PREFABRICATED HOUSE:

DEFINING ARCHITECTURAL QUALITY AND IDENTITY

THROUGH THE INNOVATION OF PREFAB TECTONICS

A DARCH PROJECT SUBMITTED TO THE GRADUATE DIVISION OF THE

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Precast Concrete Culvert, Cross Nailed Timber system

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Technologically, I owe to the GPRM precast concrete and Hundegger CLT company. Through actual meetings with GPRM, I was able to understand precast concrete in terms of materiality, detail, process, and cost estimate. Moreover, I could make test sample of the CNT with actual aluminum nails from the Hundegger in Germany. Beyond the CLT, I was able to gain knowledge of CNT, an economical and environmental friendly system.

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Lastly, I would like to thank my parents and wife Chae-Eun Bang's parents for their great help and patience during this challenging, long journey.

Abstract

This dissertation is for design of mid-income people house that they can afford "Jense" Korean rental system. Therefore, I focused on high quality design, general size for a family, and regular budget. This is because failure reason of prefab architecture in Korea came from low cost and quality. Moreover, to figure out the value of identity, I would like to begin research with customization through the eyes of the owner. I am going to research and test clients needs, both negative and positive, within prefab system. In present day case of prefab houses, it is hard to have customization due to government regulations and affordability needs; therefore I have to figure out architecturally good quality and merits to prove that possibility of customization is a benefit to society, changing the definition of prefab house.

Additionally, the existing perception for prefabrication house is negative. My proposal is researching not only economics, but also high quality design, including sustainability and adaptability in order to build prefab houses for the general population, not only for affordable housing. To figure out this issue, my research's goal is to have good architectural design by implementing mass-customization options for a variety of applications.

This project applied in Busan where Second city in Korea. The structure is a creative system by using two materials that are concrete and wood. Furthermore, I research two directions of systems for Prefab Architecture. There are Precast Concrete Culvert and Cross Nailed Timber (CNT).

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1. Background and Prefab Architecture

1.1 Statement of Doctorate Project

In the mass-production system of South Korean house design, a problem of "loss of identity" rises at the center of mass-copying daily spaces and architecture. At this moment, there are many modern people who want to differentiate themselves from others; however, it's hard to satisfy this demand with existing production methods. At the core value of the architecture, there is a missing identity within the prefabricated house. To figure out the value of identity, I would like to begin research for prefabricated customization through case studies, around USA, Japan, German, and Korea. In present day cases of prefab housing in Korea, it is hard to have customization due to government regulations and affordability needs; therefore, I have to figure out how to provide good quality and merits to prove that architectural customization is a benefit to society, changing the definition of the prefab house. With this, modern industry's direction would change from a 'plug-in' concept, where changes are made from a list of choices to a true concept of unique customization.

Figure 1.1 Korean Housing Culture, Seoul

1.2 Prefab Dilemma

In Korea, prefabrication methodology is at the very beginning stage of development which focuses only on the prefabrication's function and economic feasibility for housing, making it difficult to get good quality private homes and high-value properties for clients. Additionally, the existing perception for prefabrication housing in Korea is negative. My proposal is to research not only economics but also high-quality design to design prefab houses for the general population. In other words, this proposal is not for affordable public housing. Instead, the research focuses on privately owned houses design with prefab system. To figure out this issue, my research goal is to develop a good architectural design by implementing mass- customization options for a variety of applications.

Figure 1.2 General Korean Prefab Housing

1.3 Hypotheses including cultural context

In Korea, there is a smaller budget for construction of private housing compared to foreign developed countries, due primarily to limited and expensive land. Thus, in the big city, the needs for narrow houses are increasing. Moreover, owning a house is very important in Korean culture. Some people consider it as their final dream, so it should reflect the client's wishes. The hypothesis for this Doctoral Project is to research diverse solutions. This research, which is connected with private homes, will help to develop Korean prefab houses' possibilities.

Table 1.1 Korean Housing Construction

1.4 Social context regarding Mid-income Housing

In the Herald Design Forum in Nov 2014 in Seoul, Korea, the architect, Rem Koolhaas anticipated that the private domain would be much bigger than the public domain in the future,[1] which has been proven recently in Korea as many people start moving from a housing unit to a built house. Thus, this project hypothesizes that even though prefabricated systems are led by the Korean government for public housing, architects would consider implementing the system at private house design. The existing research did not address the private housing sector. Therefore, we should research valuable foreign cases to be developed into good options and systems.

1.5 Research Methodology

My historical research helped as a standard to figure out architecturally significant references. The research focused on four parts: the transition of the prefab's cost, value, flexibility, and size. The research context helped understand prefabrication's character, cultural implications, and their history through the perception of architects towards the prefab housing. Moreover, a direct correlation between resources shows what clients want to get in their prefab house. The research would be useful to adjust

[1] Seoung Chan Back, "An architect is a person, who answers for client's question." *Kyungyang News*, December 11, 2014, accesed May 8, 2015, http://news.khan.co.kr/kh_news/khan_art_view.html?artid=201411262115465&code=960202 .

occurring patterns in current trends of the Korean housing situation. Finally, my case study research determines which prefab options are suitable for the Korean environment.

1.6 Summary of the existing body of Prefab architecture

A prefabricated house is a different method from existing tectonic ways at the architecture level specifically in regards to budget and construction duration. Also, prefab assembly refers to the system of the delivery structures and materials from a plant and then making the houses with machinery and electronic equipment together at the construction site. In Korea, the word "prefab house" is confused with "modular house" and "industrial house" because there is no clear concept of the definition. To be more specific, the characteristics of a prefab house in other countries, such as Japan, are superior in quality, Seismic properties, short build times, re-locatability, design flexibility, sustainability, safer construction, and convenient up-keeping. For these characteristics, we are aware of the needs of prefabricated houses in Korea. Prefab research has been studied in Korea since 1990. This is because the government only researched construction of prefab housing to schools and military barracks design. Moreover, the Korean government proclaimed a rule to the vitalization of prefab housing on Dec 3, 2012.[2] I consider that the researchers have focused on housing regarding the economics assessment

[2] Hyun-Rim Lee, "The Study on the Utilization of Prefabricated House as Public Rental Housing," 43.

and mainly methods such as fabrication and construction, rather than focusing on proper design techniques and comfort for the owners. The private home part of the research is very much insufficient in Korea. Also, I think that urban designers and developers have led their public housing research without architects' perspective.

Research questions:

- What are a good design and the possibilities for prefab houses learned through historical research and case studies? (Research)
- How can we design for prefab houses for the private domain? (Application)

Investigating Housing Quality

I would like to emphasize a different direction not found in current research in Korea. Through this research, I show gaps between my research for private housing and existing research for public housing. First of all, I am studying the current background for Korean prefab construction to know why we need to develop new Korean prefab houses, what the purpose of existing research is, and how I can process the prefab research in Korea into a new direction that applies to the private sector as well. For this, I have to figure out the limitation of existing research and problems with the view of customization at prefabrication in architecture. Hence, I try to answer some main questions about Korean prefab house by applying my research into specific focus categories: background, limitation, merits and solutions.

Kieran Timberlake Architects design two case studies. First of all, Loblolly House rethinks architecture in terms of new means of prefabrication with customization. Through this work, they try to achieve different constructive language of architecture by using aluminum, glass, polycarbonate, and traditional wood. Furthermore, Loblolly House reveals not only an approach to prefab system but also refined research and philosophy about prefab housing. In this case, many construction parts are integrated into five elements. Secondly, the Cellophane House is based on a customization system. The house was for a "Home Delivery" exhibition in 2008. Thus, they designed this house, which is easy to assemble, disassemble, and reassemble its components. Also, the building is a one-family private home. In both case studies, we can select cladding options. Moreover, the prefab home can be installed in any place. In the Loblolly House, the architects employed the wood on file and cladding to mingle with the site's environment. On the other hand, At the Cellophane House, they use glazing and thin film integrated with photovoltaic panels. Furthermore, the house has customizing mechanical and electronic systems. Finally, quick construction is also an important issue in the prefab house.

1.7 Transition of Korean Housing

Prior to the 2000s, Northeast Asian cities adopted urban policies that focused on quantitative growth based on rapid economic and growth, population growth, and productivity gains from capital concentration. However, recent growth drivers have

been shown by high-quality housing investments. In Korea, the number of single-person households has risen sharply, and new town-like plans are reaching their limits.

Investigating Quality with housing

In 1997, the IMF system and the global economic crisis in 2008 led to a sudden change in the Korean economy. Furthermore, housing policy focused on the ineffectiveness of supply and sale real estate and apartment policies, which are in line with existing economic growth, have come to the point of change.
'Residential refugees' and 'House Poor' were mass-produced. Instead of a uniform apartment, there is an increasing demand for houses that emphasize individuality, and there are also shared houses that emphasize communities accordingly.

Urban area

The private domain must be much bigger than the public domain in the future, which has been proven recently in Korea as many people started moving from apartment units to own-built house for “Jen se system.”[3] Thus, this project hypothesizes that even though the Korean government leads prefabricated systems for public housing, architects would consider implementing the system in the private housing domain. According to the change in Korean society, the program of housing is diverse

[3] The kind of charter system, 2 years contract rental system in Korea

for the new needs of society. For example, in the fast, people had large families but not families can consist of two and even one person. In Urban setting, housing culture is challenging.

Recently, commercial space can combine with private house or share housing. Moreover, some of the housings do not just minimize private spaces; instead, they provide public spaces and diverse programs. Recent projects in Korea reflect social housing issues such as a narrow house, one-person family, same hobby housing, and own housing instead of the “Jen-Se rental system” in Korea. Especially, there are new young clients who do not want the unique rental system anymore because landowners ask raising money every two years.

Figure 1.3 Korean Housing Change, Urban Area

Narrow House

The land cost is significantly higher than the construction cost of constructing a small-scale building in a city. So architecture is naturally facing roads, and it becomes narrow but higher story buildings. The project is to bring a new possibility of small scale housing and expandability of human life as an alternative method for urban area vitalization against large-scale development projects, such as new town developments. The site which was formed in the era of Japanese occupation is 5m wide and 12m deep and is a narrow rectangle shape facing north. This project is about the discovery and utilization of inevitably derived space which cannot find any meaningful architectural alternatives away from legal or physical limit caused by regulations of parking, direct evacuation stairs, and micro-proximity to neighbor buildings. In this case, the application shows new urban context.

Figure 1.4 Narrow House, JMY architects, 2014

Share Housing

As a result of delaying marriage and increasing the number of applicants, other programs are required at home. The concept of the share Housing is to support the new lifestyle of the young, single demographic household by sharing common spaces such as the living room, kitchen, and dining area. The architects tried to focus on a design that creates a balance between the common and private spaces deeply considering the 'share house' amenity. The balance is coordinated by the outdoor space which is defined to gap, a design which helps bring in nature to the residents and encourage interaction and mingling amongst housemates. In the project, I found that some of prefab possibility because the units are stacked to provide gaps. Also, these projects show a new type of housing that we could not imagine in the past

Figure 1.5 Share Housing, Archihood WXY, 2015

because the kitchen and dining space are sharing for residents. However, at the same time, the private rooms are secured in the units.

Micro Housing

This type of housing was minimized as much as possible to reduce the private area from the early recruitment of tenants and to secure a lot of shared space where people with the same hobbies can enjoy the same people. In order to use space effectively and neutrally, all furniture was planned and included in the building. The problem of urban density and housing costs is global. To compensate, unit types get smaller micro-housing and have the danger of becoming provisional housing

Figure 1.6 Micro Housing, SsD 2015

with little social value. By mining the discrepancy between maximum floor area ratios and maximum zoning envelopes, The micro-Housing provides a new typology that extends the limits of the unit to also include semi-public circulation, balconies, and visual extensions. The units include furniture such as bedroom, dining, and kitchen as micro housing units. Moreover, the project provides unique programs for gathering spaces, because when the building found new residents, they asked to have the same hobby and to share it during the resident periods.

Retail House

The project was planned based a house and a retail building after the borrowing of the owner's bank loan to raise the deposit. Three floors were made of rental income spaces, and three floors were made of residential spaces to help pay off the bank debt rather than the lease of a single-family.

Figure1.7 Retail Housing, System lab, 2016

Rural area

According to the change of Korean society, the housing program is diverse due to the new need of society even though the location is in a rural area. In Korea, there are not enough professional structure engineers for wooden houses. Therefore, the wooden house could not develop a lot. For this reason, most of the clients think that the concrete housing is the best option for housing materials. However, depending on their site and clients' needs, the materials could be diverse and customized for housing projects. I found that recent projects in Korea to reflect diverse materiality and multi programs for multi-generational families into housing projects. There are two projects: one housing project is for a regular family. Another project is for three generation house. However, in some events, such as ancestor's rites, the family needs more space for gathering a big number of family members.

1. Understanding diverse materials such as wooden house

2. Invest money together for reducing burden of construction for multi-generational housing

Figure 1.8 Korean Housing Change, Rural Area

Simple TMT house

Korea has a narrow view of the wooden system because they prefer concrete materials. Thus, this is the only case where water is used as an exterior finish using TMT. I also designed the building through the funeral culture of Korea. Shear House, a single family house in Korea, seeks a simple treatment in pitched roof typology that improves environmental qualities and influences to program organizations. The volume of a gable on the West end changes its placement along with the body of the house. It projects out toward the South at the East end, while maintaining its triangular shape. The sheared volume is continuously pulled out to the South, responding to sun orientation. It creates a deep eave in the South and a terrace in the North. The eave blocks direct sunlight in summer and allows natural lighting in winter. Openings at the terrace in the second level increase natural ventilation throughout the whole house. Also, double skin facade controls heat and humidity; thus, the house reduces 20% of heat gain and loss in summer and winter.

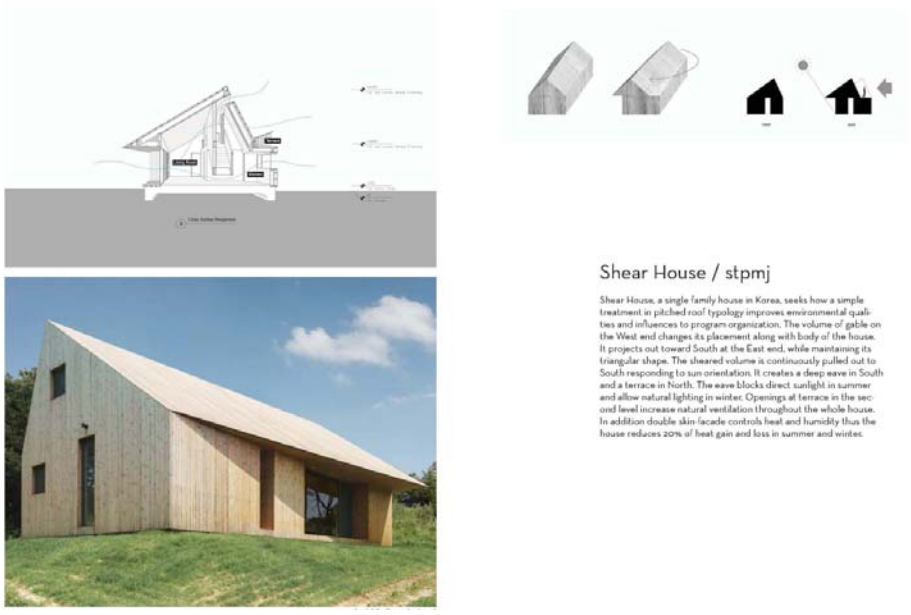
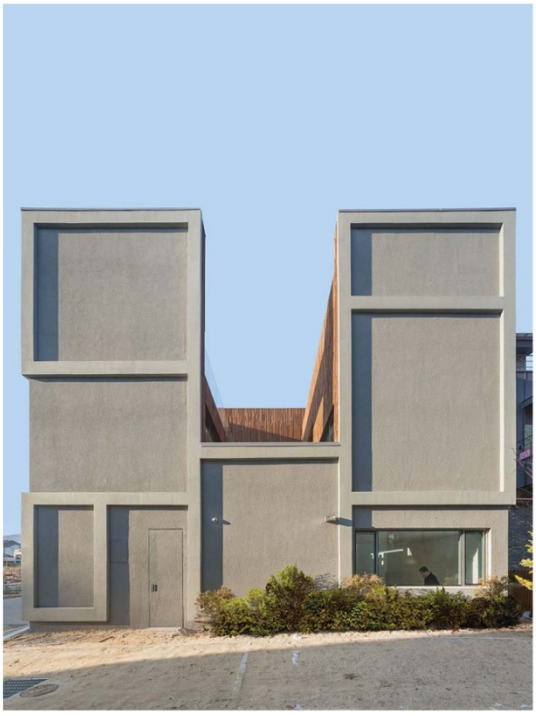


Figure 1.9 Thermal Modified Timber House 2016

Multi-generational family house

It is a house for multi- generational family. I think that the building was too choppy and it was difficult to fully enjoy the inner courtyard. So I think that I wanted to have a house that could reflect the change of family. The house is for three different generations to have eight individuals. The situation is very rare among the Pangyo housing. The life of a family, living in a 155 square meter apartment, is tightly displayed on a plan view drawings, much more privacy is gained because the floor level is divided. In the project, I think that the expanding and reducing possibility are important because the number of families would change depending on their situations such as marriage, employment, and children. However, the projects do not fully accept the possibility.



Layered Terrace House / Jinman Jo

A house for Three different generations and eigth indiciduals. The situation is very rare among the Pangyo housing. The life of a family, living in a 155 square metre apartment, is tightly dispalyed on a plan view drawing. Much more privacy is gained because the floor level are divided.

Figure 1.10 Multi-generational families House 2015

Therefore, I believe that we have to consider the change according to time for multi-generation family housing. In the prefab projects, it would be possible to give customization depending on families' history.

1.8 Long History of Prefab House

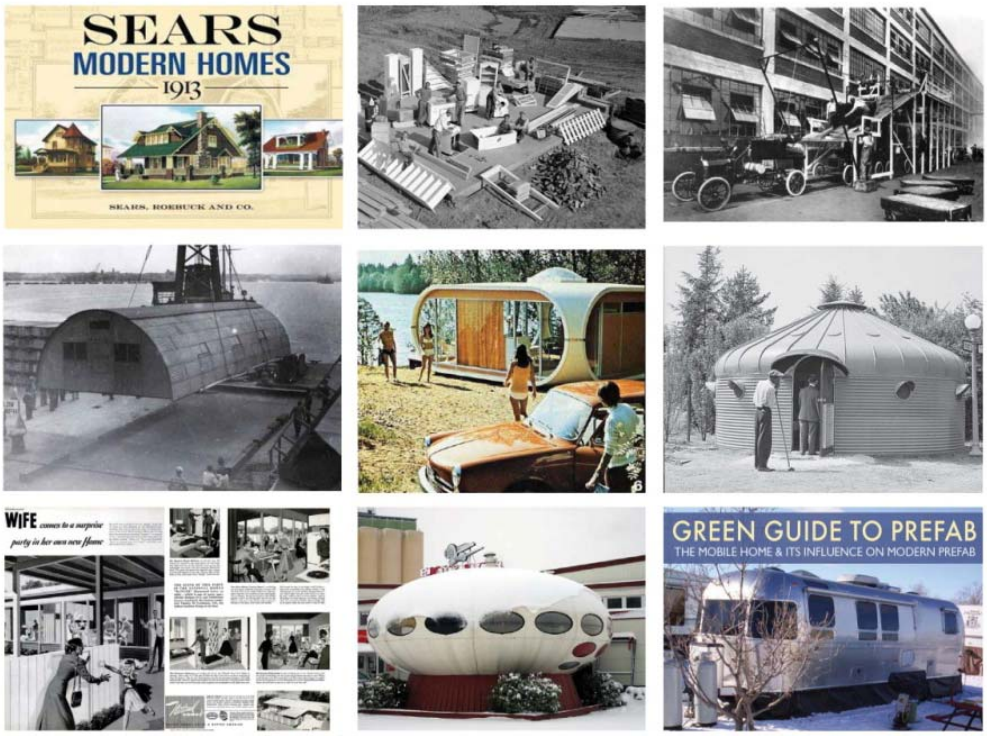


Figure 1.11 History of Global Prefab House

In "*Buckminster Fuller: At home in the universe"* by Alden Hatch, Hatch's key point is Buckminster's idea for architecture. He also describes an architectural philosophy for the background of prefabrication. This background and philosophy can be his major issue. In the book, Buckminster's Dymaxion Deployment Unit is connected with the prefab system.[4] By showing the floor plan of the unit, the writer discusses a basic concept of prefabrication. Regarding mass production, the idea is assumed as required studies for architecture. This book's key issue is different from Korean research for housing. Thus, the key theories would be important for my Doctoral project.

[4] Alden Hatch, *Buckminster Fuller: At home in the universe.* (New York: Crown, 1974).

1.9 Principles of Prefab House

1. Industrialization
2. Affordability
3. Mass production
4. Modular
5. Sustainability and Customization

In “Towards a New Architecture” by Le Corbusier, he argued that we have to find lessons from mass production and development of engineering. He complimented engineering’s bold and simple attempt by comparing both engineers and architects. Moreover, he believed the bridge designed by the engineer Gustave Eiffel and grain elevators are the best modern forms of design. This is because the images of them are greatly distinct and tangible without vague elements. Therefore, he valued and focused on the functionality for the development of architecture design. For this reason, the importance of function has stood out among all his arguments. As a result, the beauty of function spread in modern architecture globally. I think that his proclamation still influences modern architecture today compared to other books or theories. This is attributed to the fact that many prefab architects such as Buckminster Fuller and Jean Prouve followed the simple form and the beauty of function that Corbusier maintained.

Furthermore, "*Marcel Breuer, Architect: The Career and The Buildings."* by Isabelle Hyman, Hyman argues that Marcel Breuer discussed prefab house. In the book, Hyman states the small metal house among the projects. The key issue shows Breuer's six variations for the private house. These are variations could be a customization concept for prefab house. Hyman's key source, which is Breuer's six variations, can be similar to "Resolution: 4 Architecture's works". Through the book, he insists that plan and possibilities for prefab house could be developed.

Figure 1.12 History of Prefab House projects by famous architects

Moreover, *"Jorn Utzon: Drawings and Buildings"* by Michael Asgaard Andersen. Anderson introduces Jorn Utzon's Espansiva system[5]. He argues that the

[5] Michael Asgaard Andersen, *Jorn Utzon: Drawings and Buildings* (New York: Princeton Architectural Press, 2014),166.

system is for an architect's vision by using prefab components to make diverse housing types. His major issue is residents' interests in designing their own homes. I understand how an architect can customize prefab houses for clients. Also, the author mentions not only freedom plans but also materials in detail at Espansiva system. Furthermore, he explains why Utzon had chosen this module system. To sum up, this shows that Utzon's Expansiva system has a lot of varieties. This is very beneficial to figure out prefabrication design and customization. By interpreting his system, I could get an idea for prefabrication's components.

In *Buckminster Fuller: At home in the universe.* New York: Crown, 1974, This book introduces Buckminster's ideas for architecture. He also explains his life and architectural philosophy. Buckminster's Dymaxion Deployment Unit is connected with prefabrication. By showing the floor plan of the unit, the prefab architecture is discussed for what is the concept of prefabrication. Regarding mass production, the idea is assumed as required studies for architecture.

1.10 History of Korean Housing (1945-2016)

1. Urban area

In Korea after the independence in 1945, we did not care about regional characteristic and natural architecture for needs of rapid development. This led to the Korean housing directly jumping from “Hanok” (traditional architecture) to modern apartments, with no relevance to them. We obviously have skipped this kind of thoughtful considerations, partially because they were government led.

2. Rural area

In a rural area, it has been developed with same needs from government. Therefore, there were standard housing systems.

1950-1960 1960-1970 1970-1980 1980-1990 2000-2016

Figure 1.13 Transition of Korean Housing

1.11 History of Korean Prefab House

In "A *Study on Performance and Economics of Low-rise modular building"* by Jong-Dae Bang and his partner, the researchers explains the needs of prefab housing for Koreans by mentioning the background of the Korean construction environment, the social change of population, and sustainability for the global environment[6]. Bang and his partners' key sources are simulation testing with an existing prefab housing. They deal with the safety of construction, noise reduction, energy issues, air quality, and economic problems with a mock-up test. Their major theories are based on the assessment standard of performance. Also, the major issue of the research is whether or not the modular housing is helpful in Korea. In the result of the test, the performance is positive. However, they mention, "the economics are still higher than existing construction skills for 2.1% - 6.1%." Additionally, they say that "we can overcome the disadvantage of the prefab system if the prefab housing could reduce the construction time and it would be the general way of building construction in Korea." By reviewing this research, I found the gap between their research and my research. I understand that because, in Bang's case, the main issue is for a government housing project, Bang's and his partners did not research prefab house for a single family with customization factors.

[6] Jong-Dae Bang, "A Study on Performance and Economics of Low-rise Modular Housing," *Paper presented at Review of Architecture and Building Science*, (2014): 20.

In Jin-Hyung Kim's dissertation *"A study on variety of prefab architecture,"* Kim's thesis is connected with mass-production and standardization for housing. Unlike "*A Study on Performance and Economics of Low-rise modular building,"* this research argues for a variety of prefabrication. In the research, Kim explains the meaning of standardization, which is systematic action by making standard. [7] Kim insists that industrialization of houses are failed in Korea. Also, Kim states the reasons for failing. Moreover, his major argument is that when prefab can be flexible to the clients asking, the prefabrication house can get ahead in business in Korea.

Moreover, according to *"A Study of Current State Examination for Prefab Architecture and Manufacture"* by Young-hak Song argues that the most prefab projects in Korea are for military barracks or schools. Therefore, Song's key sources are prefab companies and their products tobuild public housing in the city. In terms of comparing with my Doctoral research, I consider the prefab house beyond site's limitation. The reason is that lands in the city are still expensive. Therefore, clients can select their land in any place, where they want. Through this research, I could learn recent construction field for Prefab house in Korea.

[7] Jin-Hyung Kim, "A study on variety of prefab architecture," *Paper presented at the Korea Academia-Industrial Cooperation Society annual conference,* (2010): 24.

What is more, referring to the Woo-Chul Wang, Chang-Jae Lee, and Seok-ho Lim is research, *"Study on the Design Characteristics of Housing that applied the Modular Construction,"* Wang and his partners compare and contrast two modular houses. One is made by modular unit type. The other one is Han-ok modular type. In their research, the authors mention prefab home's characteristics, base, and assembly [8] I think that their research is practical to apply to the Korean prefabrication situation. However, there is clear limitation to apply in modern society.

Finally, the research topic asks how we can re-discover prefab's possibility Korea? To begin with, Korean Modular Market could not activate, unlike the Europe or Japanese. As shown in *"The Study of Domestic and Foreign Case Studies for the Improvement of Unit Modular Housing" b*y Young-A Mun and her partner, Prefab houses in the United Kingdom and Holland are different. They explain that this comparing process is very important for the Korean prefab public housing. In the research, they use five examples (Korea: Two, United Kingdom: Two, and Holland: One)[9]. The researchers divide prefab housing by flexibility, sustainability, economic, and time management factors. I think that this research still has a limitation because it deals with the United Kingdom and Holland public housing

[8] Woo-Chul Wang, "Study on the Design Characteristics of Housing that applied the Modular Construction,"*Paper presented at The Korean Housing Association annual conference*, (2012): 196.

[9] Young-A Mun, "Domestic and Foreign Case Studies for the Improvement of Unit Modular Housing." *Paper presented at Architectural Institute of Korea Conference at Fall*, (2013): 71.

only. Hence, in my research, I am going to be investigating other samples for the private domain to value my research. As a result, I have to figure out customization for prefab houses.

Moreover, the limitation of "The research of Utilization of Prefabricated House as public Rental housing" by Hyun-Rim Lee and colleagues is similar to research in the past that focus on Public housing in Korea. This research' key argument is that the prefab house is for government rental housing. A major question raised by the limitation of the prefab house to be used as public rental housing. Also, Lee and his partners point out legislation in Korea. However, they already understand the lack of diversity in the prefab house. Hence fragmentary units are a problem. This reason is why the public rental housing is for newly married couples, the single professionals, or the elderly. Thus, Lee and his partners maintain that the space of prefab homes should be diverse for a variety of classes and lifestyles.[10] My research is different from this finding. This is because the prefab house is for the private home. In Korea, apartment units of the building have been the main residential building type from 1970 to 2016 now. But as the price of apartment and Jun-se (Korean rental system) are increasing in Korea, therefore, this environment is prodding Koreans to buy homes. Today, Koreans are expending money for getting their own home instead of an apartment unit. Thus, my research

[10] Hyun-Rim Lee, "The Study on the Utilization of Prefabricated House as Public Rental Housing," 44.

can suggest the possibility of design perception beyond only affordable public housing. In Korea, most clients want to build their house quickly and cheaply[11]. Therefore, cost and time are big issues in the construction part. If we suggest a way to reduce cost by decreasing construction time and budget, mid-income Koreans' perception for prefab design must be generous.

1. 1956, First precast housing, the American-Korean Foundation (A.K.F.)
2. 1960-1970 Government housing
3. General wooden prefab house (1970-1980 disappear for technique, 1990-2016 appear in Suburban)
4. Government prefab housing (2012)
5. Construction firms' prefab housing (2014)

Figure 1.14 History of Korean Prefab Architecture

[11] Personal discussion with my first client on June 31, 2014.

1.12 Reason of Failure (Global-Korea)

1. Prefab system was for cost oriented development.

2. In the past, they focus on the affordability and development without considering design quality.

3. There was no relationship between architects' ideal and business

4. Prefab architecture could not overcome negative images of prefab from clients (cheap structure, less durability)

5. Prefab architecture was led by Government or Construction firm. Therefore, there was low design quality.

1.13 Benefits of Prefab

Equally importantly, in "Shigeru Ban" by Matilda Mcquaid, Macquaid argues that Japanese prefabrication systems could be developed in their environment in Japan. This research is meaningful for my Doctoral project to understand eastern prefabrication and its situation because Japan is close to Korea, I can reference its prefab system. In Japan, the prefab is succeeded unlike in Korea. Thus, the author's key idea is from lots of prefabrication designs by Shigeru Ban[12]. The writer aims to show prefabrication detail and its test results. Those are general benefits; Save time and money for construction, High-quality control for climate, Customization in advance, Response for family's size, Quick application after Disaster, Temporary structures for Homeless

Figure 1.15 Prefab Architecture's benefits

[12] Joseph Tanney, *Modern Modular: The Prefab houses of Resolution: 4 Architecture* (New York: Princeton Architectural Press, 2014).

Point of view for Korean prefab house

1. If we do not have a land, we can build a house on the rented (leased) site. After the rental time, we can disassemble the house, move it, and Re-assemble again.
2. We can not only revise length of house but also expand or reduce the house according to the life cycle.
3. We can order a prefab house on the internet and delivery it without big discussion and whole construction.

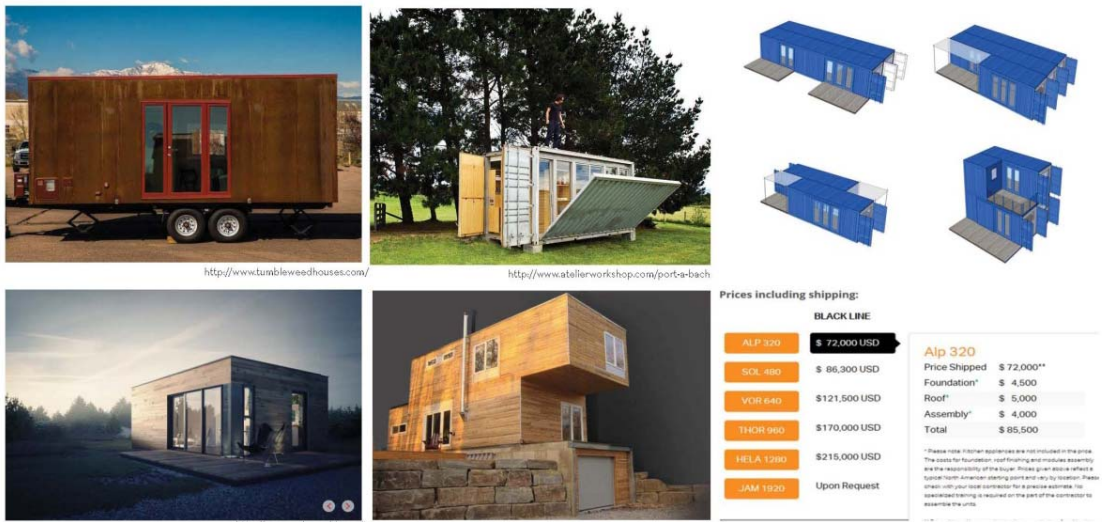


Figure 1.16 Three Benefits

1.14 Literature Review

In Allison Arieff book *" PREFAB,"* point is how to define prefab houses. In the book, a history of prefabrication house is a major issue. Therefore, Arieff argues historical factors for prefab houses, which were started by Raymond Parsons. Raymond mentions that

> *" I t can almost be taken for granted that when good prefabricated house become a fact, their architectural style will be different from the quaint English cottages and Cape Cod Colonials that are the present favorites of the speculative builders. The idea that we should take new and better building materials and mold them into the lines and textures of old materials possessing and number of shortcomings is abhorrent."*[13]

Also, Parsons explains the background of prefab houses in the world. In particular, the modern part of prefabrication is important to him. This is because Parsons asks us why prefab houses are customary. Parsons states that prefabrication houses could have good quality and unique characteristics. Even though there is no detailed drawing, the backgrounds of customized prefabrication house would be useful to find out my direction.

Furthermore, in *"PreFab"* by Alejandro Bahamon, his key sources that the terminology of prefabrication, are introduced by five contents. Their sources are mobile, light, dismountable, modular, and adaptable. Bahamon divides

[13] Allison Arieff, *PREFAB* (Utah: Gibbs Smith, 2002), 9.

prefabrication types by his standards.[14] It is desirable for me to get specific definitions and classifications that are connected with prefabrication. In the book, Bahamon provides a variety of projects with construction issues. Moreover, he states that their big idea and main characteristics are. I think that it is practical since it includes broad ideas beyond conventional ones. Through this book, I investigate prefabrication's plan and figure out a direction for Korean prefab homes.

In "Modern Modular: The Prefab houses of Resolution: 4 Architecture" Joseph Tanney and Robert Luntz[15], the key sources are private houses by using prefabrication system. They argue that their typology matrix has designed over 120 prefab homes on the Modern Modular. Their major issue is to investigate customization for prefabrication plans. They designed many projects from big to small prefab. Their main idea is that by adding numbers of boxes, the house could be bigger. In this case, the main idea is similar to my doctoral project. I think that prefab homes are not any more only mass-produced units. On the other hand, they could be customized well for private homes.

Additionally, Pamela Bell argues that New Zealand's prefab is developed, *"Kiwi Prefab: Prefabricated Housing in New Zealand."* Bell is not only a researcher but also

[14] Alejandro Bahamon, *Pre Fab* (New York: Loft Publications, 2002).
[15] Joseph Tanney, *Modern Modular: The Prefab houses of Resolution: 4 Architecture* (New York: Princeton Architectural Press, 2014).

a New Zealand architect, who manages own prefab company. Thus, the key sources have effective and significant materials more than other resources. Furthermore, this thesis includes both western prefab houses and eastern prefab houses. Bell explains that what is important. The key sources are diverse and good quality in research. To be specific, the author changes the prefabrication to contemporary designs and trends.

Lastly, Jill Herbers wrote what future prefabrication houses are in "*Prefab Modern,"* This book is very desirable for my research. This is attributed to the fact that it includes future prefabrication house design in its chapter 3[16]. Furthermore, the author argues construction parts, cost information, and prefabrication guidelines. Herbers argues that the cost part is important for prefab houses. Thus, Herbers insists that to get a reasonable cost; the architect should make an effort by researching prefab houses. Also, its future examples from the book would help me to build new ideas for Korean prefabricated houses. Finally, at the last part of the book, the author provides building guideline. Herbers examines prefabrication houses and thus she could make guidelines for prefab houses. As a result, the author provides practical details for prefabrications. She argues that components and system are important. Herbers suggests that the history of prefabrication can be divided by materiality such as concrete or wood construction.

[16] Jill Herbers, *Prefab Modern (*New York: Harper Collins, 2004), 136.

Part 2 | Applied Research & Initial design

2. Case Studies

2.1 Kings road house (Richard Neutra)

I visited this project in Dec 2016 as field study. The kings road house is great prefab architecture legacy. I have researched light study and details between Concrete walls and slim glass. Therefore, I imagine tilt-up construction process. Moreover, the program is different with general house. To be specific, there is no conventional living room, dining room or bedrooms in the house. The residence was meant to be a cooperative live/work space for two young families. The concrete walls and sliding glass panels made novel use of industrial materials, while the open floor plan integrated the external environment into the residence, setting a precedent for California architecture in particular.

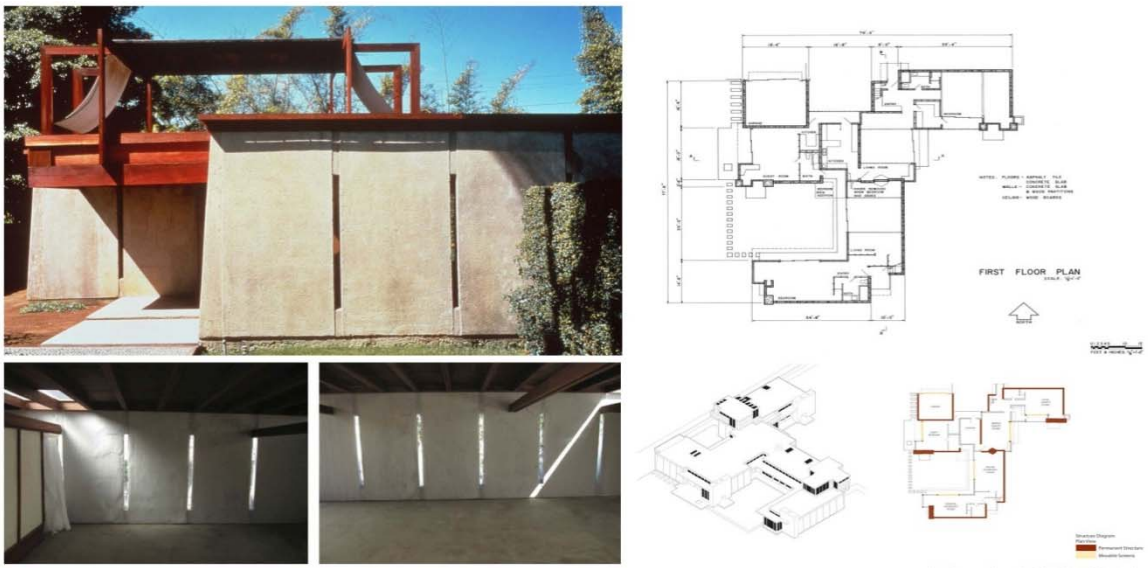


Figure 2.1 Kings Road House

The Schindler House (Richard Neutra), Dec. 30. 2016

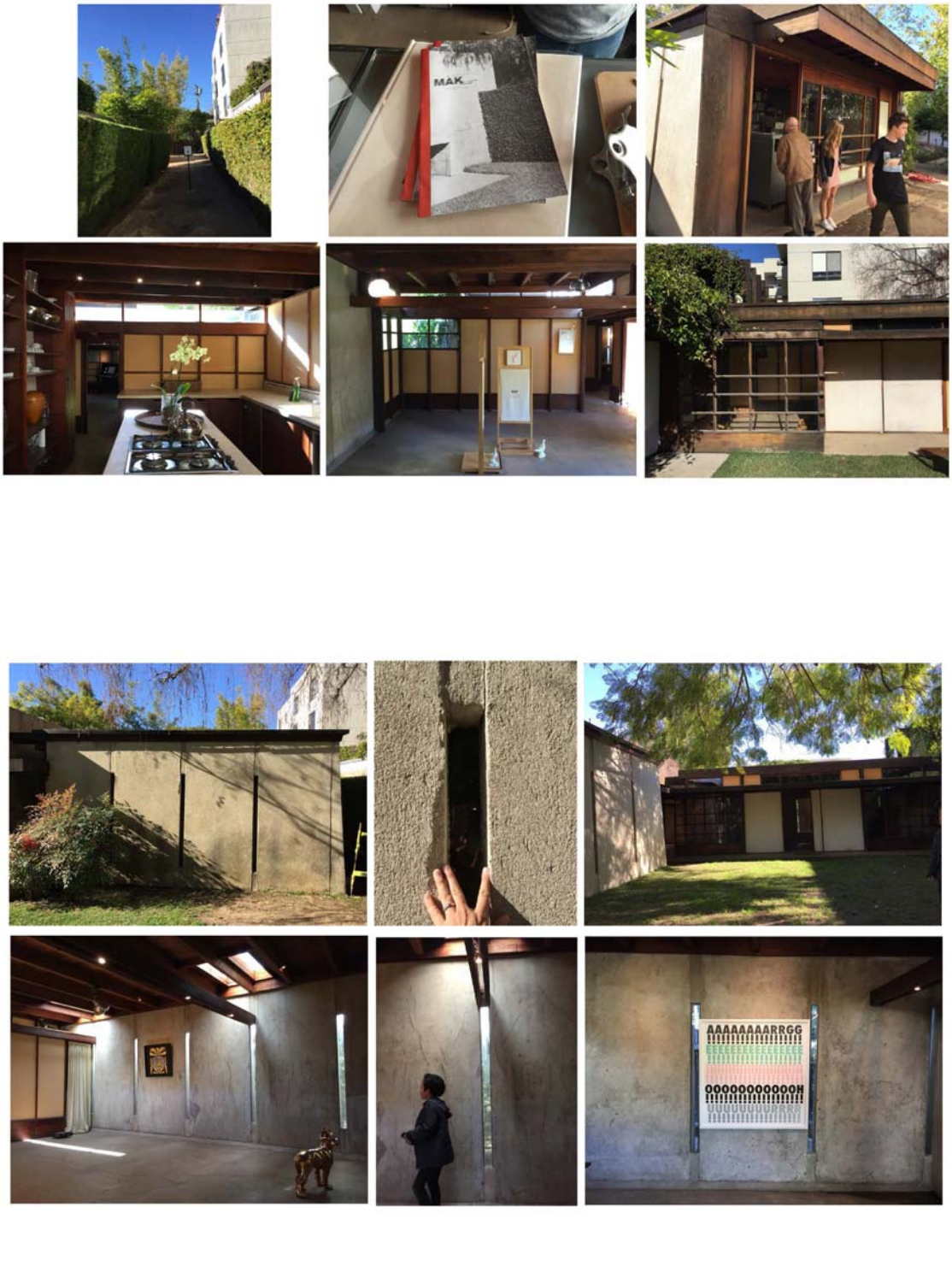


Figure 2.2 Field Study at Kings Road House, Dec 2016

2.2 Usonia house (Flank Llyod Wright)

After prairie house designing the Frank Llyod wright, he changed his architectural focus for middle income people. Usonia House is a pragmatic housing type that is as widely known as wright's Prairie House. Oil Smithsonian house is the right size demonstrated corrosive-free light that appears in the initial housing and suburban housing means, which are more efficient for planning, and keeping building costs low. Wright wanted to spread the economic housing that might be artistic to America. Thus, in 1937, in Madison, Wisconsin, Wright designed the first Usonian House. First-floor heating was realized in the United States with heating pipes on the floor, and bricks were used for structural walls and chimneys to support the roof.

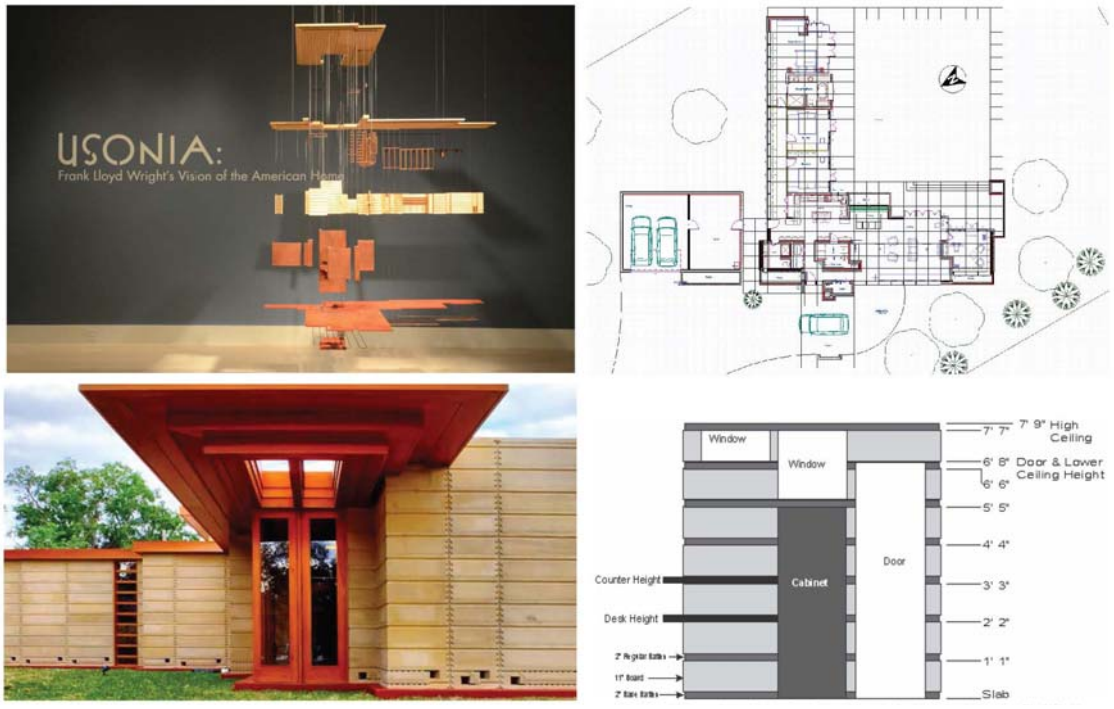


Figure 2.3 Usonia House

2.3 Miller House (Eero Saarinen)

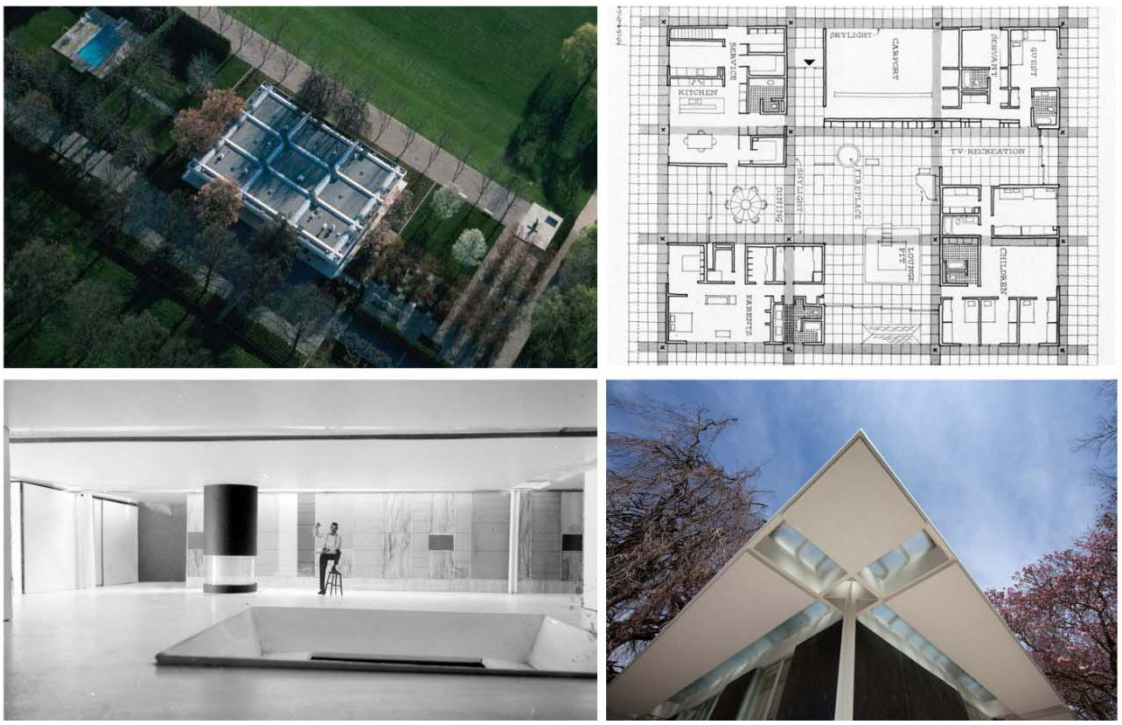


Figure 2.4 Miller House

Eero Saarinen's steel and glass composition has held together very well, proving the quality and use of materials to be worthy of being considered innovative for its time. Light and column details are present in its design.

Saarinen placed skylights throughout the house so that there was a supply of natural light. Saarinen placed these strategically so that the rooms with the highest necessity got the most light.

2.4 Eichler house (Joseph Eichler)

Eichler's radical contribution to the Mid-Century Modern movement was to strip it down and make it affordable and, to sell his homes to anyone who wanted to buy one. This strategy made him unique, because back in the 1940s, racial housing discrimination was still widely practiced. Joseph Eichler was the only merchant builder in America who built modernist style homes on a large scale, designed by famous architects and using quality materials. Uniquely, all of his houses has an inner courtyard. His contemporary houses have not been equaled since, and 50 years on they still look great from a design approach.

Figure 2.5 Eichler house

2.5 Case study house 16, 18 (Craig Ellwood)

Figure 2.6 Case Study House

The Case Study House program was a unique event. The program seeks to respond to the postwar building boom with prototype homes that would be both replicated and affordable to the average income people.

Using a prefabricated steel frame and wall panel system, Case Study 318 was Elwood's most successful attempt at integrating industry into the design and construction of a prefab house. One of the first purposes of the house is to show how good design quality could be best applied to prefabrication. Frames and panels are showing the base of the prefab architecture approach.

2.6 ELEVATE STRUCTUR (Hawaii, USA)

- Not only ADA But also Unban Applications (Commercial, Advertising, Homeless, Government use), Consideration for land problem (on empty parking space)
- Working for Elevate Structure Company (Feb.2016 - Present)

I developed many prototypes and application into an urban setting with ELEVATE Structure Company. I researched and illustrated many types of projects from the prototype with Nathan Toothman P.E. I found that the prefab architectures can be easily applied in an urban setting. Also, the construction trend needs prefab architecture globally. To be specific, I helped the design for affordable housing in India and homeless housing developments for San Francisco. Moreover, I am researching a new elevated structure system by using prefab steel frames.

Figure 2.7 Design Developments with Nathan Toothman P.E.

2.7 Prefab architecture (Germany)

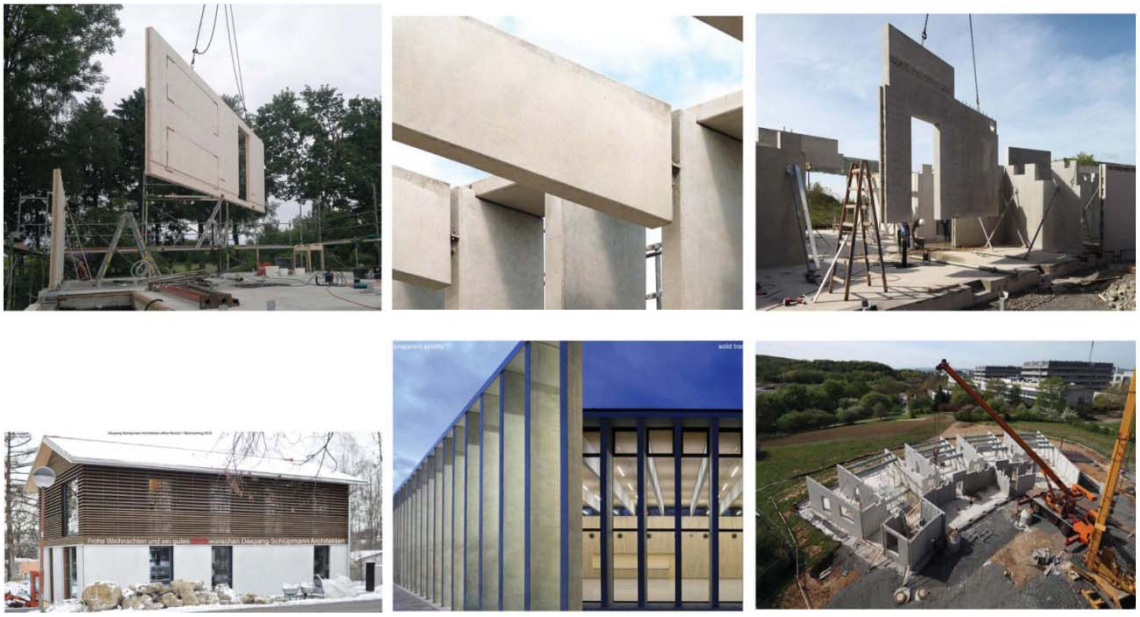


Figure 2.8 Office home and Kindergarten project

I have researched Cross Laminated Timer (CLT), Thermal Modified Timber (TMT), and precast concrete projects designed by prof. Martin Despang. Utilizing factory produced precast elements in the form of insulated sandwich panels for the exterior walls and thinner slabs for interior bearing elements ensured rapid assembly and better quality control. A limited amount of joints also aided in the rapid assembly with only a few minor interior demising walls requiring infill construction components. As the concrete walls radiate from the centroid of the conical floor plan, their non-parallel orientation in combination with ceiling mounted wood diffusers lends itself to enhanced acoustical properties typically not associated with predominantly concrete construction.

2.8 MIMA housing (Portugal)

MIMA architects researched for years to design a fast produced, flexible, light and cheap, yet good quality product, wrapped up with a pleasant, clean design. MIMA uses prefabricated construction methods, the secret for its quick production and low price. Likewise, traditional Japanese residential post-and-beam construction could be considered an inherent system of prefabrication. It was based on regularized column spacing known as the ken, the infill elements of shoji screens, fusuma panels and tatami mats, prefabricated by individual craftsmen in different locations of Japan could be precisely put together, almost like pieces of a puzzle.

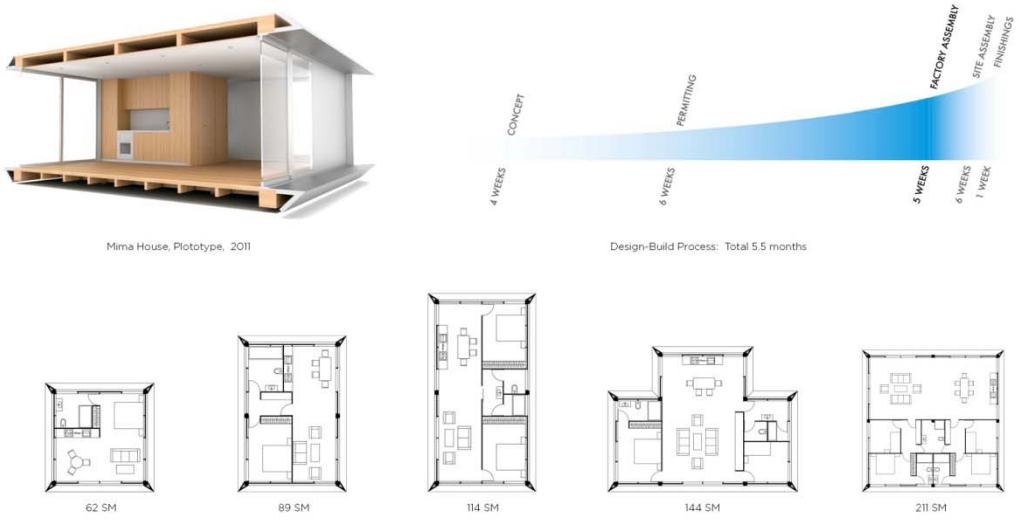


Figure 2.9 Mima housing and plan options

2.9 MUJI House (Japan)

A global household goods company based in Japan, ‘Muinyangpum,' makes and sells houses by using the prefab system. After the collapse of the bubble, the housing market in Japan has not escaped from the recession, but there is still a continuing demand. Unmanned products have sought the demand. What market are they looking at? The case of the unmanned product has implications in Korea, where the population is rapidly decreasing as in Japan.

It is in 2004 when it was considered to be just after the bubble housing collapse that unmanned goods started selling houses. After the collapse of the bubble, Japanese people rarely tried to buy stock houses (in Japan, used houses) that somebody lived in. When the price of real estate continues to rise, the depreciation of buildings was not

Figure 2.10 Muji House

taken into consideration because of rising land prices when buying a house, but the situation is different now. It is due to the nature of the building, which is worthless to zero after 30 years of construction. Real estate is not an attractive asset if the value of a building falls without land prices rising. Of course, an inventory house is not cheap either. So it is natural that inventory housing transactions do not work well. On the other hand, there is still demand new construction. It is because of the desire for "my space." As a result, it is "overwhelming" compared to the stock housing transaction which used new housing demand. However, building a new building is not economically feasible due to cost problems.

In this dilemma, the solution that Japanese society finds is an architecture called pre-fabricated. Prefabran is a way to build buildings on site using pre-cut materials. According to statistics from Japan, the number of new buildings using the prefab method was 11,850 last year, 13% of the total (82,398 cases). Sekisui House and Daiwa House are leading companies in the housing construction market using prefab method. That's not all. In fact, the core of the prefab method is the unification of the standard through factory production and maintenance of high quality rather than the low price. The quality of the final product can be kept uniform and high regardless of the skill of the field workers. Also, the period of construction on site can be drastically shortened, and the complaints of neighbors can be minimized. Regardless of the conditions of the land, pre-built ‘ready-made’ houses are uniform and average, which may lead to the side effect of being disabled. In the new housing market, which reflects

the demand 'my space,' it will be a big drawback. Unmanned products added one important factor to overcome these shortcomings.

2.10 Prefab Han-Ok (Korea)

This building is vulnerable to soundproofing and insulation as well as a structure that does not fit the modern life that pursues convenience and comfort. It is due to the construction cost of 8,000 to 10 million won per square meter. According to Professor Seok-Ho Lim, a research fellow at the Korea Institute of Construction Technology' "The use of double insulation and triangular windows minimizes the heat that is taken to the outside, and the soundproofing satisfies the performance requirements of the building method " The process of moving and assembling modules from the factory to the site is

일반 한옥과 모듈형 한옥 비교

구분	일반 한옥	모듈형 한옥
3.3㎡당 건축비	1000만~1500만원	500만~700만원
현장 공사 기간	3개월	2주~1개월
특징	현장에서 대부분 공정 진행 서까래, 기와 수작업	공장에서 벽체, 문틀 만들어 현장에서 조립 전체 공정 70% 이상 공장서 진행

Figure 2.11 Han-ok prefab architecture

enough for just one day. The design, materials, and construction are standardized and automated, making it possible to build up to 4,000,000 won per 3.3 ㎡. This design is merely an imitation of the past of housing design. Although some people may like this design, there are discussions to the board application.

3. Material research

3.1 Materiality of Prefab (Concrete)

1) Grace Pacific Precast + Rocky Mountain= GPRM Prestress,

I have to solve the precast curvert in terms of prototype's length, thickness and details. Therefore, I researched precast concrete by visiting and having professional meetings with GPRM in Hawaii. I have an idea for prefab architecture for future construction through the several meetings for detail development and cost estimate with their engineers.

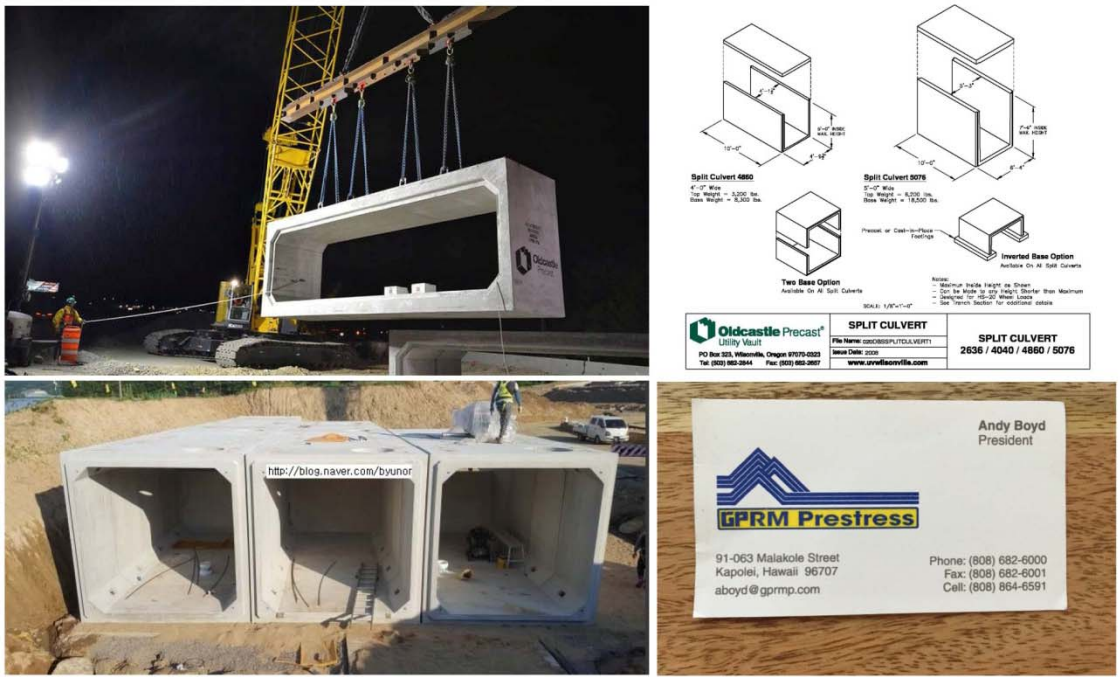


Figure 3.1 Precast Concrete Culvert and GPRM Precast firm's Consulting

Precast Concrete

I think that this building is recently built by using the precast concrete system. To be specific, the vault is enveloped by the “veil,” a porous, honeycomb-like, exterior structure that spans across the block-long building and provides filtered natural daylight.

Dubbed “the veil and the vault,” the museum’s design merges the two key programs of the building: public exhibition space and the storage that will support The Broad Art Foundation’s extensive lending activities. Rather than relegate the storage to secondary status, “the vault” plays a key role in shaping the museum experience from entry to exit. Its heavy opaque mass is always in view, hovering midway in the building. Its carved underside shapes the lobby below and public circulation routes. Its top surface is the floor of the third-floor galleries.

Figure 3.2 Broad Museum, Diller Scofidio + Renfro (2015)

Fabricated mold system

Figure 3.3 Unique mold system

In this project, the special type of mold system is used to prefab idea. A steel plate split-mold system was fabricated to construct the series of 3-dimensional curved facade structure. The concrete was poured into the 3-dimensional mold which required the cast to be separated at the inflection point. The method of color coding helped the field workers to easily understand the process, which also created a new working environment for the construction crew. In order to create this free- form surface, we need to profile our data at this stage. The fade integrates several similar curvatures that form a curved surface and makes a reasonable unit system. This process is a basic step for an economical and efficient production. Dongdaemun Design Plaza by Zaha Hadid in Seoul is an example of a project that was essential to this process. Because DDP was designed to be curved throughout the building, both inside and outside, profiling was an

important task that linked to the calculation of quantity. At first glance, it was a free-form surface or a completely irregular-shaped surface, but the construction was done with a combination of rationalized unit surfaces.

Meanwhile, the Hannam-dong project also included the profiling of roving frames in the design process.Although it seems to be ruggedly irregular at first glance, it crosses the A type frame (the leftmost standard of the second floor) and the B-type frame (the second standard from the left of the second floor), ABAB on the second and fourth floor, BABA on the third and fifth floor Arranged. The building has patterned of irregularly shaped balconies. The balconies are the leftmost started of the second while the floor B-type frame are the started for the left of the next floor.

Precast Box Culvert

The significance of improving efficiency through shortening of the construction time and the factory by using the culvert which is used as the structure and the exterior material has been diluted with the trial and error in actual construction. However, the modularity of each room and the minimal addition of architectural devices make it possible to predict the scalability of the scale and the flexibility of the usage transformations.

This is read as the architect's intention calculated from the beginning. I tried to put the variation of the room positively according to the constitution of the visitor and the usage pattern through the placement experiment of the cask box beyond the limit of the given site. If the careful consideration of specialized furniture systems and finishing materials for each room's circulation rings (e.g., living room> café> warehouse> room) is accompanied by close attention to structural flexibility and architectural flexibility that encompasses a variety of programs Can be. This prefab design is an experimental construction that goes beyond the boundaries between the uses and functions outside the prescribed framework, as Jeju Island weekend houses should be able to do so.

Figure 3.4 Precast concrete culvert project, Jegong Architects

Precast panel + insulation + Stone finish

To apply on Korean environment, I have to consider insulation with the precast concrete structures. Moreover, the finish layer can be designed.

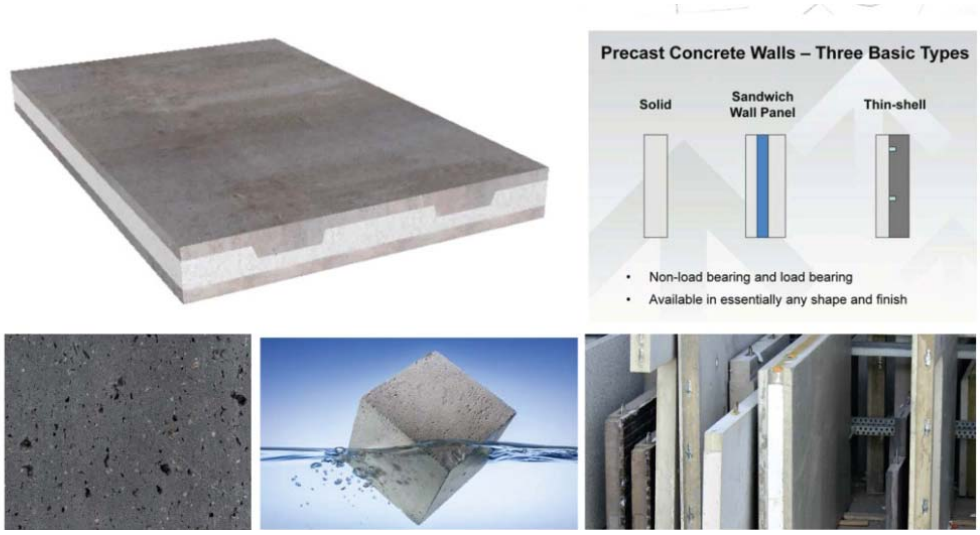


Figure 3.5 Precast insulation

Figure 3.6 Light weight Concrete

3.2 Materiality of Prefab (Solid Timber)

There are general Cross Laminated Timber types. Mostly, it has used glue to attach different layers together. However, I tried to research new type of CLT system. It is Cross Nailed Timber (CNT).

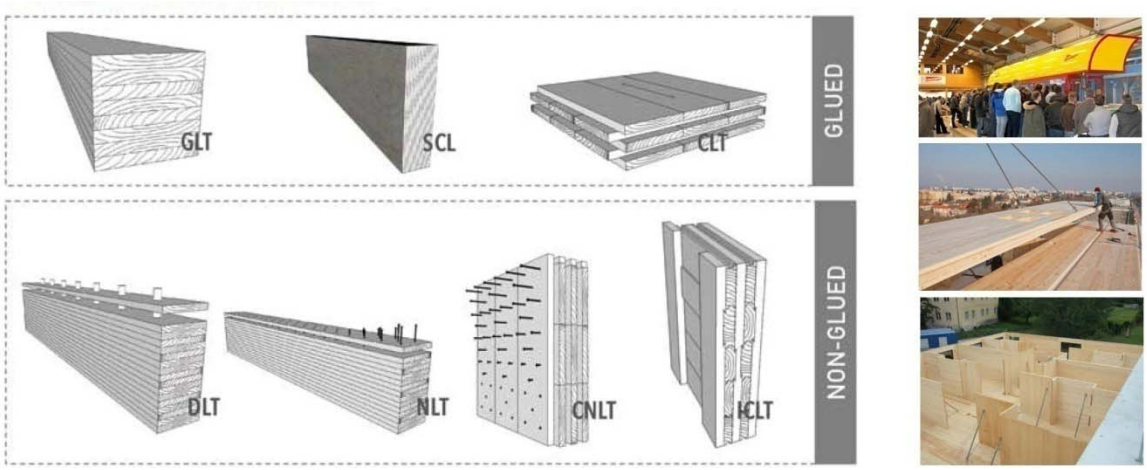


Figure 3.7 Cross Laminated Timber system (CLT and CNT)

Figure 3.8 Aluminum nails and CNT sample

Cross Laminated Timber (CLT)

Biggest wooden roof pavilion

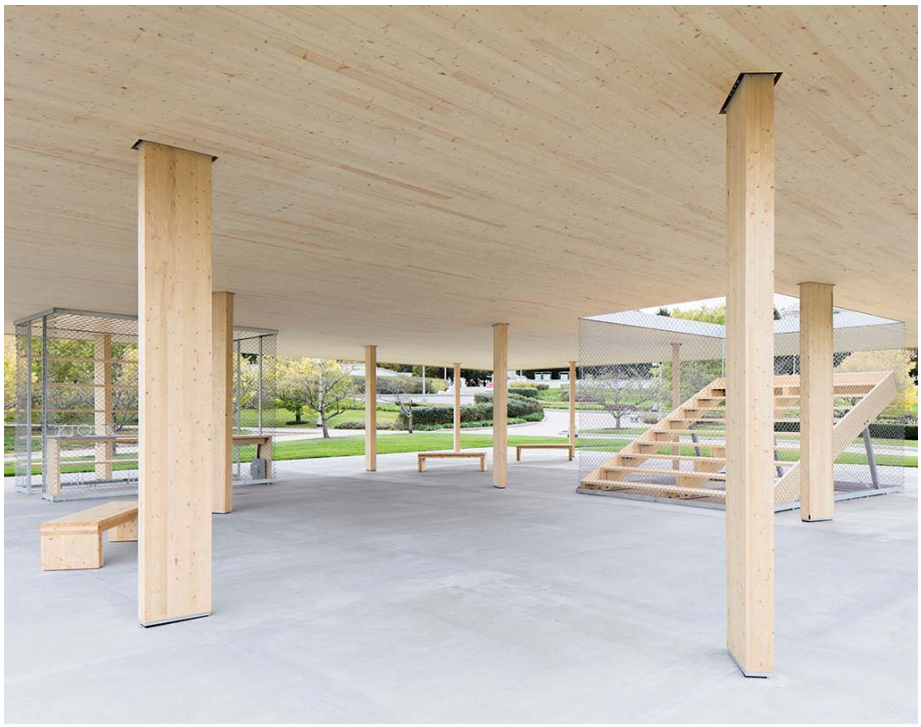


Figure 3.9 CLT project, Ultramoderne Studio, 2015

This project is purely used CLT. It is showing the possibility to get customized roof with CLT. The pavilion roof structure represents the application of the principles of a flat plate (typical to concrete construction) to the material of wood. Two layers of CLT panels—one layer oriented in each principal direction, and each outer layer oriented lengthwise to the 8-foot-wide by 56-foot-long panels—combine to form a two-way spanning plate supported at points by columns. Each layer carries bending in the

direction of the panel, with the layer above or below providing a shear transfer between adjacent panels (and vice versa in the other direction). The result is a surprisingly thin 8.25-inch roof structure that spans upward of 30 feet between columns.

Benefits CNT over CLT

I propose Cross Nail-Laminated Timber dwellage (CNT) with thin light in the Schindler House. Moreover, I think the dead trees in the local areas are abundant so that they can be materialized through CNTing. The structural system of solidarity compensates the imperfection of the single individual board. Finally, the advantage of CNT over general CLT is glue outgazing. For gluing, lumber needs to be milled to the exact size because it is expensive. The solid timber with only these has both having thermal mass and R-value, so it's ideal for year-round thermal comfort.

Thermal Modified Timber (TMT)

By using TMT technique, the woods are able to get more durability.

Figure 3.10 TMT Hawaii local wood sample

Materiality of Prefab (Metal)

Later efforts in pre-fabricated structures included multi-use designs for African colonies. These structures could be catered to their tropical climate with attachable louver systems and panels featuring portholes. A large number of these structures were built in Brazzaville, Republic of the Congo, where in some cases numerous structures were connected or bridged together. Other prefabricated structures included a temporary school in Villejuif (1956), the Métropole House (1949, winner of competition for a mass-producible rural school with classroom and teacher accommodation), and a filling station for energy company Total (1969).

Figure 3.11 Jean Prouve's prefab architecture

3.4 Technology of Prefab (3D Printing)

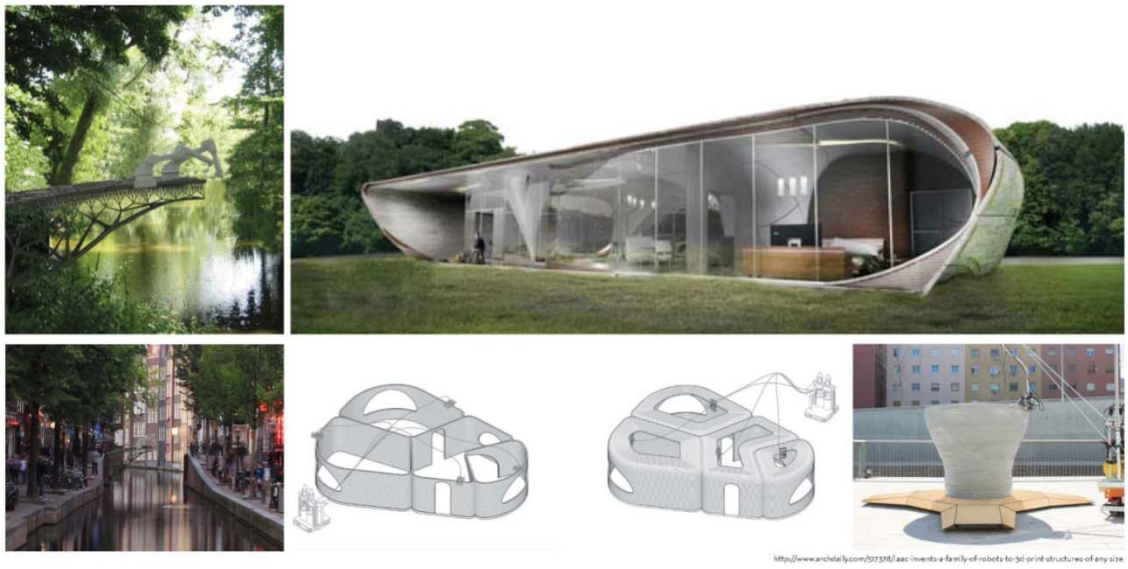


Figure 3.12 3D printing projects, WATG

Recently, we are focusing on the possibility of 3D print. I think that it can be great construction method on site.- 'The Freeform Home Design Challenge' 3D printing competition Winner 2016, 2017 start

- IAAC Invents a Family of Robots to 3D Print Structures of Any Size (Jun. 2014)

  recognizing the limitations on the size of 3D printers, the Institute for Advanced Architecture of Catalonia (IAAC) has developed a family of

  three small, mobile robots which together can print a structure of any size.

3.5 Technology of Prefab (Robotic-Fiber)

- Achim Menges to Create Robotic Pavilion for V&A (Sep. 6. 2016)

Figure 3.13 Robotic structure, Achim Menges

Elytra Filament Pavilion will explore the impact of emerging robotic technologies on architectural design, engineering, and make," says the V&A. "Inspired by a lightweight construction principle found in nature, the fibrous structures of the forewing shells of flying beetles known as elytra, the Pavilion will be an undulating canopy of tightly-woven carbon fiber cells created using a novel robotic production process."

3.6 Technology of Prefab (Robotic-Brick)

- 'This Brick-Laying Robot Can Construct an Entire House in Just 2 Days (Jul.2016)

The machine even has the ability to leave spaces in the brickwork to make room for wiring and plumbing and can be used with a wide range of block sizes. The high-level accuracy of the finished product means very little human intervention is necessary – simply design the structure in CAD and hit send.

The robot is the result of 10 years and £4.5 million of research and development, and Fastbrick hopes that it will be able to streamline the construction process, saving clients time and money.

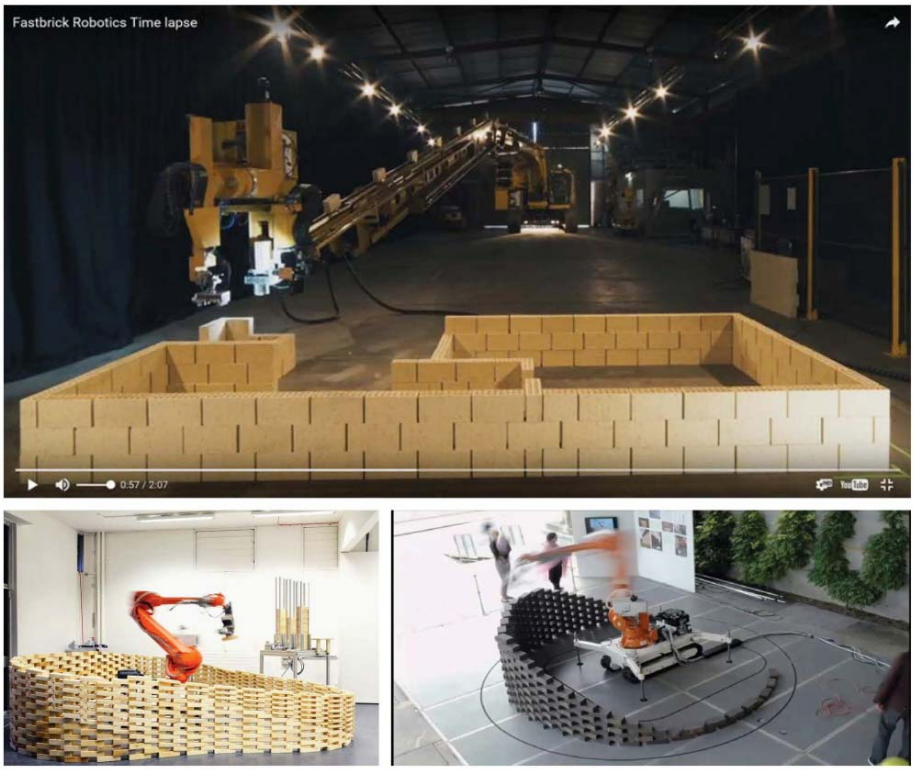


Figure 3.14 Robotic Construction

3.7 Semi conclusion (Design adopted parts)

Based on the research, I chose the main material for the design research project as precast concrete and CNT and TMT wood system. Steel or 3D printing is expensive to apply to universal homes and also is not familiar to consumers, so I use concrete and wood to accommodate more sophisticated details and prefab systems. I think that precast concrete and CNT + TMT system were the most needed materials in Korea

King roads house

After exploring the Kings Roadhouse, I found many advantages inside. At that time, the building was built with a breakthrough tilt-up system and was rather interesting because it was not conventional construction way.

Unit Design (Type1)

The initial design is C-shaped as well as the cross-section. The outer side was tightly closed, but the inside of the eye was easily visible. This design made it possible to reduce or extend this house according to the demand or change of the family based on the standard form.

Unit Design (type2)

The initial design is detailed but shows the combination of an important wood and aluminum nail. There are nails and air caps on the inside of the thick solid on the top and bottom.

Environment Model (Green walls, movable Roof, perforated sliding doors)

PHPP TEST

Material in Korean timber

Larch is the most abundant timber in Korea, but the goal is to recycle dead trees during times of drought and insect infestations.

Simple building

I studied Korean cities and rural areas, but it is hard to have a real ideal housing type in the city center, so I designed a prefab house with a one story building through the new systems and high-end plan at a satellite city.

Budget Range

Meeting with GPRM, Steve Hill, and the local company has established buildable design an approximate budget range.

4. Initial Design for Korean Prefab Housing

Initial Design Development

Initial Physical models for Philosophy support

- Light and Shadow (In Praise of Shadows, Junichiro Tanizaki)

- Phenomenology; Experience and Perception (The eyes of skin, Juhani Pallasmaa)

4.1 Prototype-1 Precast culvert

Expanding and Reducing

Transportation

Shading system research (Sean Godsell's projects)
:Green House , Edward Street House, Tanderra House

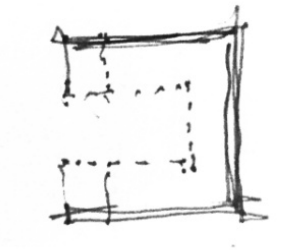


Figure 4.1 Initial design sketch

To check energy efficiency, I use Passive House Planning Package (PHPP) program.

I took test by using many design options for the shading of building. This design can been analysed and optimised with reference to energy efficiency.

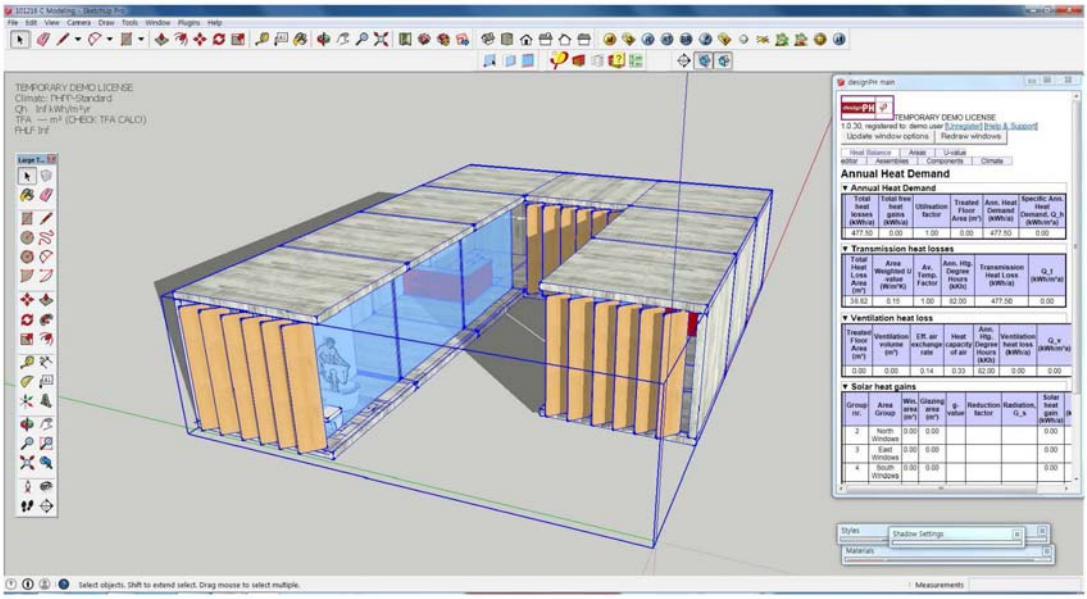


Figure 4.2 Environmental model

Figure 4. 3 PHPP test

Figure 4.4 Initial design structure

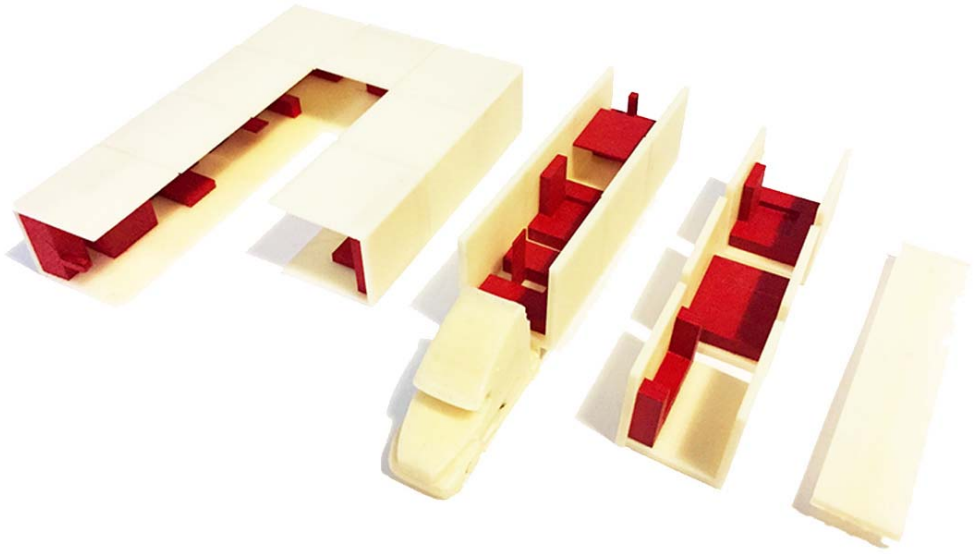


Figure 4.5 Prefab Logistics

Figure 4.6 Indoor space rendering

I made intial design models based on the precast culvert idea. By doing so, I can understand relationship between light and my design.

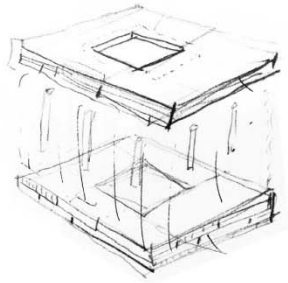
Figure 4.7 Initial physical models

4.2 Prototype-2 Cross Nail LaminateTimber

CNT Details,

Finding courtyard location and reasonable size

Wood market in Korea, Ethylene Tetrafluoroethylene(ETFE) roof detail



Type-2 Cross Nail LaminateTimber;
Courtyard location and size

Figure 4.8 Initial design sketch

Figure 4.9 General CLT details

Japanese larch (self-sufficiency of Korean wood)

Among artificial reproduction woods, Japanese larch is a huge amount. Quickly growing, the truck is straight, can be produced in short time. Strong for harmful insects. The Wood structure is helpful for an earthquake because the force is according to the building's weight.

Figure 4.10 Self-sufficiency wood species in Korea

I decided that to pass the PHPP test for better energy efficiency, I use perforating sliding doors with the windows.

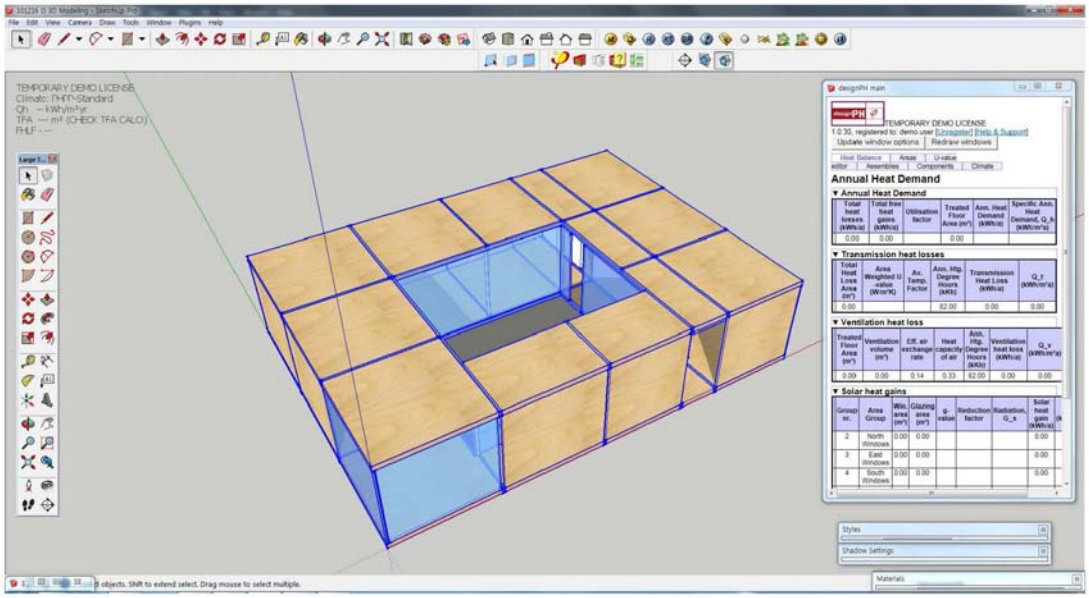


Figure 4.11 PHPP test

Figure 4.12 Initial physical model and Courtyard rendering

Figure 4.13 Initial design structure

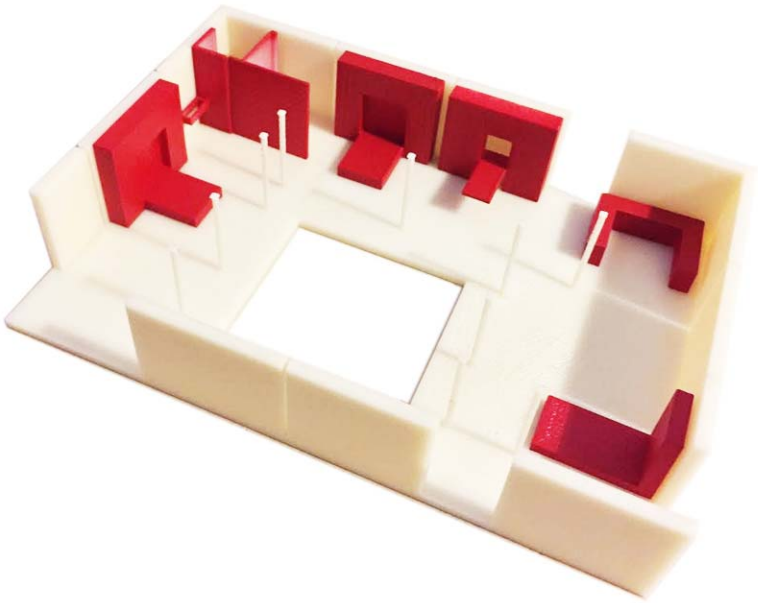


Figure 4.14 Prefab logistics

Figure 4.15 Initial design for main entrance

Part 3 | Design & Prototype

5. Pilot Design Project

The selected site is a satellite city belonging to the city of Busan. Busan is the second largest city in Korea, and the “Kijang” is the second largest city in Busan. The site has the convenience of being close to the city center as well as the surroundings where it can produce food that is impossible in the city.

5.1 Preliminary Analysis (Macro)

The city of Busan, Korea, is the city of refugees that began during 1910-1950 and is Korea's largest maritime city. It is a city where many people come and go, but on the other hand, the urban element is less developed than Seoul after 1950. However, the survey shows that Haeundae, located in the eastern part of Busan, has the highest increase of housing price in Korea. As a result, the residential environment is being expanded with the Kijang, which is a nearby subcenter.

5.2 Site Analysis (Micro)

For the site, micro-fact is a suitable environment for a new satellite city planning, close to markets, government facilities, sports facilities, and abundant forests already existing with the mountain.

5.3 Site Design Concept

First, in designing a satellite city, the design concept is not a car but a pedestrian-oriented town. It is believed that It will become a post-fossil satellite city because we are discussing the appearance of the city after the world of petroleum energy.

The site plan is located in the northern and southern part of the forest. So, in the north, a green precast concrete village was placed south facing a wooden village using CNT system. Instead, in the site section, residents' convenience facilities, mainly forest roads, were used, and the two villages were connected using permeable paving materials. It is a pedestrian-centered village, but the car drivers were intended to automatically slow down. , The site construction order is prefab system in both villages, but CNT type is given priority for the development of the underdeveloped Korean modern wooden house culture.

illustrations

Renderings show the facilities where the two villages meet. Farther, CNT type towns and close-ups provide everything you need as a village. Pedestrians gain full freedom from the vehicles, especially within each village; and instead, use cargo bikes as the main means of transport within the village.

5.4 Community facilities

I made community by using same structures with the housing prototypes. The library, the elderly facility, and the kindergarten are located in the courtyard type (CNT Structure) and other small-scale facilities. Small schools, cafes, and other facilities are placed in C-type facilities (Precast Concrete). In the CNT structure. Functionally, we use movable ETFE roof to create a unique community culture in winter.

5.5 Site Design

Post-fossil satellite / Post-fossil Tectonic / Post-fossil Dwelling

Applied Site

City cannot make feeding itselt

POST-FOSSIL SATELLITE

"Satellite communities feed the cities." I propose a post-fossil city with an existing site by applying post-fossil tectonics and a post-fossil dwelling system to make more actual and factual proposal. The site is located in the Korea. This is because there is a distinct transition of four seasons. Therefore, we have to figure out not only summer cooling but also winter insulation to reduce fossil energy. Moreover, I believe that we will not have any more fossil fuels in the future. Thus, this pilot project starts on a small neighborhood scale. For the post-fossil city, I suggest post-fossil tectonics and dwelling..

Figure 5.1 Post-fossil satellite

Figure 5.2 Pilot project: Gijang, Busan in Korea

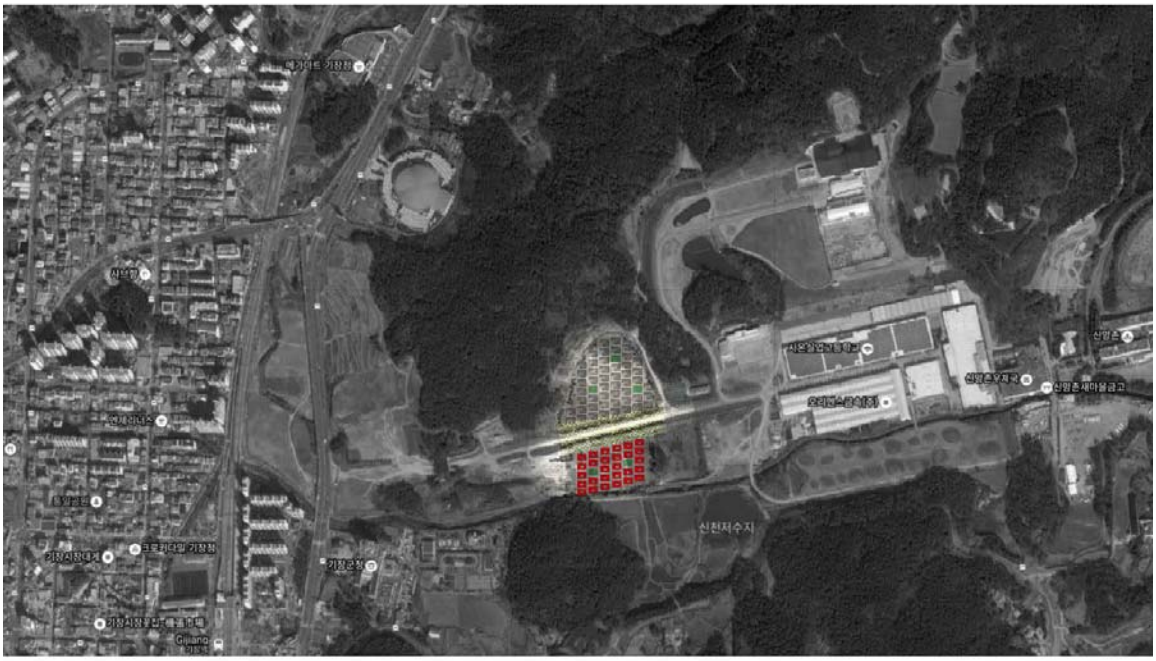


Figure 5.3 Micro site location

Figure 5.4 Main transportation in the Prefab village

Figure 5.5 Permeable paving system on the whole site including roads

Figure 5.6 Pedestrian oriented street

Figure 5.7 Slow cars

Figure 5.8 Wooden community

Figure 5.9 Indoor space

Figure 5.10 CNT Prefab village in winter

Figure 5.11 Courtyard with ETFE roof in winter

Figure 5.12 Commercial space in the Precast concrete village

Figure 5.13 Street Community

Figure 5.14 Elderly space

Figure 5.15 CNT House courtyard

Figure 5.16 Christmas season

Figure 5.17 Deck

Figure 5.18 Post-Fossil Satellite site model

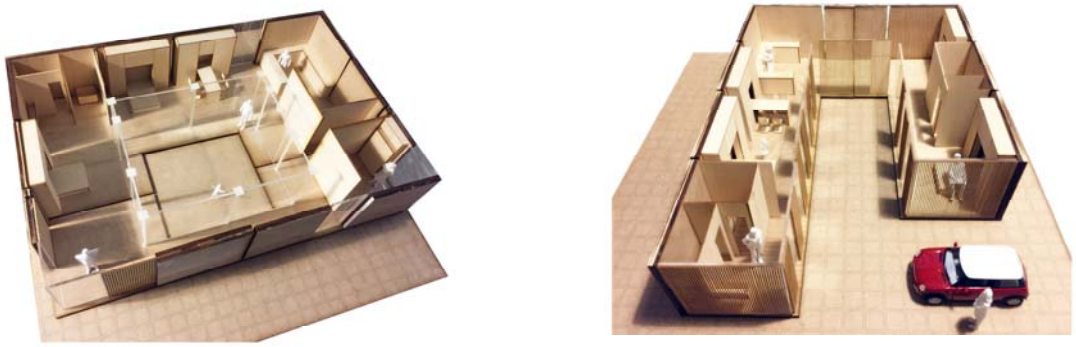


Figure 5.19 Two prototypes in the Architecture Model

Figure 5.20 Architecture Model with roof

Figure 5.21 Relationship between outdoor and indoor space

6. Housing unit-1: Precast Concrete Culvert House

6.1 Design concept

Unit design standards include a cozy C-type dining room with an antebellum, main bath, dining room, kitchen, and kids' room. All of the furniture was customized with the construction so that the bed that occupied a lot of space was folded and used. Precast Culverts Systems visited the Kings Roadhouse in LA and was interested in precast concrete systems. At GPRM precast concrete firm, design meetings have helped bring realistic possibilities and overall budget estimates. As expected, the C-shaped units in the section were selected to proceed to development.

Uniqueness

Green Wall is a great help in serving as a passive house. Korea will need more and more prefab houses because insulation standards are getting higher and labor costs become higher and higher. In the summer, the leaves lower the temperature inside, and in the winter the leaves decrease, helping to increase inside temperature.

Architecture model

The built-in model was a great help in understanding the structure. The C-type units have gaps so that they are beneficial to drainage and at the same time have a philosophical spirit.

Illustrations

The Renderings first comes closer to the concept of a post-fossil city as the pedestrians travel freely, without vehicles. When you enter the closed area, you get the different experience you get from King's Road because it has more refined details and new materiality with by getting slim light from the ceiling as well as from the walls.

Ready to build

From the drawings of the construction, I developed the system to become a building that can be built without actually staying in the initial design shown in research, with great help from the actual system and detail.

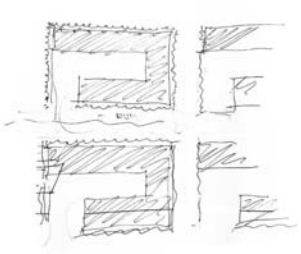


Figure 6.1 Design concept sketch

Figure 6.2 Precast concrete village

6.2 Material and Detail research

- SCHUCO FW50, Kingspan insulation, Aerol Nano Gel, and Poly carbonate

- Cedar Wood shading, Metal Grate, ISO Schock Connection

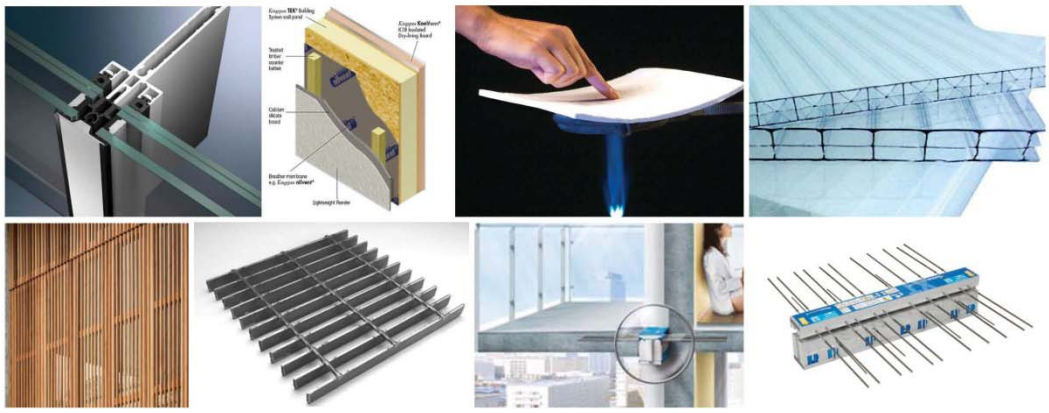


Figure 6.3 Applied materials and details

SFMOMA living wall, Dec. 2016

I found that if we select the species carefully, we can keep the green in the winter

- The living wall is the largest in the United States. the living wall is an ever-changing work of natural art supported with a recycled-water system.

Figure 6.4 Field Study for green wall at SFMOMA

6.3 Design options

Design development for window options

Material Reseach

	Outside		Inside
Option 1:	Galvanized metal	/	Gray Wood
Option 2:	Rusted + Clear coated	/	Brown Wood
Option 3:	White painted	/	Bleached Wood

Figure 6.5 Material options and programs

6.4 Professional Meetings with GPRM

- First meeting, Nov. 1. 2016 (Reseach-design meeting for Structure + Detail)

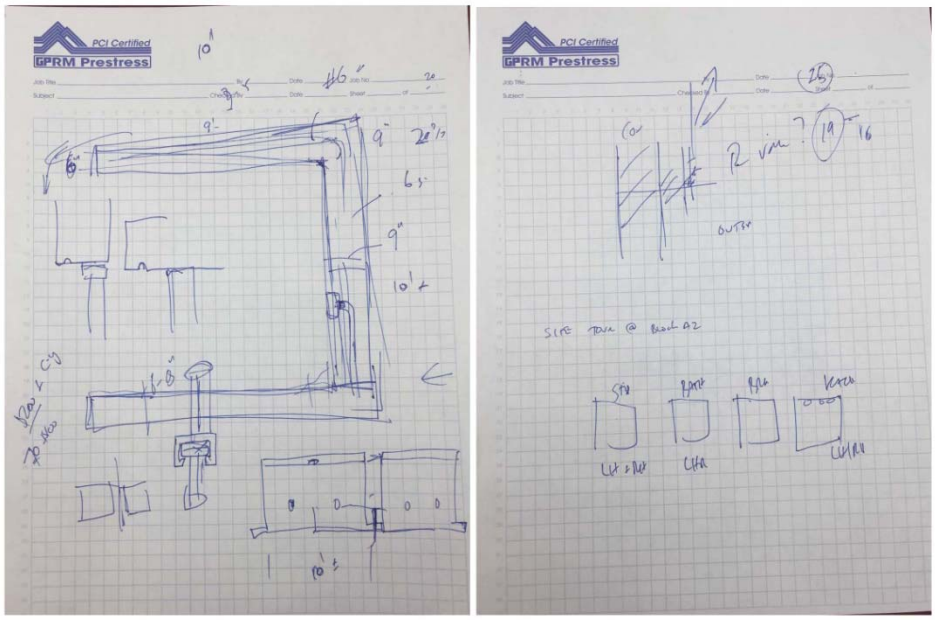
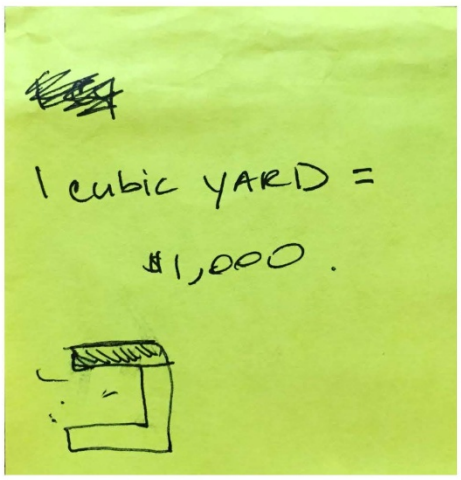


Figure 6.6 Professional enginner's sketch at GPRM precast concrete company

Figure 6.7 Field study, Precast sample and detail connections at GPRM

- Second meeting, Dec. 9. 2016 (Research-design meeting for COST + Mould + Material Finish)

Figure 6.8 Mold systems at GPRM Prestress



One Unit: 4.56 (a cubic meter) x 8 Box
Total: 36.48 (a cubic meter)
47.7 (a cubic yard)
Cost: 47,700 $

Figure 6.9 Cost estimate by GPRM

COST ESTIMATE (Concrete) 1$ = 1,200 won (Korea)

Past project : 210 Squre meter / 100,000 $, 1 squre meter= 476 $
Thesis project : 128 Squre meter X 476 $ = 60,928 $
(1377 Squre feet)

공 종 별 집 계 표

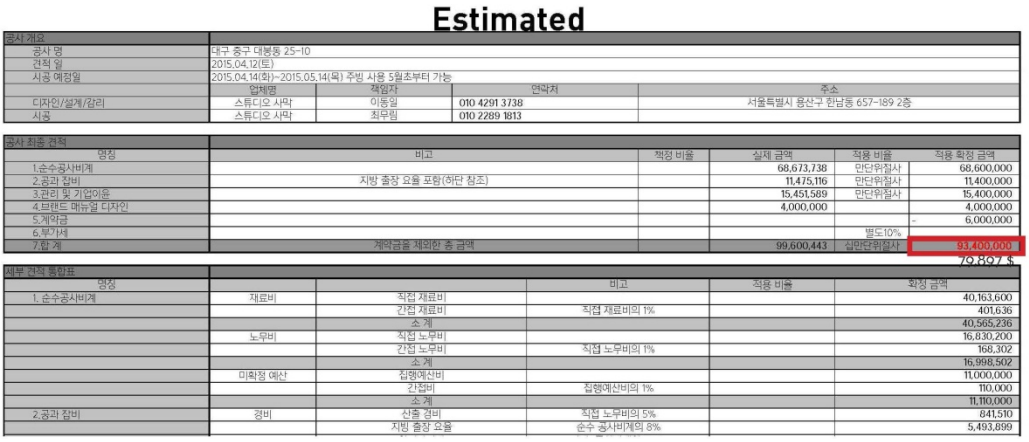
[대봉동 25-10 근린생활시설 신축공사]

품 명	규 격	단위	수량	재료비		노무비		경 비		합 계		비 고
				단 가	금 액	단 가	금 액	단 가	금 액	단 가	금 액	
01 대봉동 25-10 근린생활시설 신축공사			1	237,384,330	237,384,330	99,431,677	99,431,677	20,696,827	20,696,827	357,515,034	357,515,034	
0101 건 축 공 사			1	237,384,330	237,384,330	99,431,677	99,431,677	20,696,827	20,696,827	357,515,034	357,515,034	
010101 공통 가설 공사			1					8,926,000	8,926,000	8,926,000	8,926,000	
010102 가 설 공 사			1	1,364,719	1,364,719	6,683,250	6,683,250	1,497,000	1,497,000	9,544,969	9,544,969	
010103 토공및지정공사			1	2,405,500	2,405,500	577,150	577,150	4,327,700	4,327,700	7,310,350	7,310,350	
010104 철근콘크리트공사 CONCRETE			1	74,730,984	74,730,984	42,465,565	42,465,565	2,431,425	2,431,425	119,627,974	119,627,974	100,000 $
010105 조 적 공 사			1	119,469	119,469	219,290	219,290			338,759	338,759	
010106 타일 및 석공사			1	1,199,200	1,199,200	705,000	705,000			1,904,200	1,904,200	
010107 택 공 사			1	19,892,501	19,892,501	5,340,000	5,340,000			25,232,501	25,232,501	
010108 방 수 공 사			1	4,515,066	4,515,066	2,922,500	2,922,500			7,437,566	7,437,566	

Figure 6.10 General cost of housing construction in Korea

COST ESTIMATE (Furniture)

Past project : 210 Squre meter / 79,897 $, 1 squre meter= 380 $
Thesis project : 128 Squre meter X 380 $ = 48,640 $
(1377 Squre feet)



Estimated

공사 개요					
공사 명	대구 중구 대봉동 25-10				
견적 일	2015.04.12(토)				
시공 예정일	2015.04.14(화)~2015.05.14(목) 주방 사용 5월초부터 가능				
	업체명	책임자	연락처	주소	
디자인/설계/감리	스튜디오 사막	이동일	010 4291 3738	서울특별시 용산구 한남동 657-189 2층	
시공	스튜디오 사막	최무림	010 2289 1813		

공사 최종 견적					
명칭	비고	책정 비율	실제 금액	적용 비율	적용 확정 금액
1.순수공사비계			68,673,738	만단위절사	68,600,000
2.공과 잡비	지방 출장 요율 포함(하단 참조)		11,475,116	만단위절사	11,400,000
3.관리 및 기업이윤			15,451,589	만단위절사	15,400,000
4.브랜드 메뉴얼 디자인			4,000,000		4,000,000
5.계약금					6,000,000
6.부가세				별도10%	-
7.합 계	계약금을 제외한 총 금액		99,600,443	십만단위절사	93,400,000
					79,897 $

세부 견적 통합표					
명칭			비고	적용 비율	확정 금액
1. 순수공사비계	재료비	직접 재료비			40,163,600
		간접 재료비	직접 재료비의 1%		401,636
		소 계			40,565,236
	노무비	직접 노무비			16,830,200
		간접 노무비	직접 노무비의 1%		168,302
		소 계			16,998,502
	미확정 예산	집행예산비			11,000,000
		간접비	집행예산비의 1%		110,000
		소 계			11,110,000
2.공과 잡비	경비	산출 경비	직접 노무비의 5%		841,510
		지방 출장 요율	순수 공사비계의 8%		5,493,899

Figure 6.11 Cost estimate for interior furniture in Korea

- COMPARING WITH " Jun Se"

I compared the cost eastimate of concrete project with "Jun Se" price . It is affordable to get it.

TOTAL COST

"JunSe" Average :	290,000 $	(Rent for 2 years)
Thesis project :	109,568 $	(Concrete + Furniture)

-The Unique Korean Rental system is a crutical issue in Korea.

6. 5 Design Development

Figure 6.12 Site plan

Figure 6.13 Precast concrete House with Green walls

Figure 6.14 Entrance of a unit

Figure 6.15 Green walls and street without cars' threat

POST-FOSSIL TECTONICS

For architectural construction, we need to spend a lot of energy from the fossils. I believe that the best way to reduce fossil energy is to change conventional construction method. I propose Cross Nail-Laminated Timber (CNT). Moreover, I think the dead trees in the local area can be materialized through CNTing. The structural system of solidarity compensates the imperfection of the single individual board. Finally, the advantage of CNT over general Cross Laminated Timber (CLT) is glue outgazing. The solid timber with only these has both having thermal mass and R-value, so it's ideal for year-round thermal comfort. I believe that the tectonic helps make new forms of lifestyle for the post-fossil satellite.

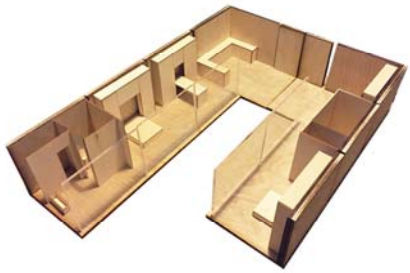


Figure 6.16 Post-fossil Tectonic model

Figure 6.17 Precast concrete unit

Figure 6.18 Nighttime view with glow light beyond the green walls

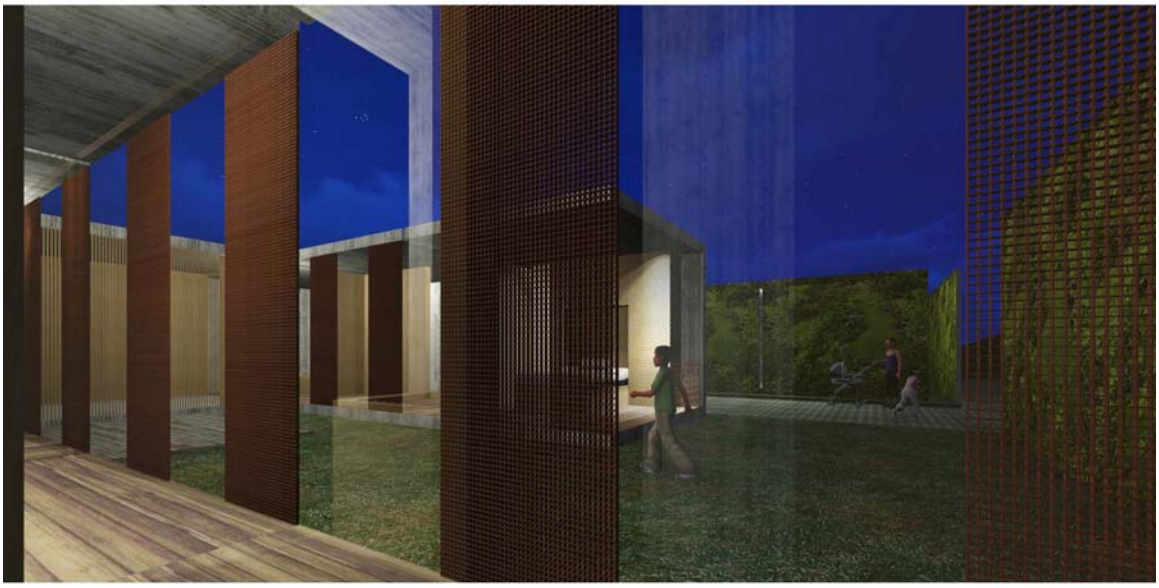


Figure 6.19 Indoor view

Figure 6.20 Natural light in the indoor space

Figure 6.21 Entrance from the indoor space

Figure 6.22 Corridor with screen system

6.6 Ready to build: Construction Document

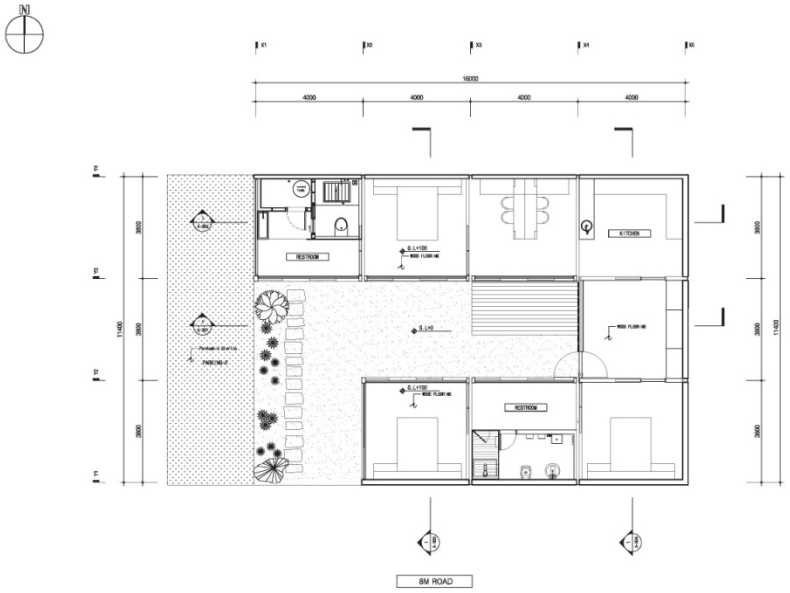


Figure 6.24 First floor plan

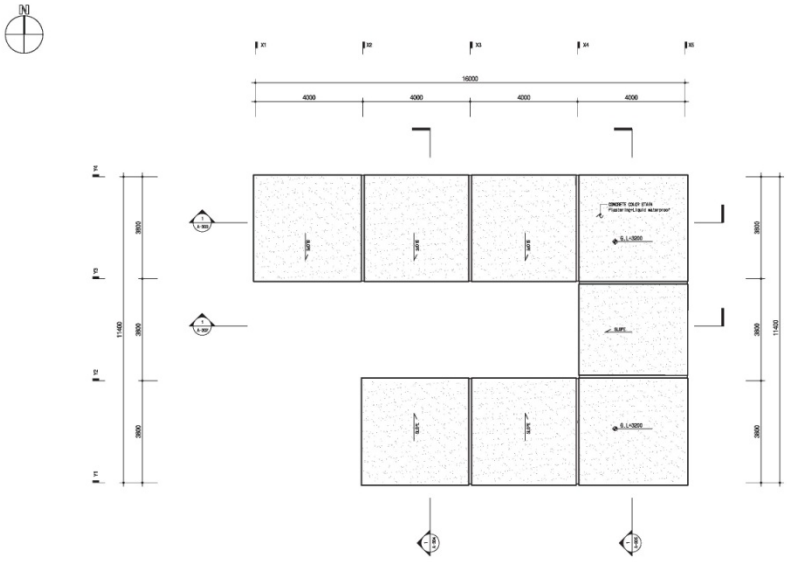


Figure 6.25 Roof plan

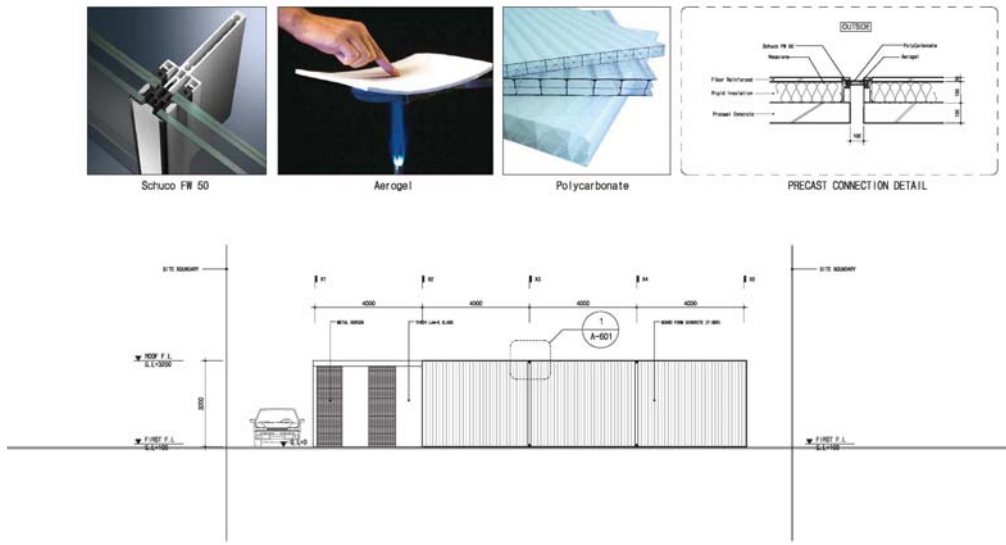


Figure 6.26 South elevation and skylight / wall-light detail

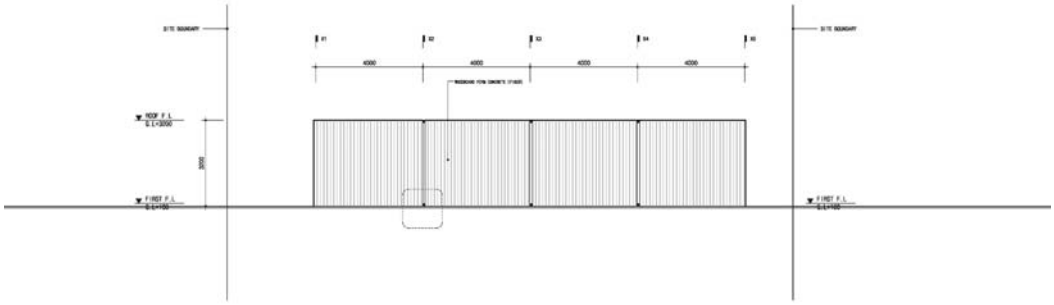


Figure 6.27 North elevation

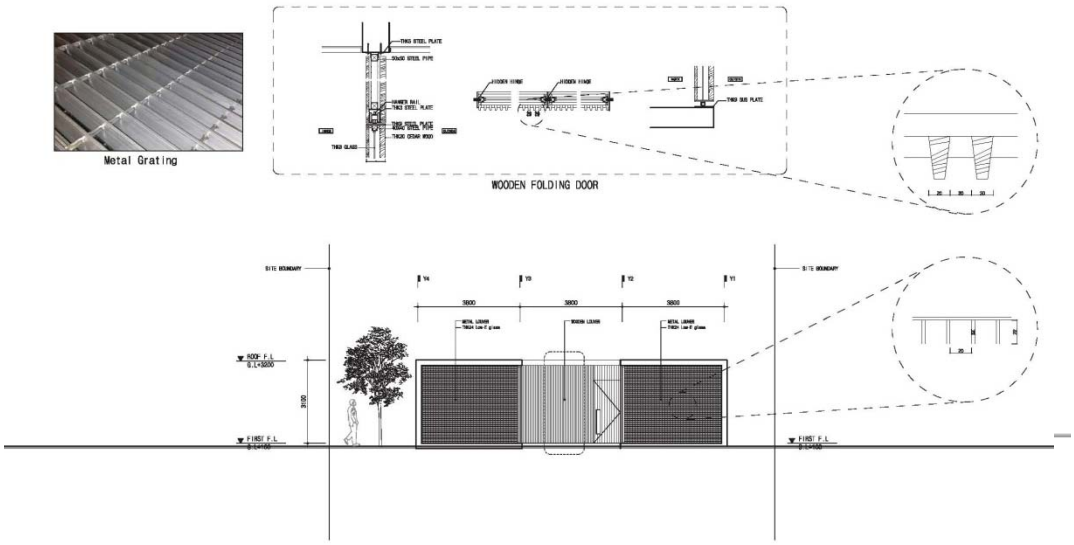


Figure 6.28 West elevation and mian door screen detail

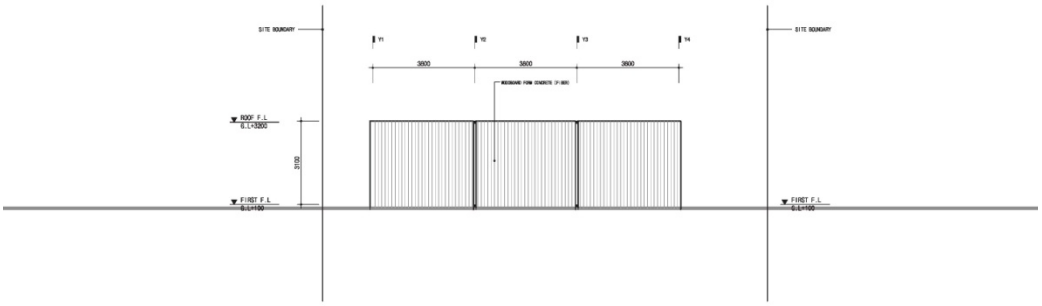


Figure 6.29 East elevation

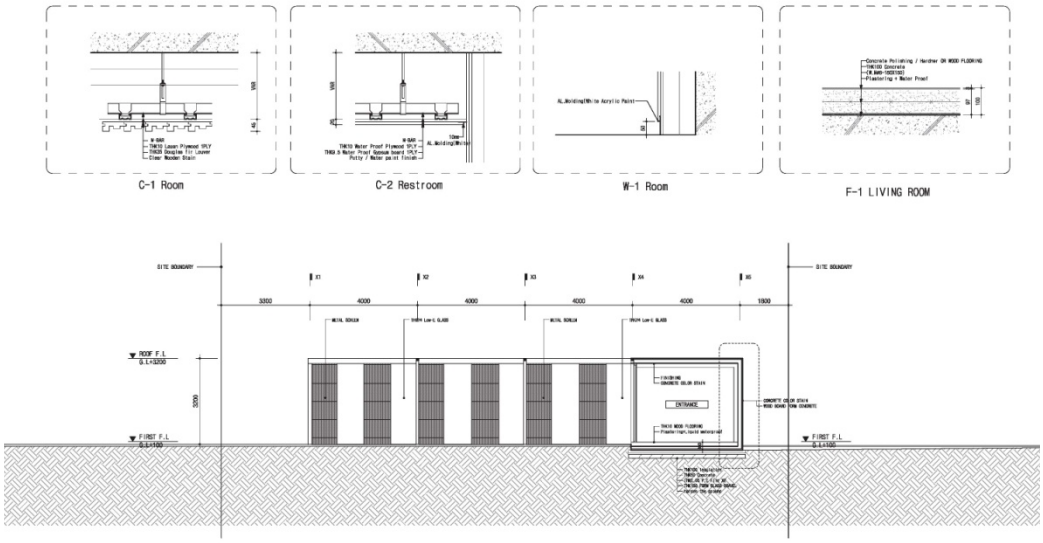


Figure 6.30 A-A' Section

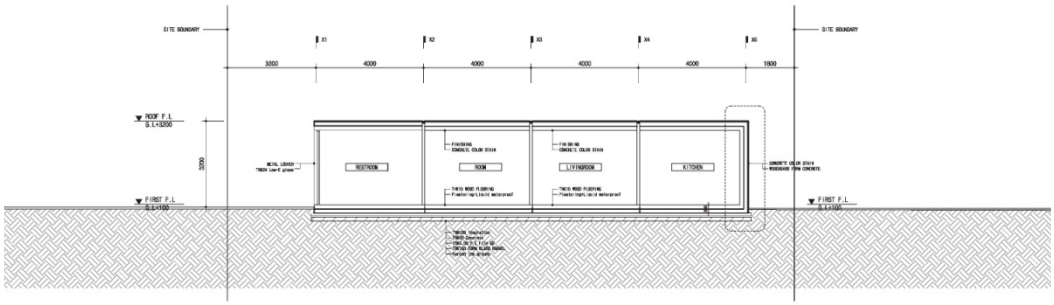


Figure 6.31 B-B' Section

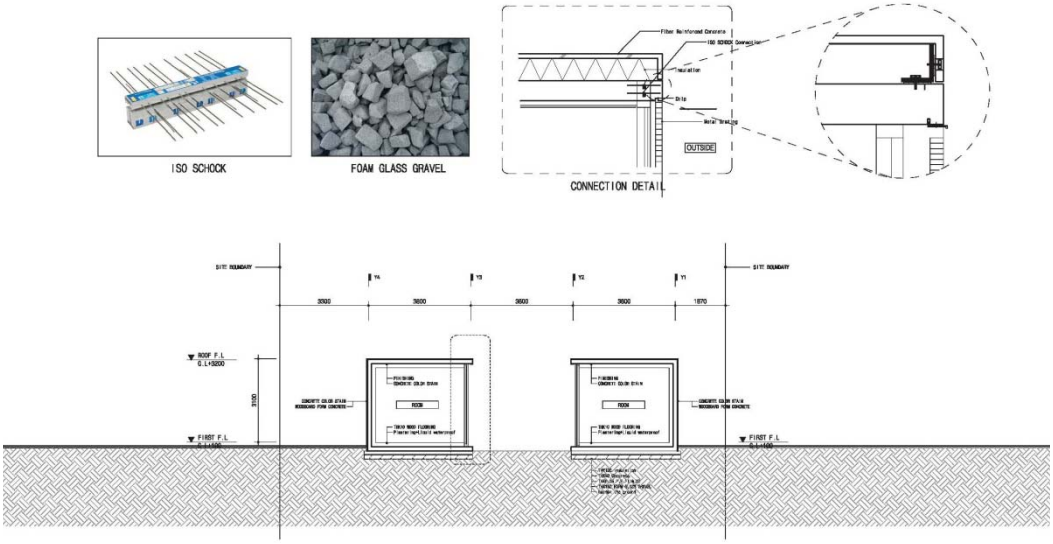


Figure 6.32 C-C' Section

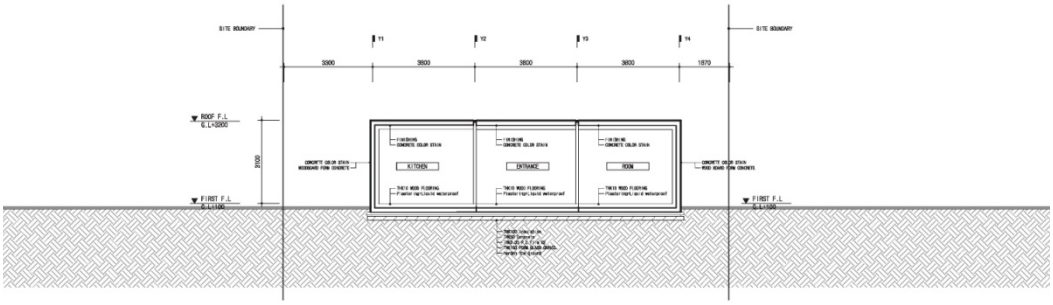


Figure 6.33 D-D' Section

7. Housing unit-2: Cross Nailed Timber House

7.1 Design concept

In Unit design standard, like C type, it has a main room, the main bath, a dining room, a kitchen, and kids room. All of the furniture was customized with the construction so that the bed that occupied a lot of space was folded and used.

However, I designed the movable roof type that can be opened and closed as needed.

Cross Nailed Timber + Thermal Modified Timber system

I learned about the superiority of the Cross Nailed Laminated Timber System. Conventional CLT becomes expensive to maintain flatness for they normally use adhesives. However, CNTs using aluminum nails have a solid mass as well as R-values and thermal mass.

Uniqueness

First, the uniqueness is in the details with the selection of materials. The solid timbers were firmly supported by cross pillars and brought light from the ceiling.

Architecture model

By creating a built-in model, I have come to understand the benefits of sliding door design with external perforations. This hot summer light is brought to light, and the heat is reduced. By opening the door in winter, the warm daylight will fill the warmth of the interior.

Illustrations

The renderings were done to show possibilities centered on experience.
I wanted to show the construction drawings about the moving loop of the ceiling at the same time as the detail of the solid timbre combination method. I wanted to show the possibility that the residence could have us, not only the material used for the bigger facilities

Ready to build

From the drawings of the construction, I developed the system to become a building that can be built without actually staying in the initial design shown in research, with great help from the actual system and detail.

CROSS NAILED LAMINATE TIMBER HOUSE (CNT HOUSE)

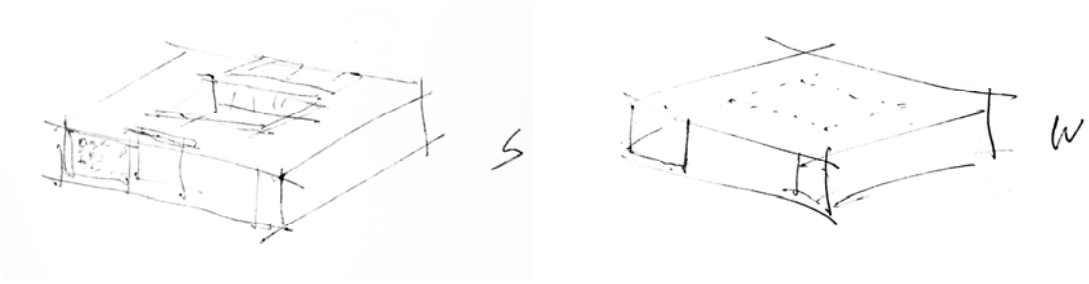


Figure7.1 Design concept sketch

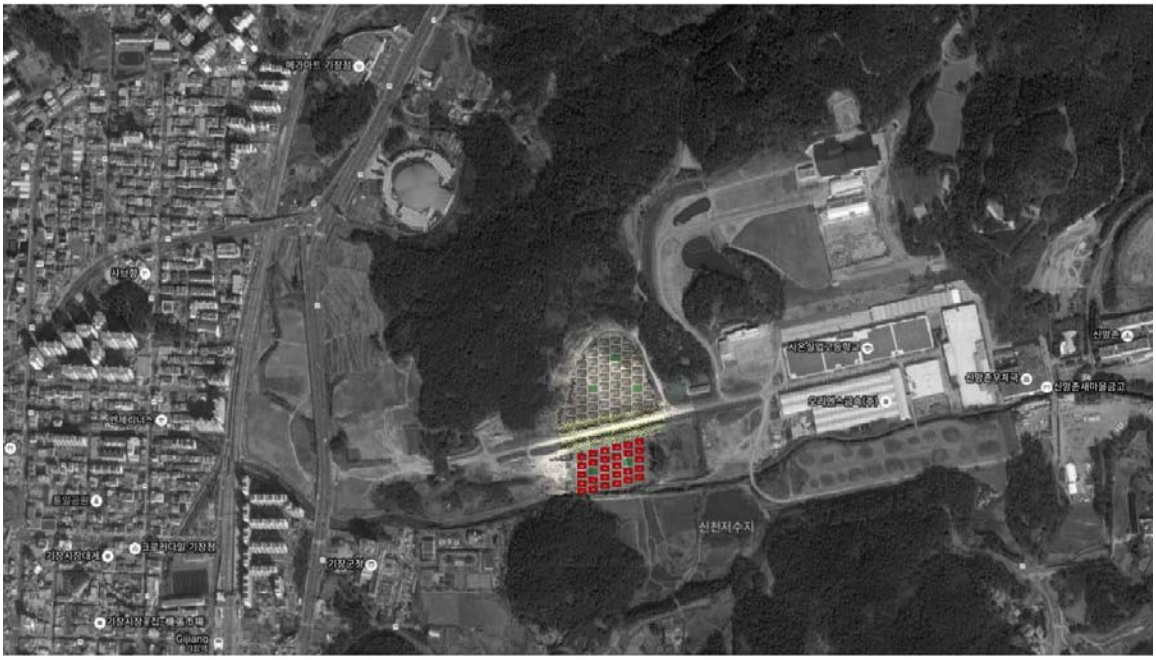


Figure7.2 Site location

7.2 Material and Detail research

Advantage of CNT(Cross Nailed Timber) over CLT(Cross Laminated Timber)
; CNT's structural system of solidarity compensates the imperfection of the individual / single board
: CLT's Glue outgazing, for gluing lumber needing to be milled exact size being expensive. But, we can use the waste woods by applying CNT.

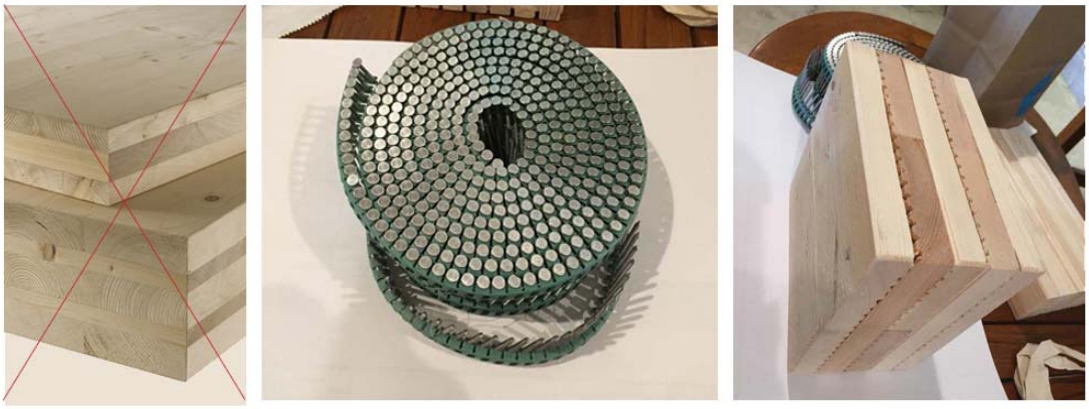


Figure7.3 CLT (Left), Aluminum Nails (Middle), CNT (Right)

CNT Test (Recyled Woods + Aluminum Nails)

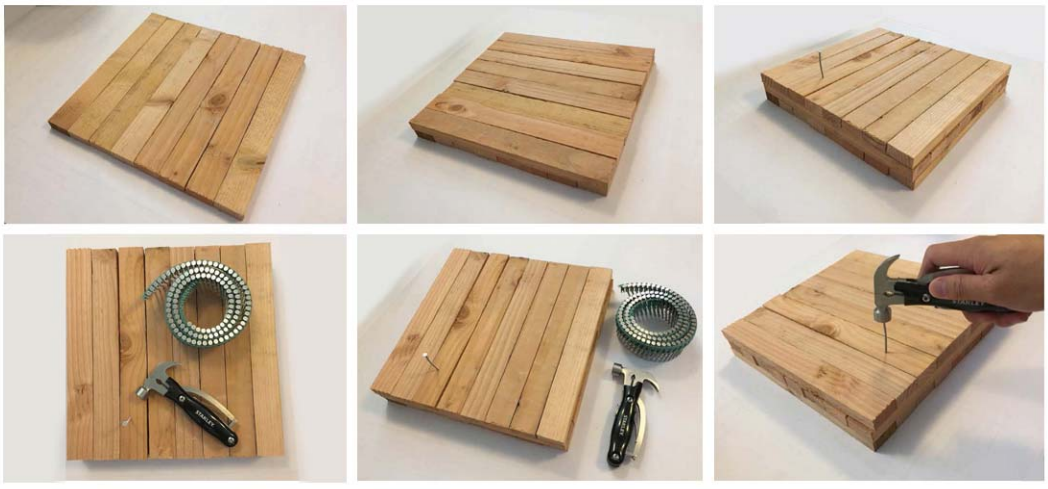


Figure7.4 Making CNT test sample

7.3 Sustainability

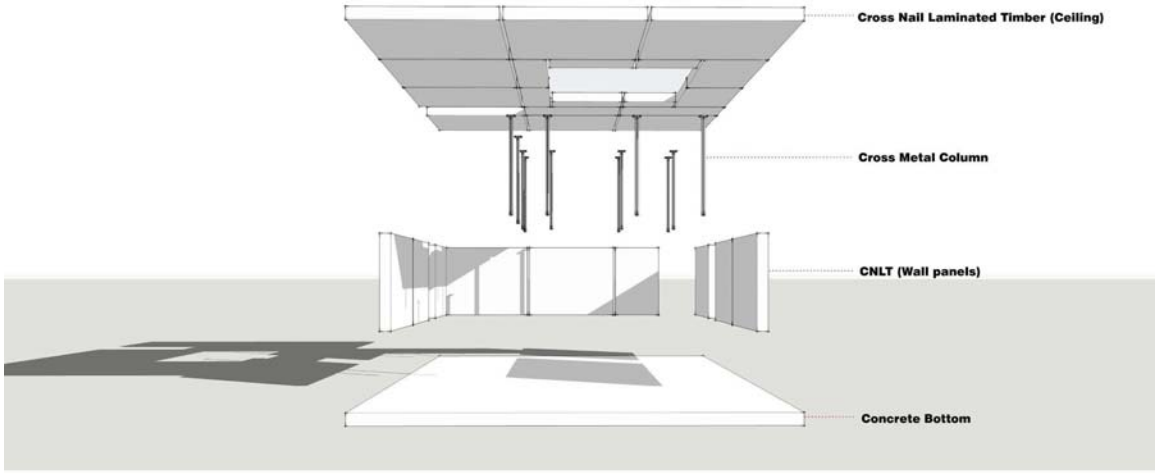


Figure7.5 Structure diagram

Figure7.6 Skylight and courtyard (summer)

ETFE roof

The ETFE roof closed perfecting its Passive House ideal compacted volume vs the roof open the houses surface maximized ideal for summer natural ventilation) being able to close and open the facade openings / fenestrations would enhance this : if both the glass would be

Figure7.7 Movable ETFE on courtyard (winter)

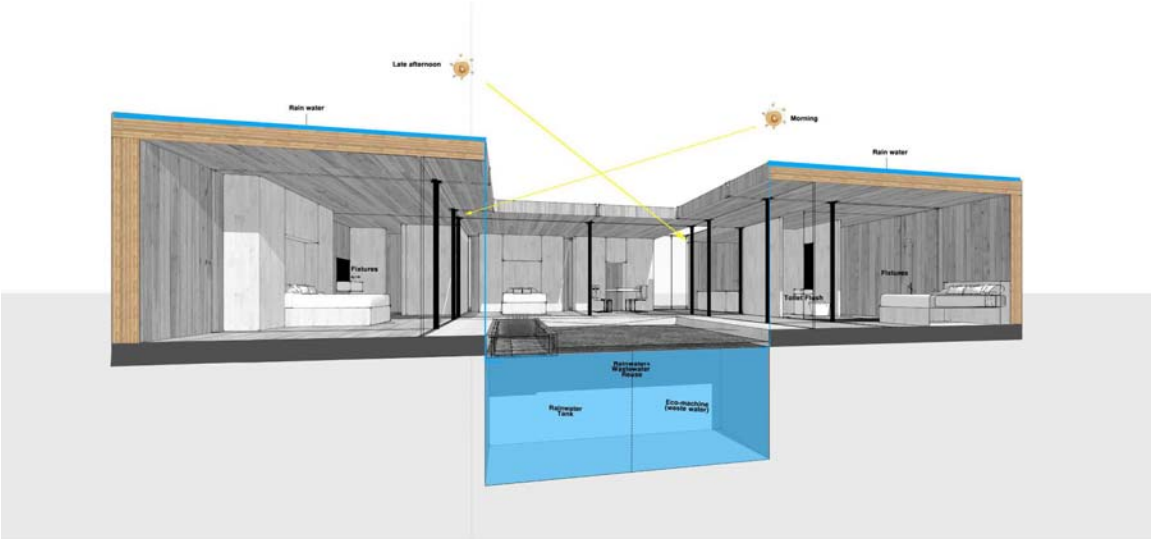


Figure7.8 Solid timber structure and Water catchment diagram

sliding doors and the shading an extra micro perforated (to let light and wind in while sun out) wood slide elements in front of them .

POST-FOSSIL DWELLING

The post-fossil dwelling is for a walking city. These people select cargo bicycles as their main transportation instead of convenience of cars because there are more benefits such as expanding a community for kids. For public community and needs, there are educational, commercial, and communal spaces in the post-fossil dwelling. However, those are using the same prefab tectonics with the housing. First, the upper village has green walls on their structures. Second, I imagine recycled houses with abundant dead trees for bugs and drought in the local area. Through CNT system, we can get a post-fossil dwelling..

Figure7.9 Post-fossil dwelling model

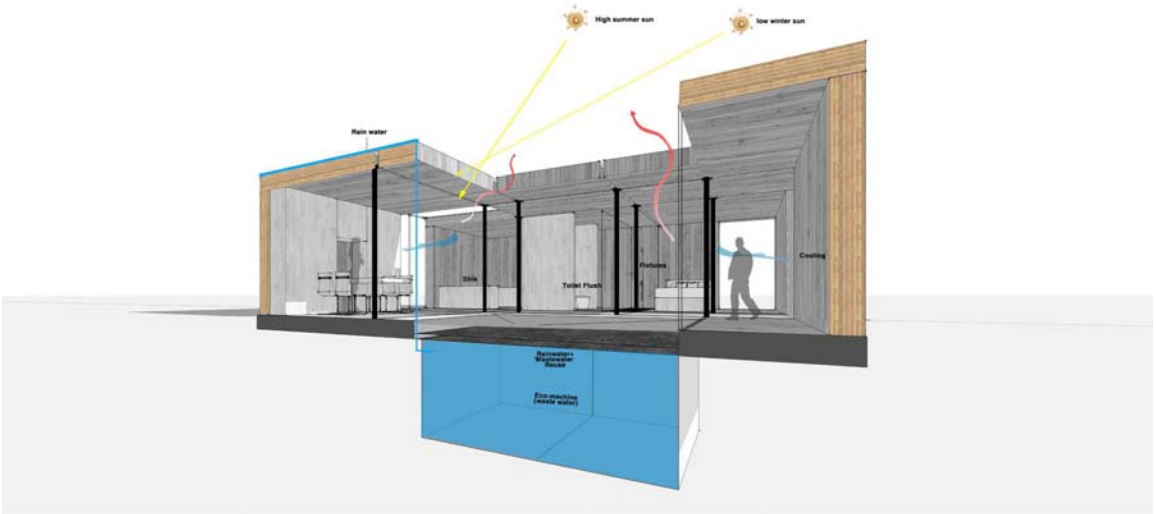


Figure7.10 Natural ventilation diagram

7.4 Design Development

Figure7.11 Outdoor space

Figure7.12 CNT housing with community park

Figure7.13 Main entrance

Figure7.14 Dining and skylight

Figure7.15 Courtyard from the bedroom

Figure7.16 Living room

Figure7.17 Courtyard from Main bedroom

Figure7.18 Courtyard from south corridor

7.5 Ready to build: Construction Documents

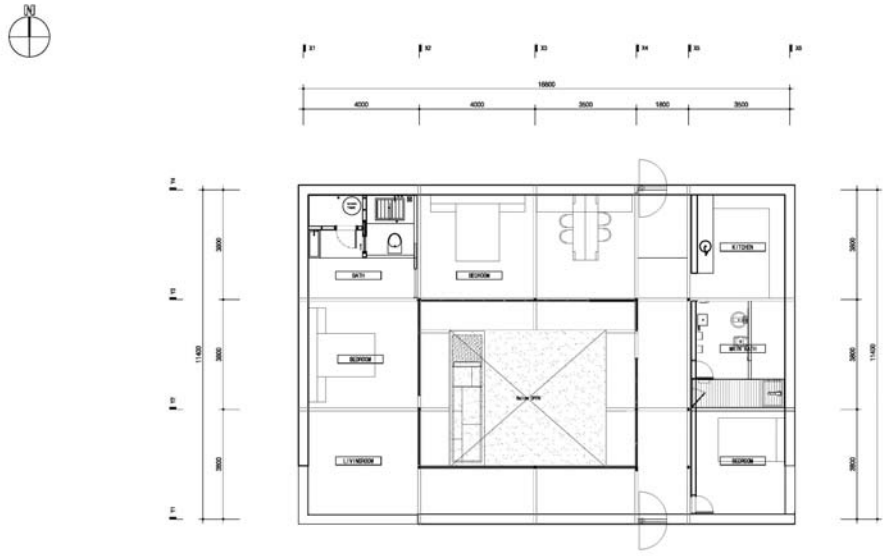


Figure7.19 First floor plan

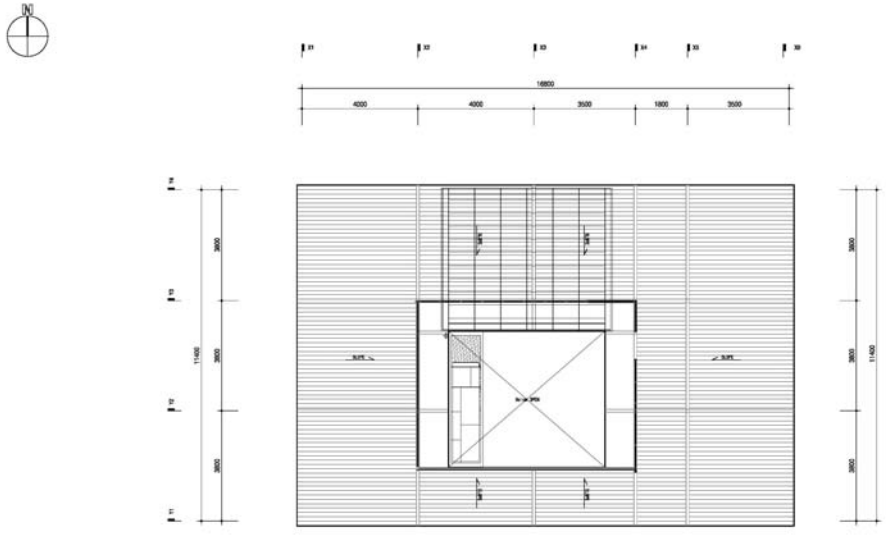


Figure7.20 Roof plan

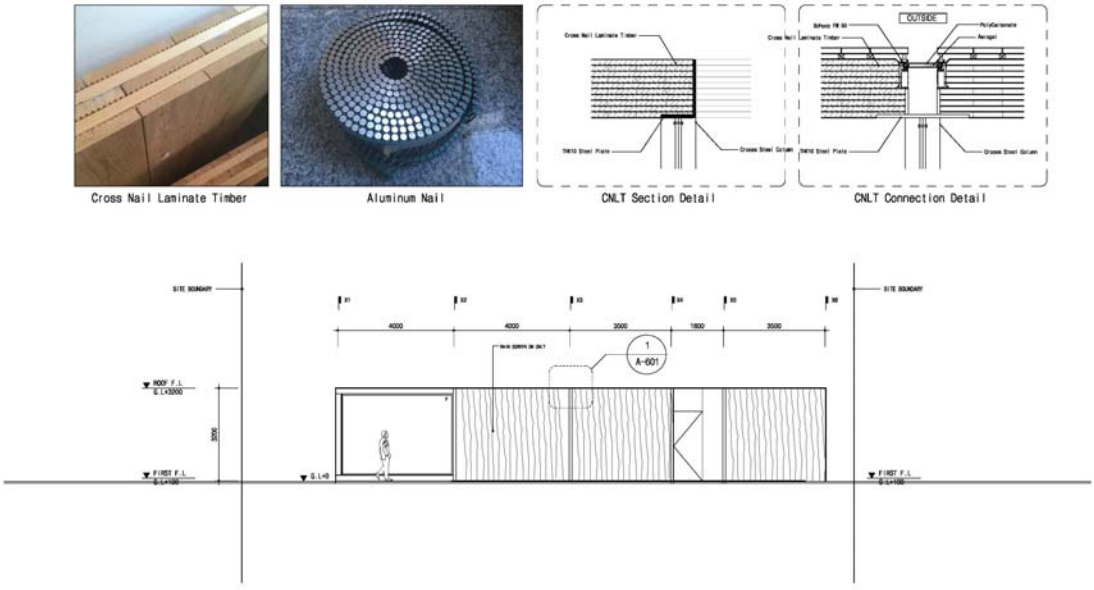


Figure7.21 South elevation (winter) and CNT + skylight detail

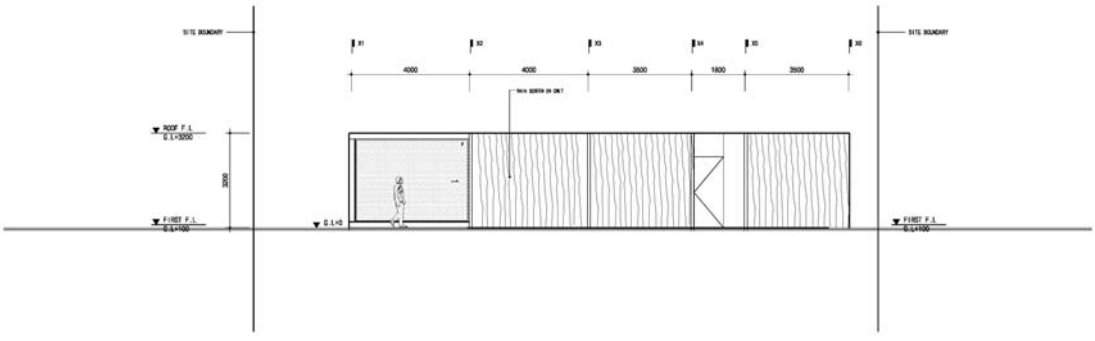


Figure7.22 South elevation with perforated screen (summer)

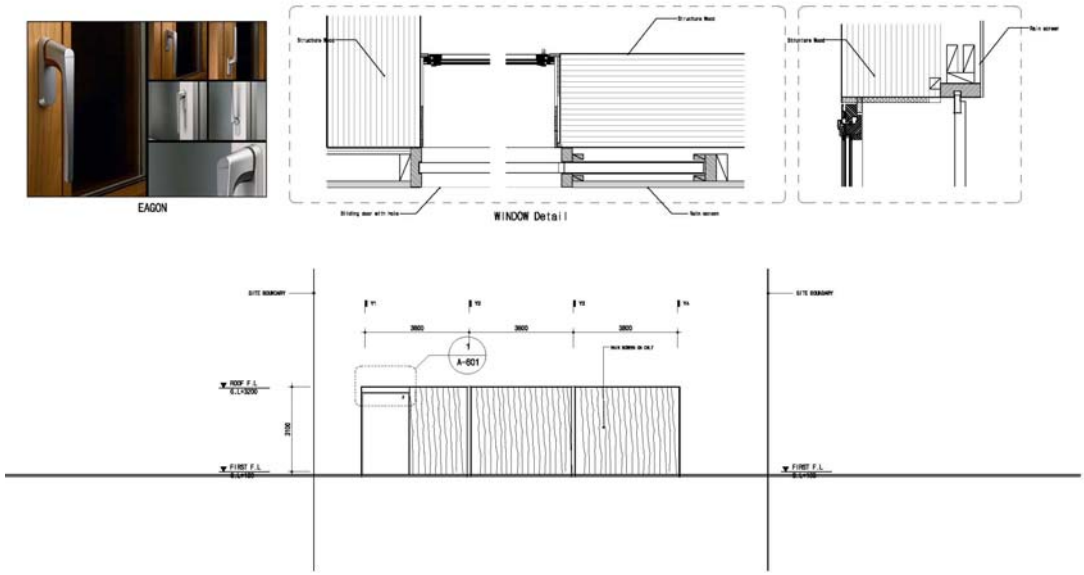


Figure7.23 East elevation (winter) and Window detail

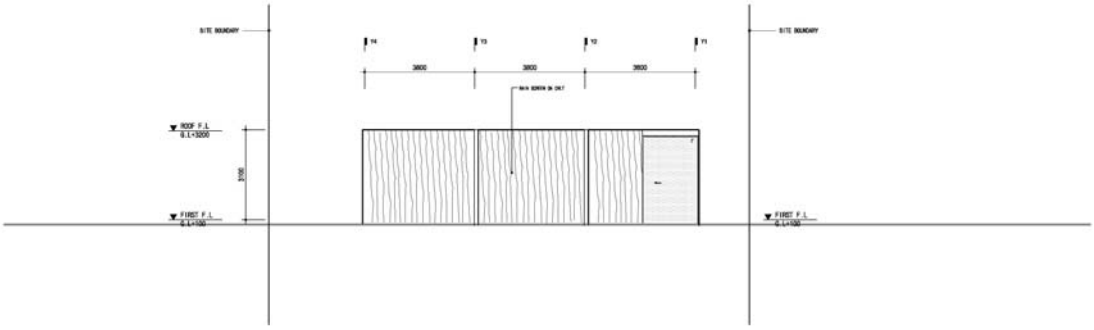


Figure7.24 West elevation with perforated screen (summer)

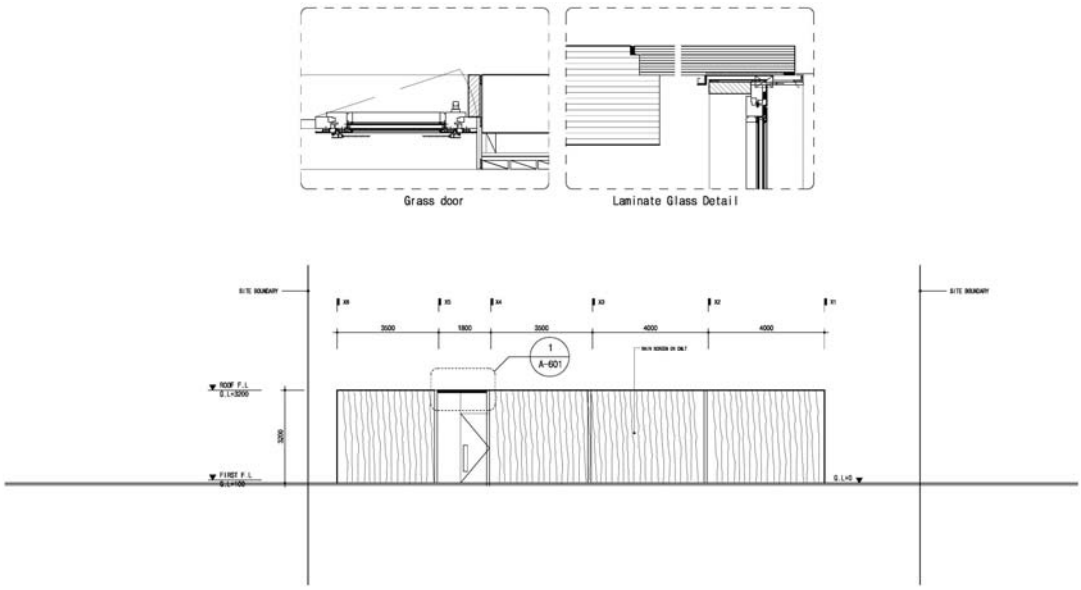


Figure7.25 North elevation and skylight detail

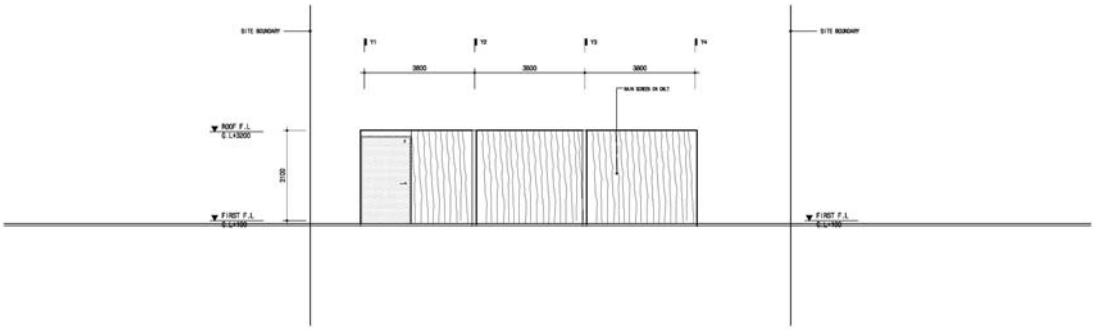


Figure7.26 East elevation (summer)

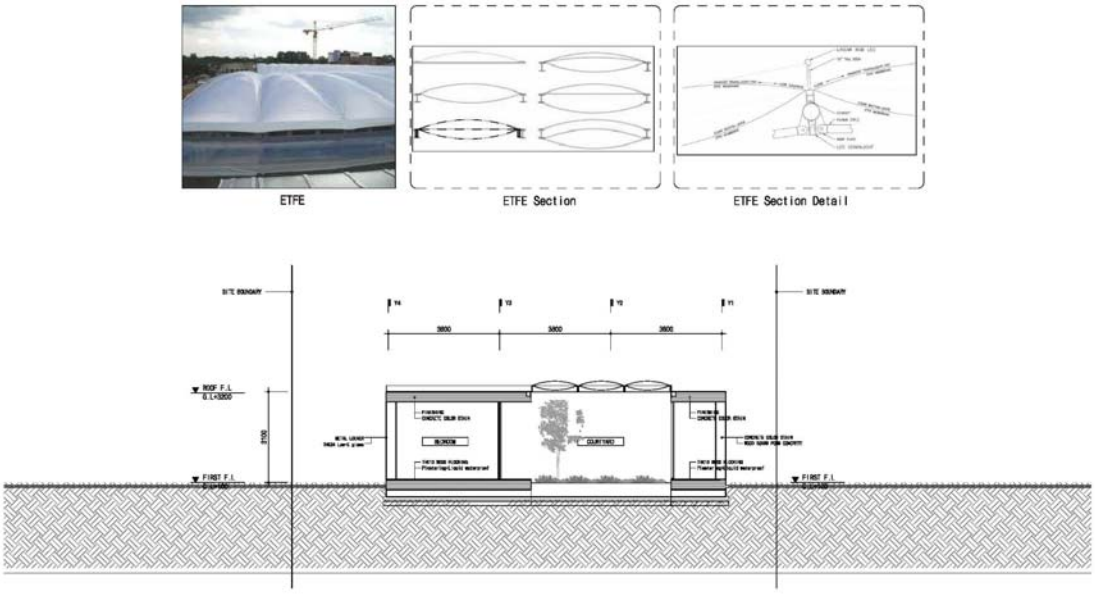


Figure7.27 A-A' Section with ETFE roof

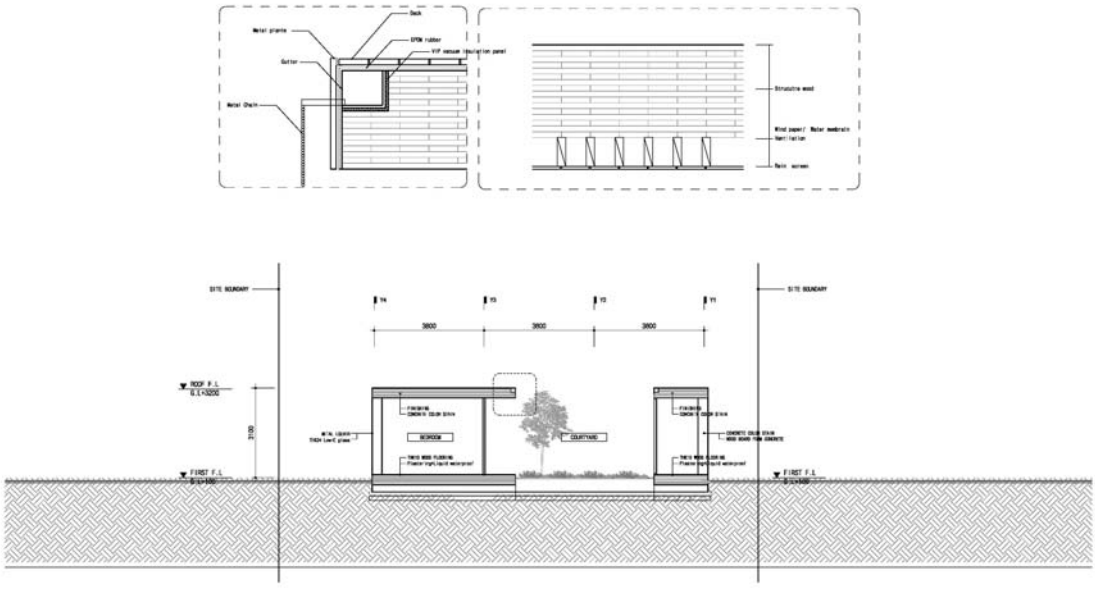


Figure7.28 B-B' Section with gutter detail

8. Conclusion

I understood that the reason for the failure of prefab architecture in Korea was because of reduction of the budget rather than the design center, and I found out that there are amazing structures in terms of materials and details through case studies. Moreover, I was able to understand more about the direction of our city through prefab building. Globally, with the lack of oil, we carried out research and design on vehicle-free cities and pedestrian-oriented cities. I made research-design prefab prototypes for middle-class families who want to get away from the charter system with unique details and two new systems that are not universal in Korea.

All in all, following my general observations about private homes research with prefab systems, it is clear that this housing research is still in a very initial stage in Korea. Thus, this was a major issue in my research. If customization issues are not reflected in the prefab houses, we could not develop the private homes with prefab systems. Therefore, I have researched prefab houses with high-quality design for customization. In addition, through this research, I found prototypes for Korean. To be specific, I got new points of view through my Doctoral research. First, prefab system would be a construction option for the private domain. Moreover, focusing only low price for prefab house in the past brought negative effects. If we invest design quality and prefab system, we can provide Korean prefab houses. Furthermore, research for prefab housing in Korea, the researchers focused on the urban design and public

housing concept. Thus, my doctoral research must be very helpful for prefab houses in private domain.

Beyond the Pilot Design Project

I wanted to conclude and test with more global needs and sensibilities and participate in Post-Fossil City, House in Forest, and the Hollywood House competitions. In a Post-Fossil city, I could study more broaden urban applications. Instead, I was able to do additional research on localization by applying each unit to different sites.
I applied the volcanic heat and salt TMT study to the Hawaii from House in Forest.

Finally, Hollywood Sign House proposed CNT using dead trees in California. Internally, I had a chance to see and enjoy the Hollywood sign with the LA local pre-fab legacy.

Appendix A: Three Boards for Prefab architecture projects

Figure8.1 Post-fossil city board

POST-FOSSIL SATELLITE

"Satellite communities feed the cities." I propose a post-fossil city with an existing site by applying post-fossil tectonics and a post-fossil dwelling system to make more actual and factual proposal. The site is located in the Korea. This is because there is a distinct transition of four seasons. Therefore, we have to figure out not only summer cooling but also winter insulation to reduce fossil energy. Moreover, I believe that we will not have any more fossil fuels in the future. Thus, this pilot project starts on a small neighborhood scale. For the post-fossil city, I suggest post-fossil tectonics and dwelling.

POST-FOSSIL TECTONICS

For architectural construction, we need to spend a lot of energy from the fossils. I believe that the best way to reduce fossil energy is to change conventional construction method. I propose Cross Nail-Laminated Timber (CNT). Moreover, I think the dead trees in the local area can be materialized through CNTing. The structural system of solidarity compensates the imperfection of the single individual board. Finally, the advantage of CNT over general Cross Laminated Timber (CLT) is glue outgazing. The solid timber with only these has both having thermal mass and R-value, so it's ideal for year-round thermal comfort. I believe that the tectonic helps make new forms of lifestyle for the post-fossil satellite.

POST-FOSSIL DWELLING

The post-fossil dwelling is for a walking city. These people select cargo bicycles as their main transportation instead of convenience of cars because there are more benefits such as expanding a community for kids. For public community and needs, there are educational, commercial, and communal spaces in the post-fossil dwelling. However, those are using the same prefab tectonics with the housing. First, the upper village has green walls on their structures. Second, I imagine recycled houses with abundant dead trees for bugs and drought in the local area. Through CNT system, we can get a post-fossil dwelling.

HOUSE IN FOREST

Figure8.2 House in forest board

(lumber) JACK SHACK

In Hawaii, Sandalwood was the first tree indigenous to the islands. After exporting Sandalwood to China, Sandalwood largely disappeared from Hawaii. Koa wood is another indigenous tree to Hawaii, but it is different to obtain because of laws and regulations that prevent it being cut. In present day Hawaii, there are Eucalyptus, Ironwood, and Albizia trees. These trees are invasive species to Hawaii. In order to utilize these trees in an unconventional way -unlike with slice frame tectonics- I change

the conditions of these trees to match safety codes for fire, hurricanes, and termites. herefore, solid timber and Thermal Modified Timber (TMT) will be used for enhanced durability. There are two environmental factors unique to Hawaii that enhance TMT. One is volcano heat or Pele's heart, which helps for thermal durability of the timber. The other is Hawaiian salt, which can be used to reduce and project from termite infections.

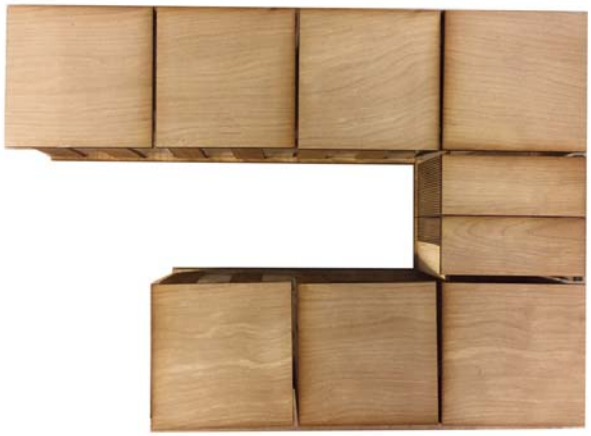
HOLLYWOOD, THE LAST HOUSE ON MULHOLLAND

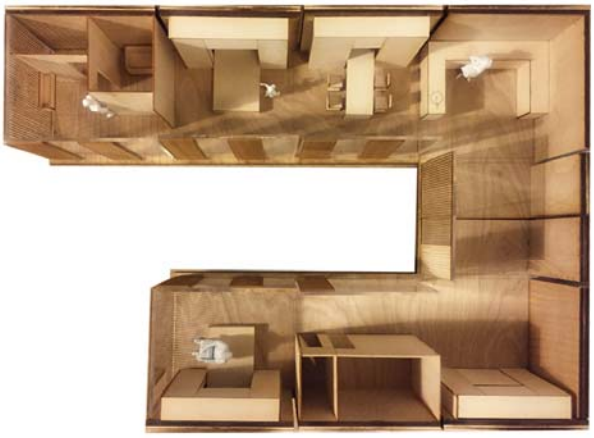
Figure8.3 Hollywood sign house board

Hollywood sign house with a moderately mild climate and related relaxed modern architecture like Schindler's Kings Road House. The leaf by the drought of the recent years dead trees become the locally abundant building material and walls and ceilings are made of Cross Nailed Timber (CNT) boards of those dead trees to form vitally active homes organized around a seasonally enclosable CA case study house legacy provided courtyard giving the home the feel of dwelling in harmony with Californian culture and climate.

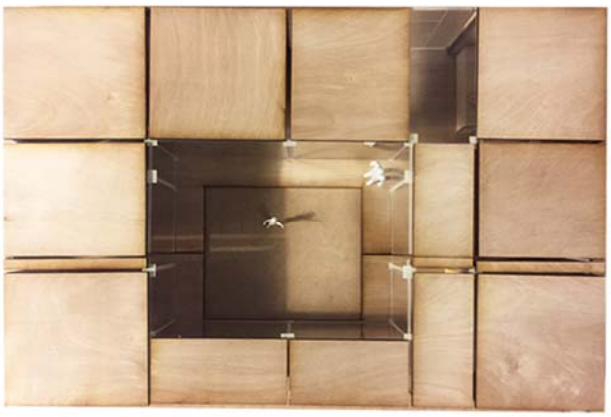
Appendix B: Prototype Models

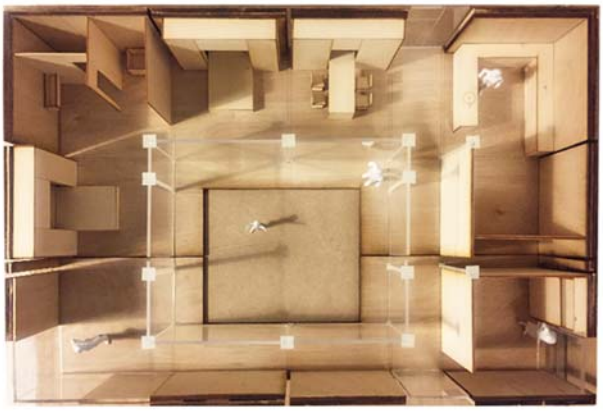
Housing unit-1: Precast Concrete Culvert House





Housing unit-2: Cross Nailed Timber House





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