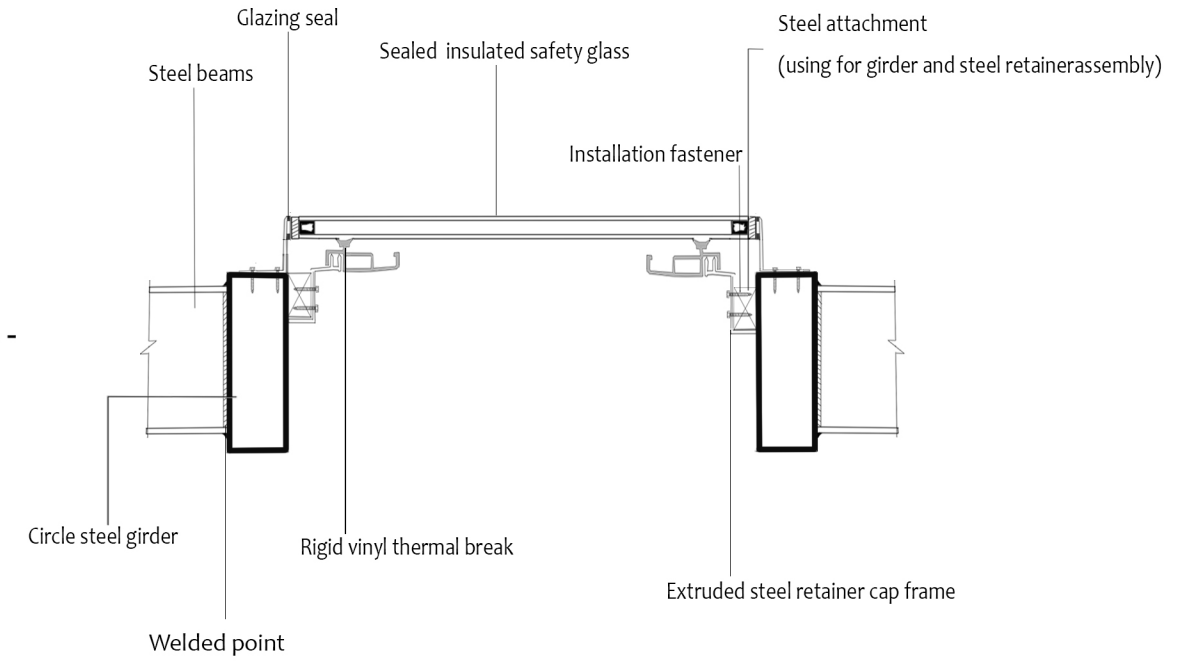
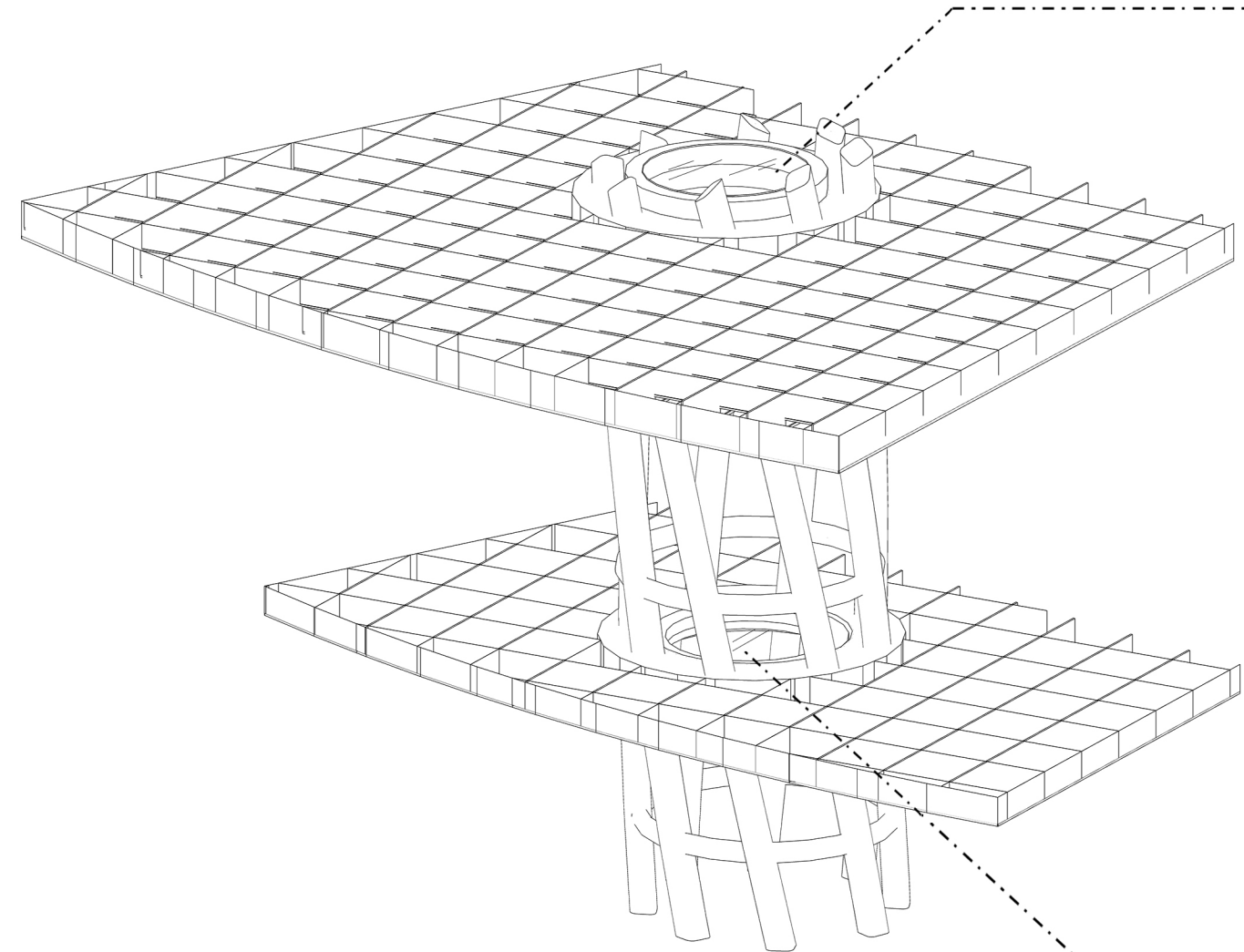


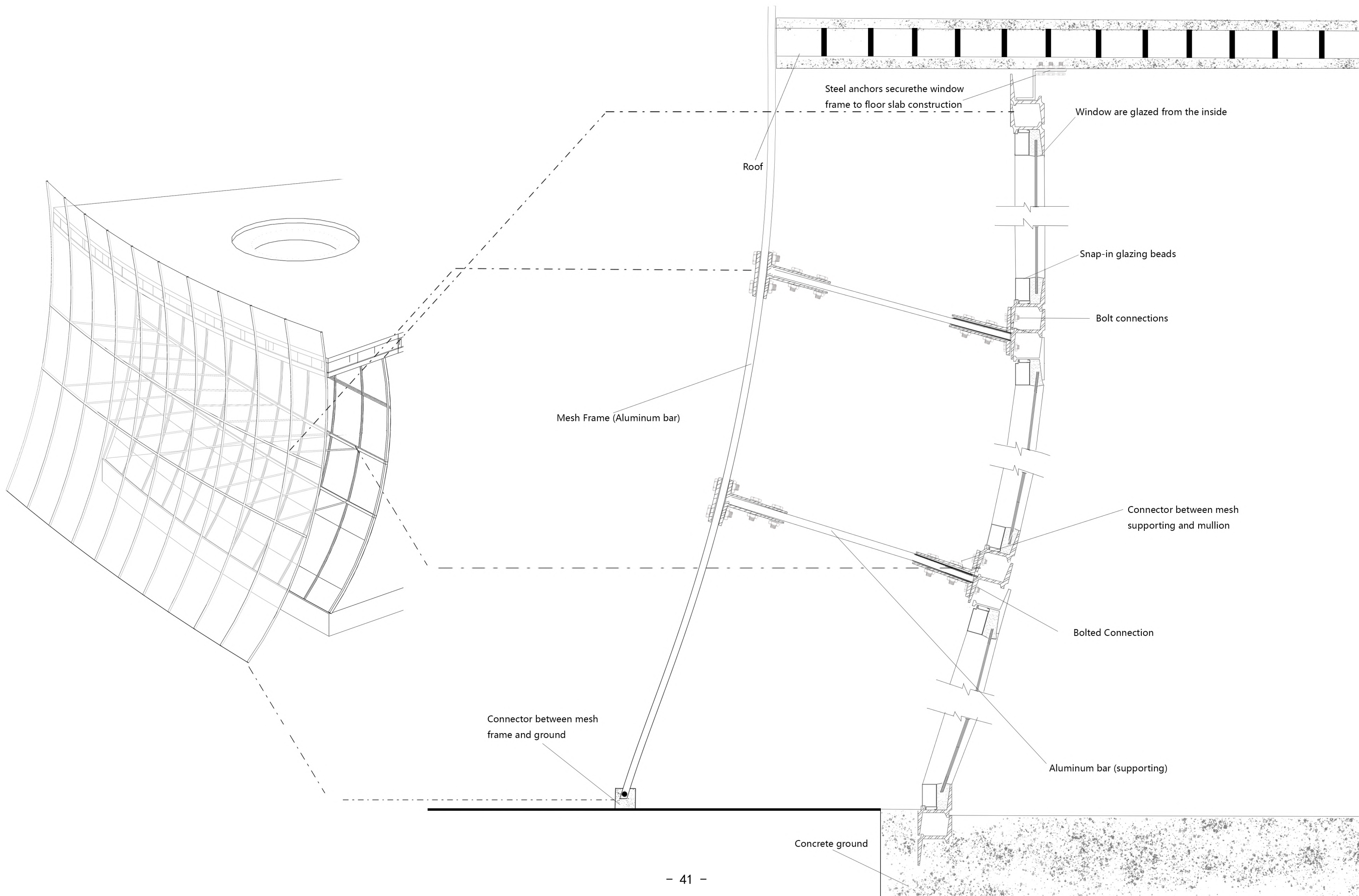
Circle girder and beams are connected by bolts.

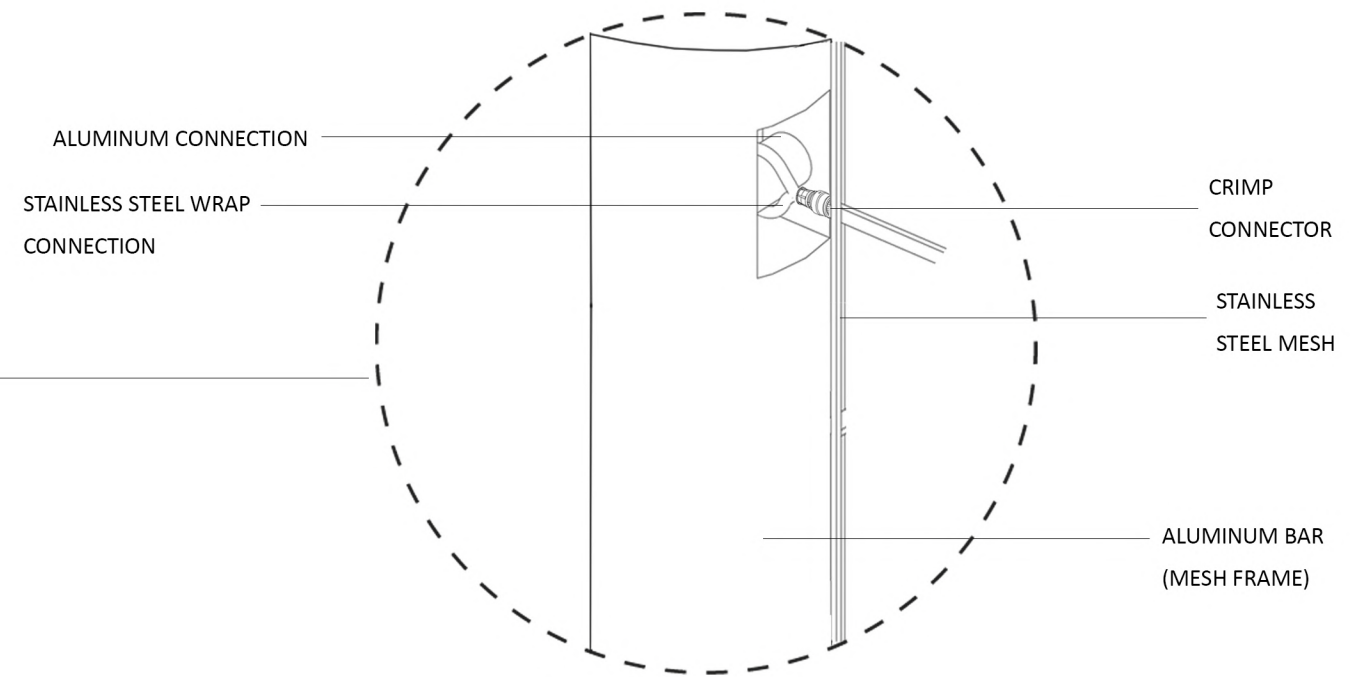
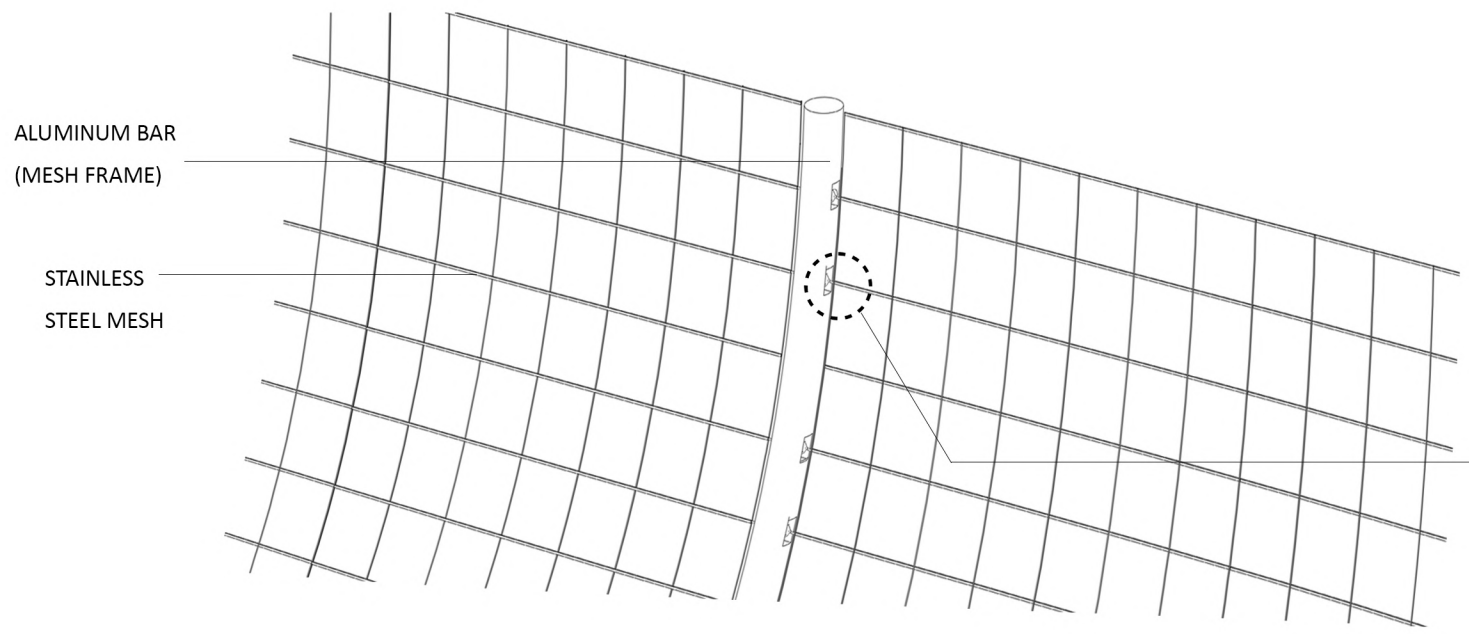
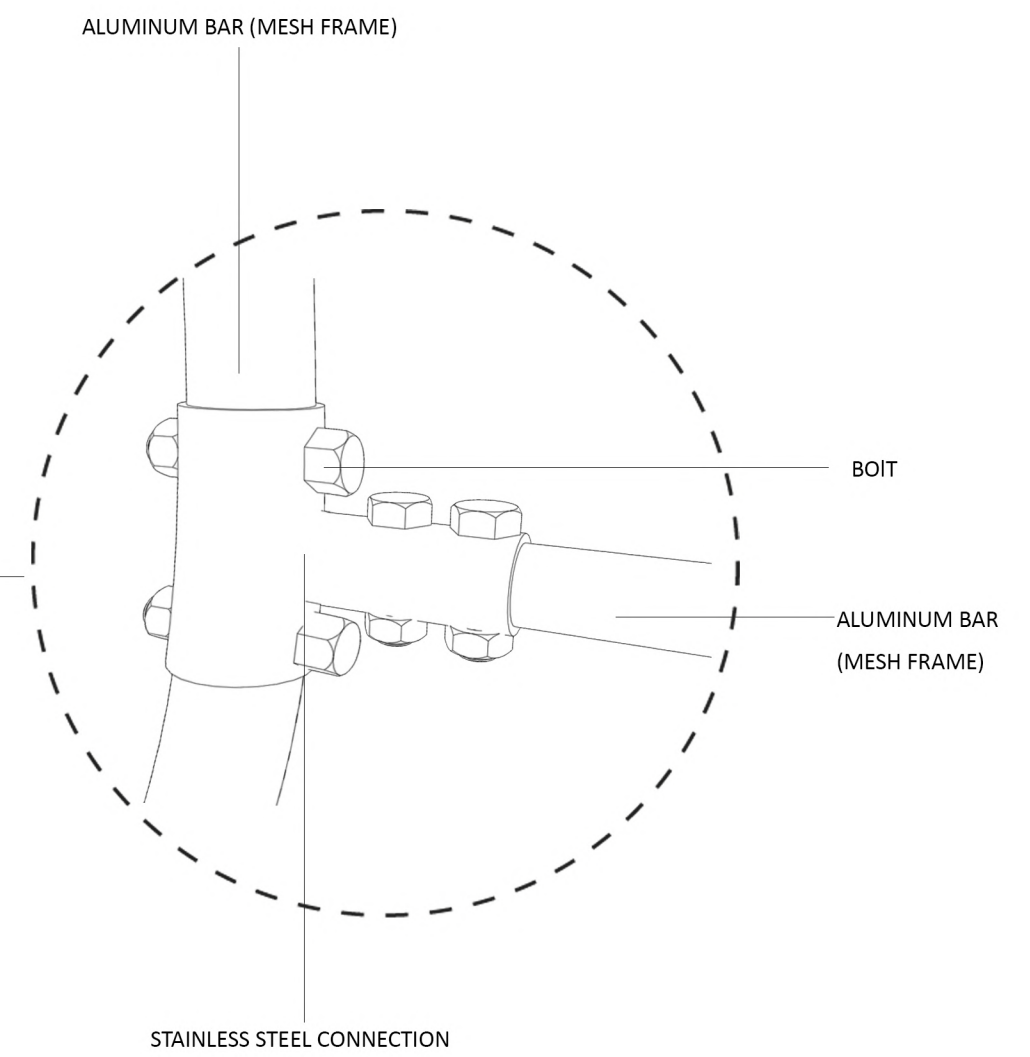
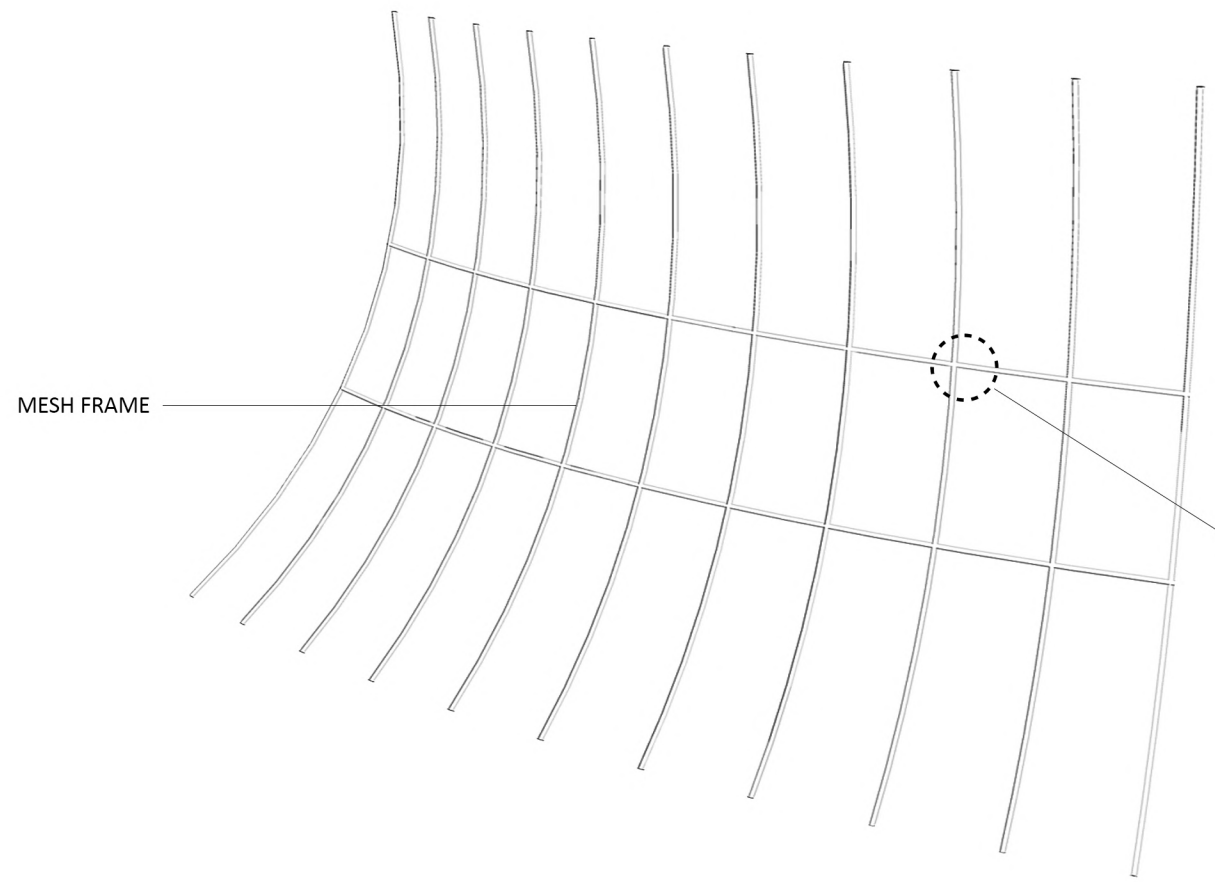


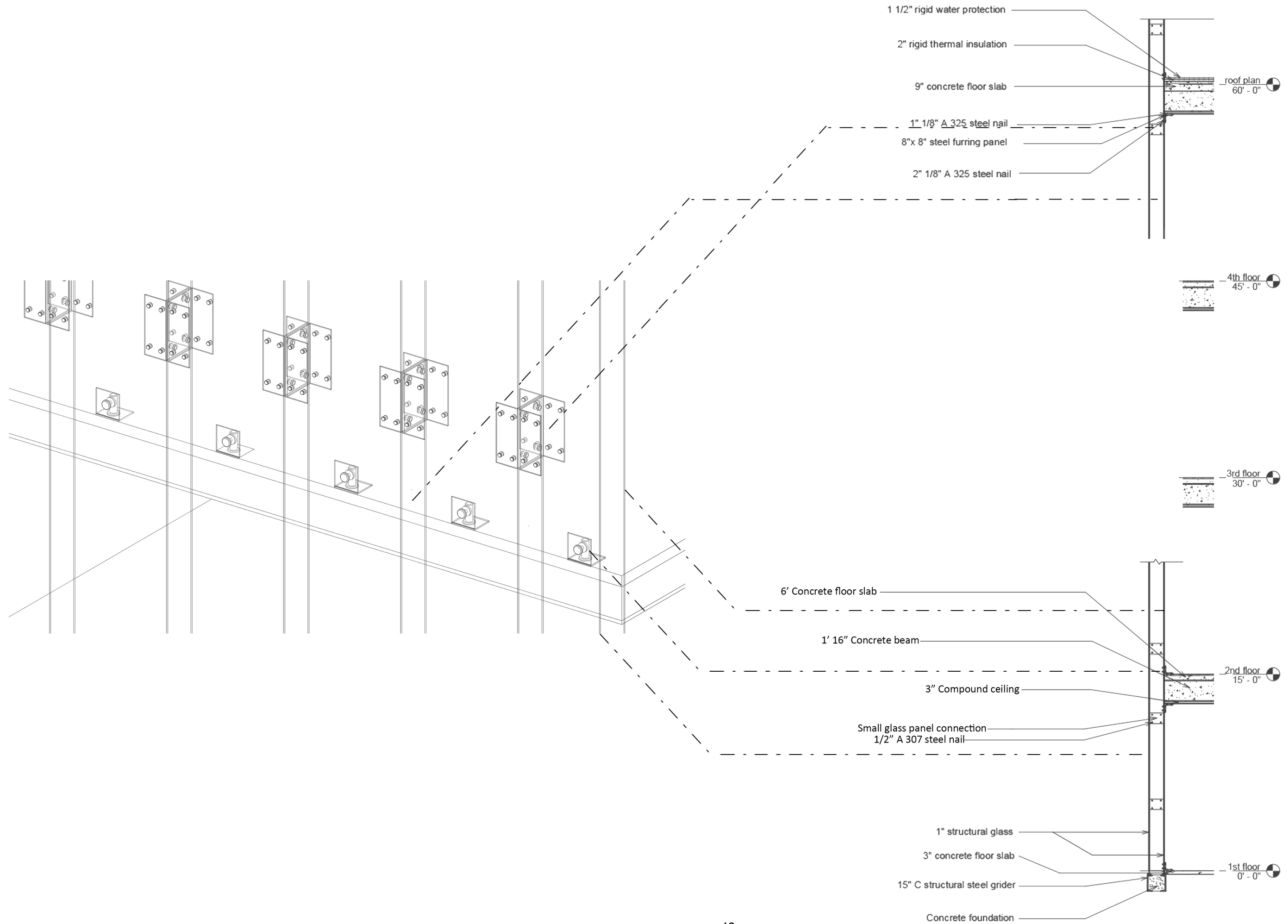
Other joints are welded to connect with each other.











CHAPTER 5 : RENDERINGS

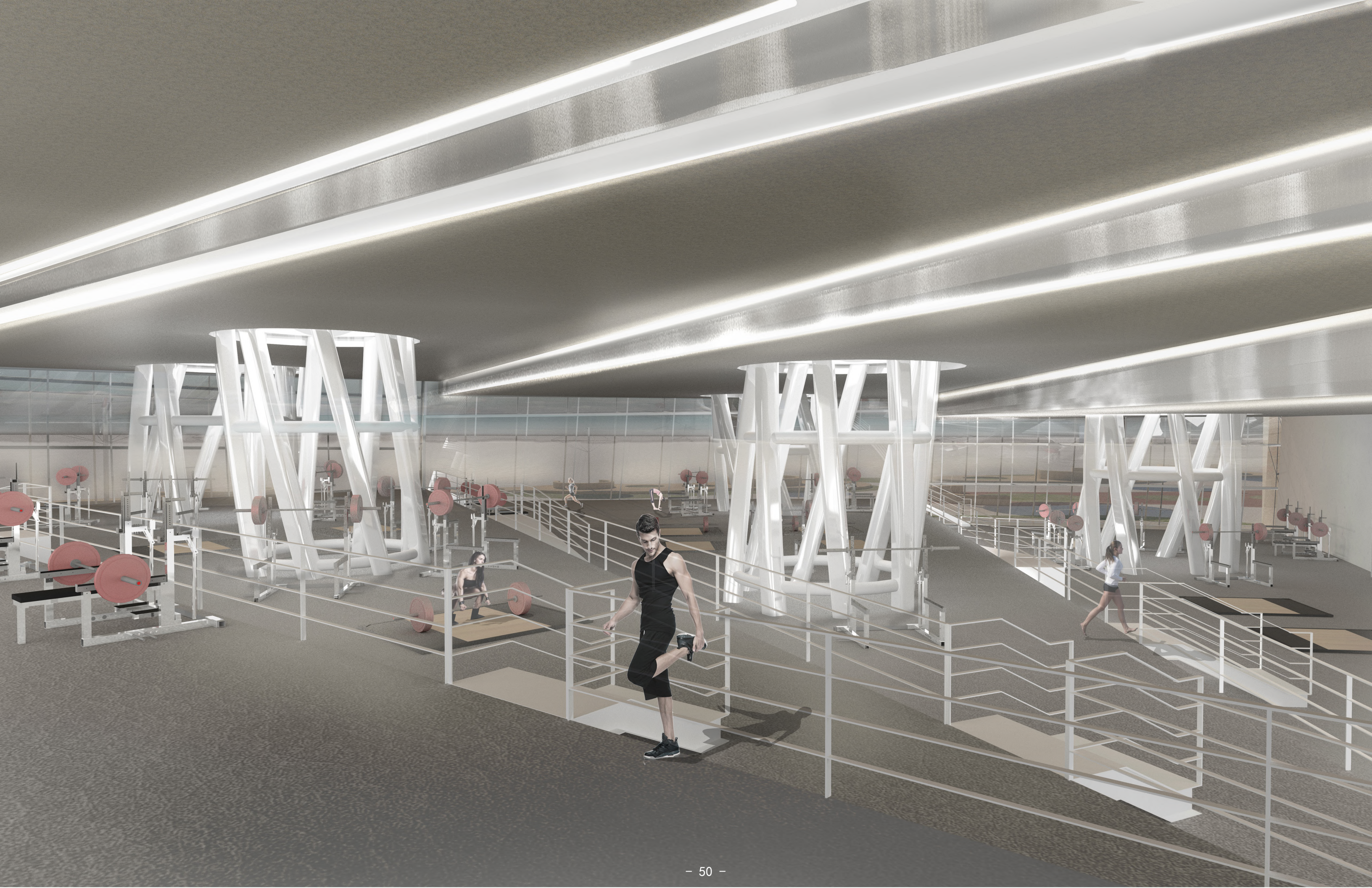


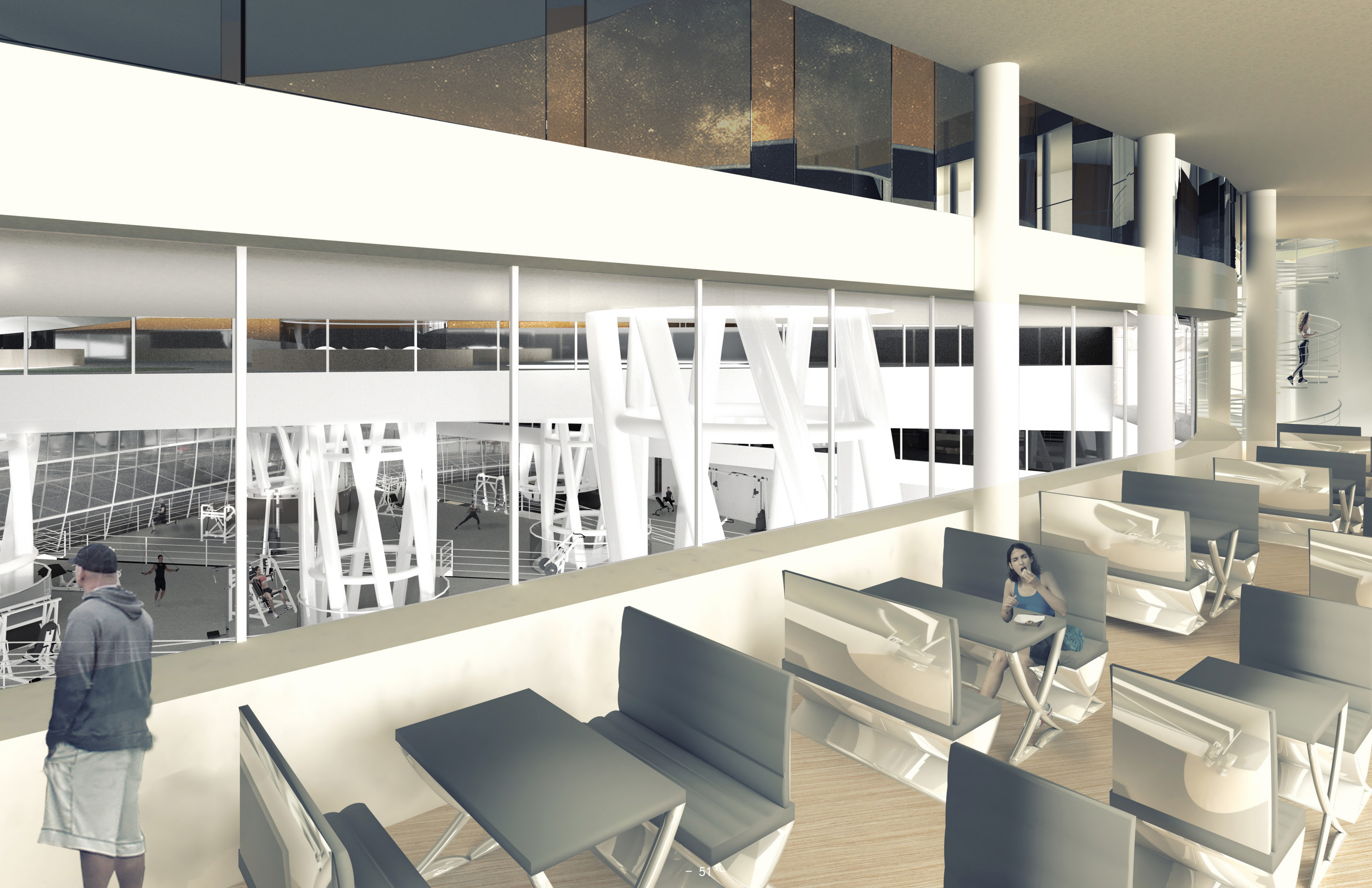












CONCLUSION

Structure is following function, the next important element in architecture. It is not just key to supporting the architecture, It also can fulfill the functional requirements.

In this thesis, the twisted structure helps to activate the central nervous system when people are actively work out. It also helps powerlifting trainers to maintain a positive body posture which can help prevent injuries. The design of other elements of the building follows the principle of using architecture to improve exercise performance.