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Title

CROSS-CULTURAL CARPENTRY

By

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MASTER OF ARCHITECTURE

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CROSS-CULTURAL CARPENTRY

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ABSTRACT

This thesis analyzes the proficiencies of light-frame wood construction and compares it to the craftsmanship of traditional Japanese carpentry. The goal of this research was to bridge the gap between these two construction styles and create an adaptation in search of a new solution to light-frame wood construction. That adaptation is then applied to a single-family residential project to refine its process and analyze its strengths and weaknesses.

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1. INTRODUCTION

1.1. Problem Statement

Light-frame wood construction is one of the most common types of construction among single-family homes today. This can be attributed to its accessibility, efficiency, and cost. Light-frame construction has not seen major changes in its history, raising concerns about whether it is the best solution. This is hard to believe as there are multiple issues with light-frame construction. It is susceptible to thermal bridging unless insulated properly because of the number of vertical studs that span the width of the wall cavity. It requires additional bracing around doors and windows. Blocking is needed to mount wall fixtures like upper cabinets. The structure is not rigid until sheathing is applied. Considering a few of the negatives, one would expect to see advancements in the construction method. The issue to be addressed revolves around the loss of craftsmanship in today's construction methods. The quality of materials and the level of care that goes into constructing homes today are not of as much concern as they should be. Instead of trying to solve these problems, we seem to be striving in the other direction. Modern construction methods, specifically light stick framing, are the product of how wood construction has been simplified and standardized over time.

1.1.1. Research Question

What is the potential of adapting traditional Japanese carpentry qualities into today's light-frame construction methods?

1.1.2. Proposed Outcomes

The expected outcome from this research will include a detailed manual that analyzes and adapts traditional Japanese carpentry methods to modern construction techniques.

1.2. Objective

The objective of this project will be to use the adaptation manual to produce a single-family home using this new construction method in a contemporary layout.

1.2.1. Aim

The aim is to understand the differences between a construction method that withholds craftsmanship and quality compared to a construction method geared towards affordability and efficiency.

1.2.2. Significance

This adaptation manual could draw attention to the potential of reconsidering light-frame construction methods. Some benefits of applying the qualities of traditional Japanese carpentry include solving problems concerning decay, molding, and overall longevity. Cut down on the dependence on metal fasteners creating redundancy. And the potential for discovering efficiencies that could be lost in the repetitive simplicity of light-frame construction.

2. BACKGROUND

2.1. Background

The information gathered in the research consisted of an analysis of structural details of traditional Japanese carpentry and modern light-frame construction. This is necessary in understanding the assembly process and reasoning behind the construction techniques. The goal was to get enough information about traditional Japanese carpentry and joinery methods to apply them to light-frame construction. This meant the background information was kept brief. This thesis does not intend to provide a history or a guidebook on how traditional Japanese and modern homes are made but rather a comparison of the structural systems.

The Complete Japanese Joinery is a manual covering the extensive craft of Japanese woodworking (Nii et al., 1995). It provided centuries of techniques that have been refined to emphasize the beauty and strength of wood. The manual illustrates the care and use of tools, laying out and marking wood, cutting joints, and their final assembly. It provides woodworkers with detailed step-by-step explanations and instructions for numerous joints and their uses. This resource provided an understanding of how traditional Japanese joinery was crafted and how the tools and techniques were performed.

The Complete Illustrated Guide to Joinery is a guide to useful joints in woodworking (Rogowski, 2002). Its illustrations and methods cover alternative ways for achieving the same result along with numerous complex joint options. The methods are shown using hand tools, power tools, and machines. The book primarily focuses on woodworking methods used in constructing furniture. The benefit of this source is the illustrations and guides that encompass the use of both hand and power tools. It demonstrated which joints and details can be performed with or without certain tools to save time and reduce the margin of error. A downside of this guide was its limitations for applying joints into building construction. Many of the joinery methods may only be effective with furniture.

The Japanese House: A Tradition for Contemporary Architecture is an extensive summary of what makes up a traditional Japanese home (Engel, 1964). This resource gave a better understanding of the measurement system and scale of each member in the structure. This aided in developing the traditional Japanese structure model.

2.2. Comparison

2.2.1. Tools

Traditional Japanese carpentry involved the use of hand tools. These tools include chisels, hand planes, pole saws, and more. These hand tools allowed carpenters to be precise and accurate with measurements and cuts. The downside is the process takes much longer with the use of hand tools. Light-frame construction uses modern power tools. This allows for fast assembly. Tools on a job site may include a table saw, miter saw, drill, impact driver, nail gun, router, hammer, and more. Precision is not as important in the modern light-frame system.

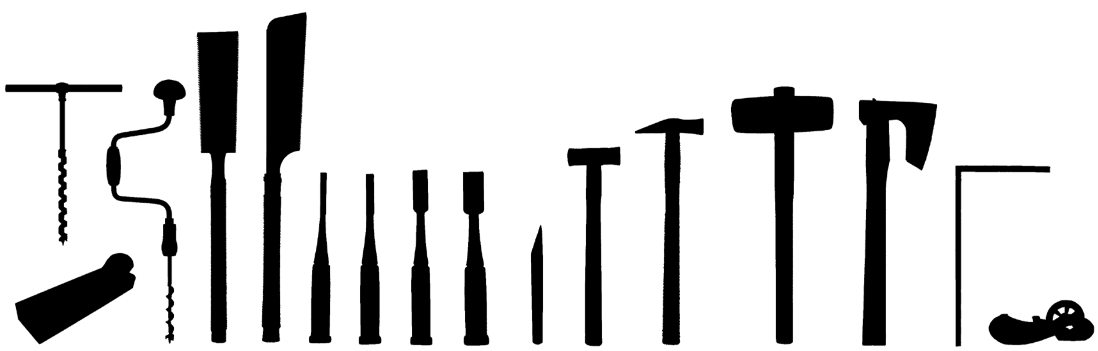

Figure 1: Traditional Japanese Tools

Figure 2: Light-Frame Construction Tools

2.2.2. Foundations

Two common foundation types in Japanese homes were the post-stone and the flat stone foundation. The main function of these foundations was to keep the wood elements away from the damp ground. These foundations had no rigid connection allowing flexibility for horizontal stresses providing an advantage during earthquakes. The raised floor prevents moisture from

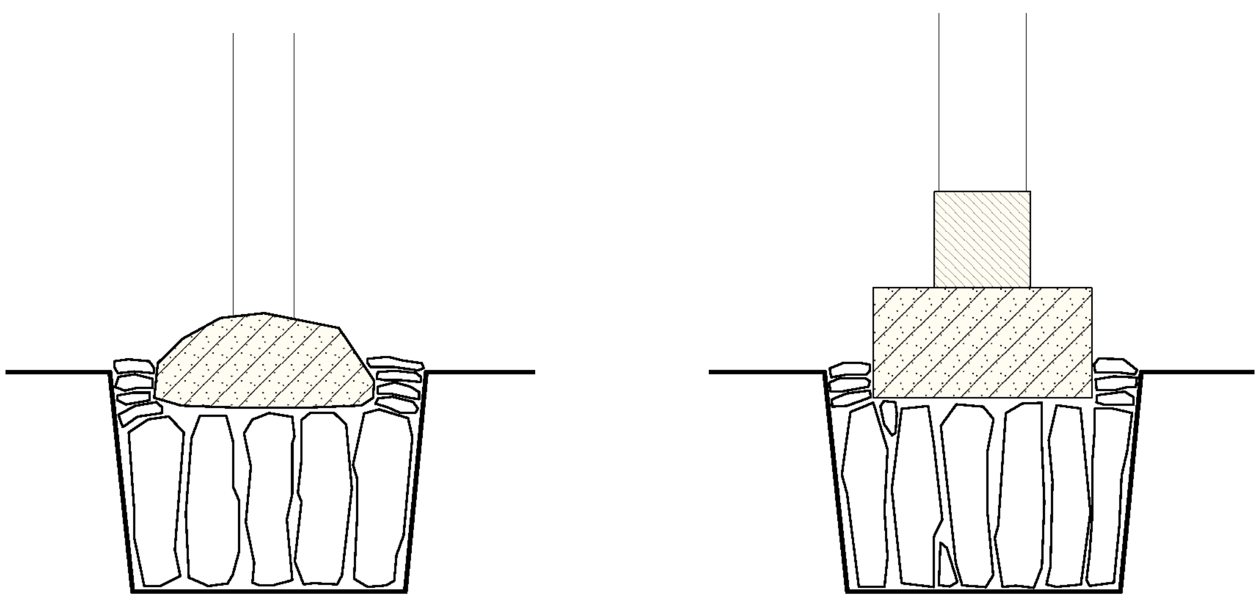

Figure 3: Traditional Japanese Foundations
Note: The left diagram is an example of a post-stone foundation detail while the right diagram is a flat stone foundation detail.

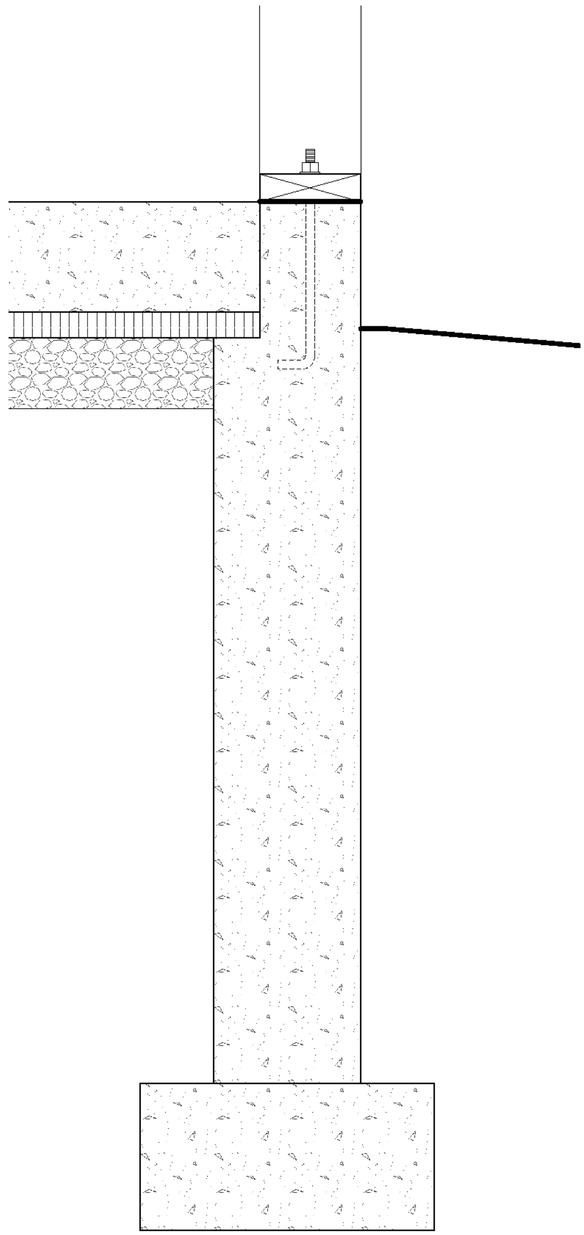

Figure 4: Slab-on-grade Foundation

reaching the wood to prevent rotting while allowing a crawlspace for easier access to plumbing and other mechanical systems for repair.

A slab-on-grade foundation was chosen to compare as it is one of the most common foundation types for homes without basements. This foundation type consists of a thin layer of concrete over the area of a house with footings below load-bearing walls. It is popular due to its simplicity, durability, and affordability. It uses a rigid connection to the sill plate using anchor bolts and drive pins. Another element of modern foundations is a sill seal between the concrete foundation and the sill plate. This creates a seal that keeps air and insects from entering under the wood and provides moisture resistance. An important quality of footings, especially in climates where the ground freezes, is that they are placed below the frost line. This prevents heaving and cracking of the foundation.

2.2.3. Sill Plate

Comparing the sill plate and its connections between the two systems there are some major differences. The Japanese home has thicker members for joinery methods while the light-frame system uses nails and metal fasteners. The members of the Japanese system take longer to produce in a workshop but make for a fast assembly on the job site. Fewer metal fasteners reduce the chances of rusting nails and rotting wood which could compromise sill plates. A skilled craftsman is needed to produce these elements and the laborers assembling the pieces need

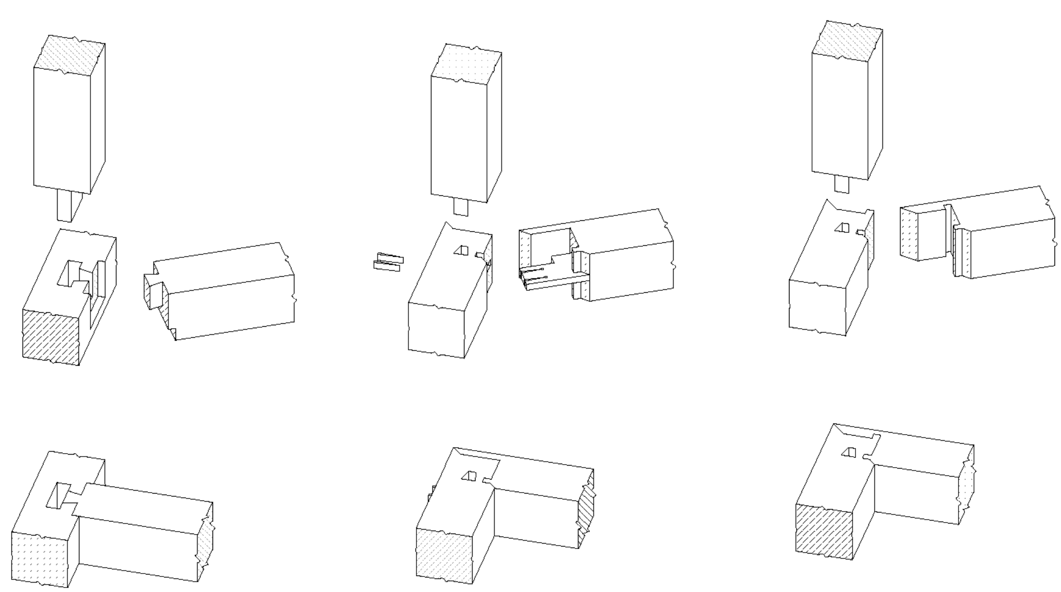

Figure 5: Traditional Japanese Sill Plate

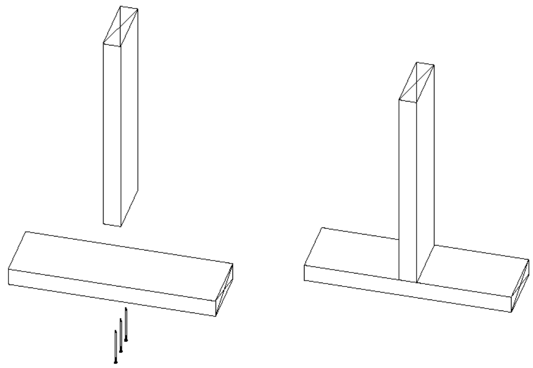

Figure 6: Light-frame Sill Plate

guidance throughout the construction process. They also must know the techniques used to alter the elements in case there need to be any changes or adjustments on site. The light-frame sill plate is straightforward. It is cut to size on-site and nailed to the studs of the wall assembly. This makes the assembly quick and easy to learn. One downside is it solely relies on metal fasteners that can deteriorate over time.

2.2.4. Joinery

Another difference between the two framing systems is that the Japanese house uses many different sizes of lumber for different purposes. It also has many different joints that serve various functions as well. Some of these joints focus on simplicity and strength while others are for aesthetics. One common feature between light-frame and traditional Japanese framing is that the length of pieces is kept shorter to make it easier to handle and transport. Certain Japanese joints can allow for long spans using small members by slicing them together. This also plays a big role in the longevity of a home because replacing pieces is as easy as joining a new section rather than tearing down and rebuilding.

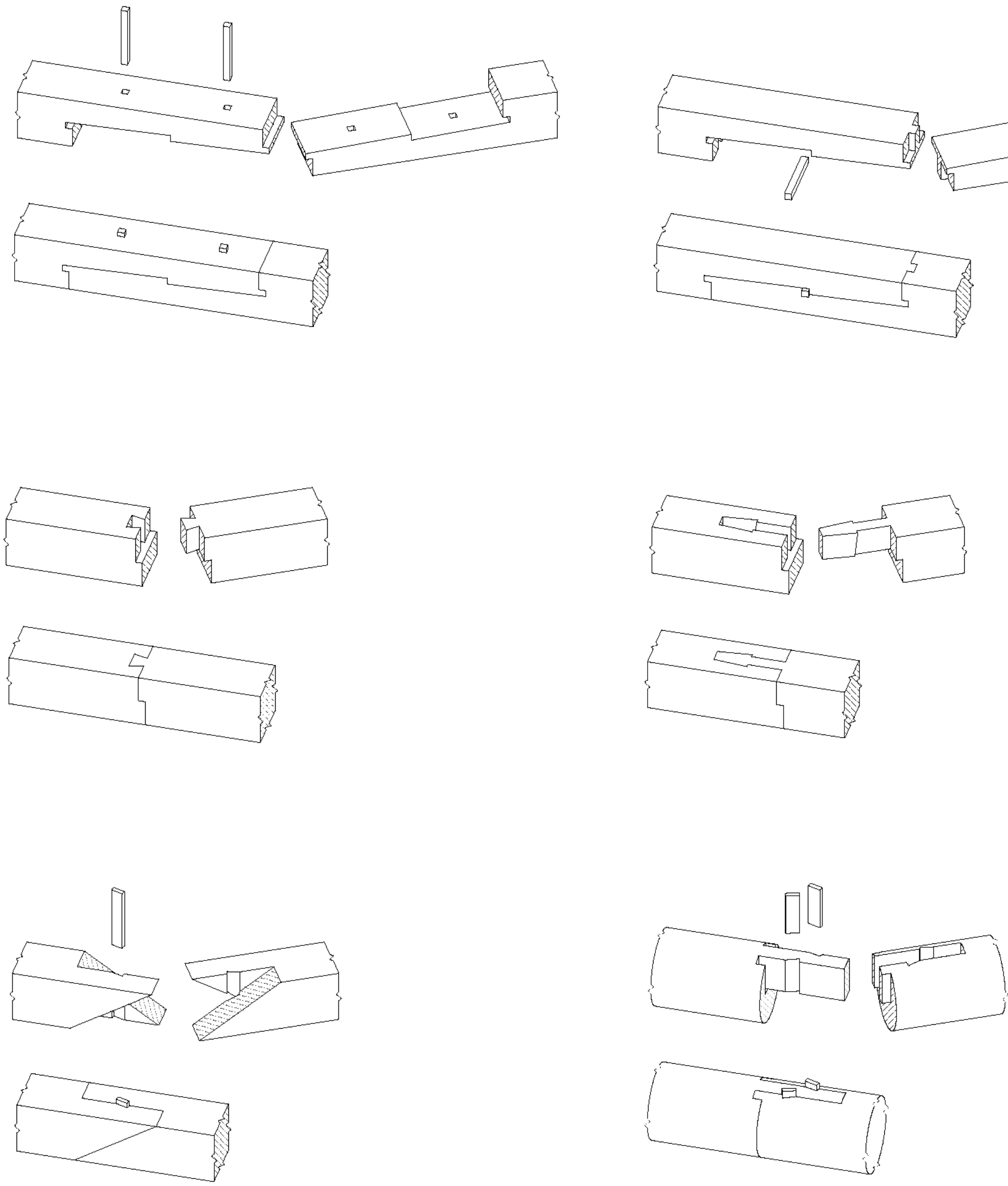

Figure 7: Traditional Japanese Longitudinal Joints

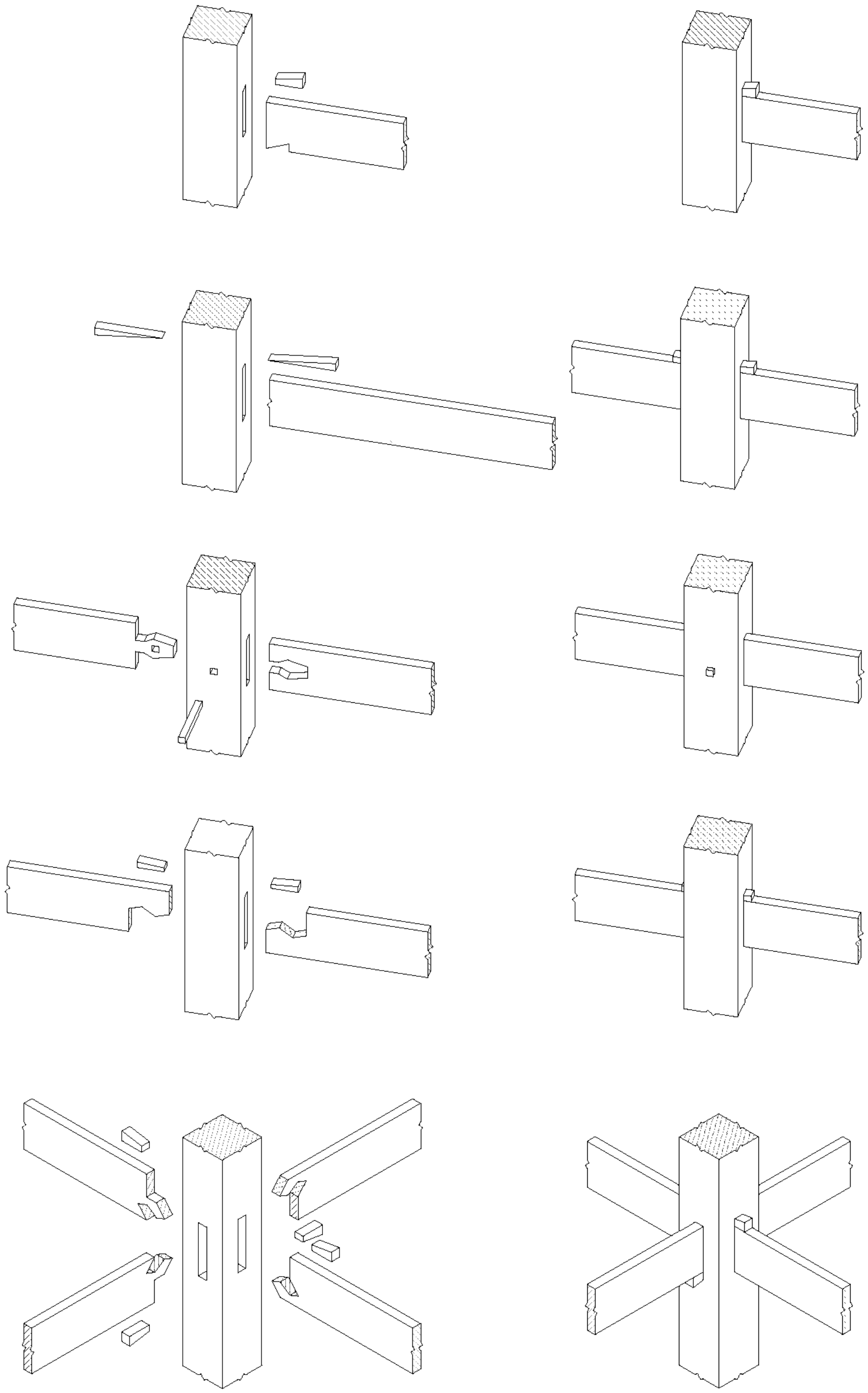

Figure 8: Traditional Japanese Column and Tie Joining

2.2.5. Wall

The Japanese wall uses horizontal members. This allows the walls to have more structural rigidity. The traditional Japanese wall also used bamboo and plaster for insulation. This meant the main structural elements were exposed. Exposed wood meant that not all types of wood could be chosen for exposed members.

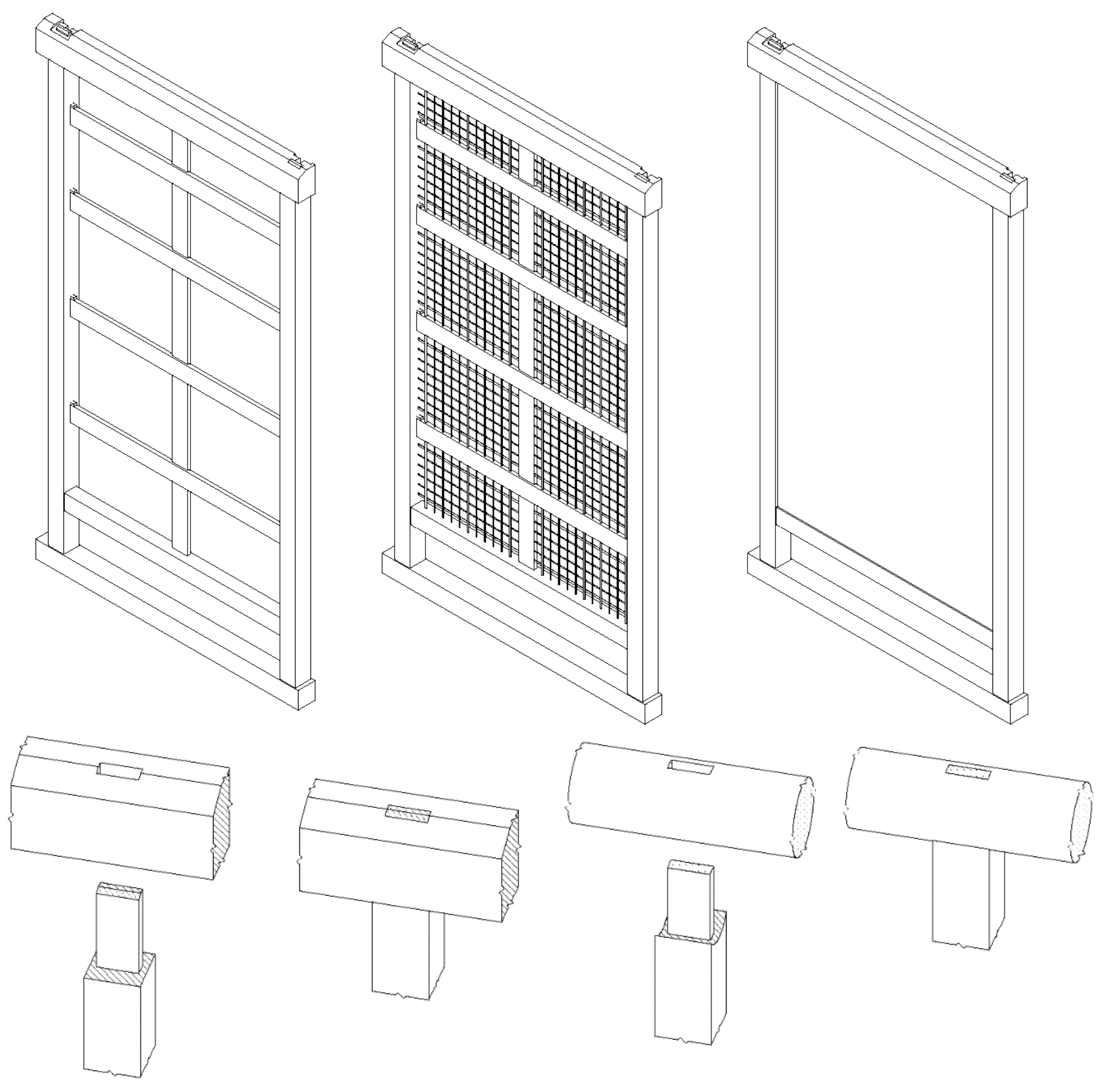

Figure 9: Traditional Japanese Wall and Top Plate

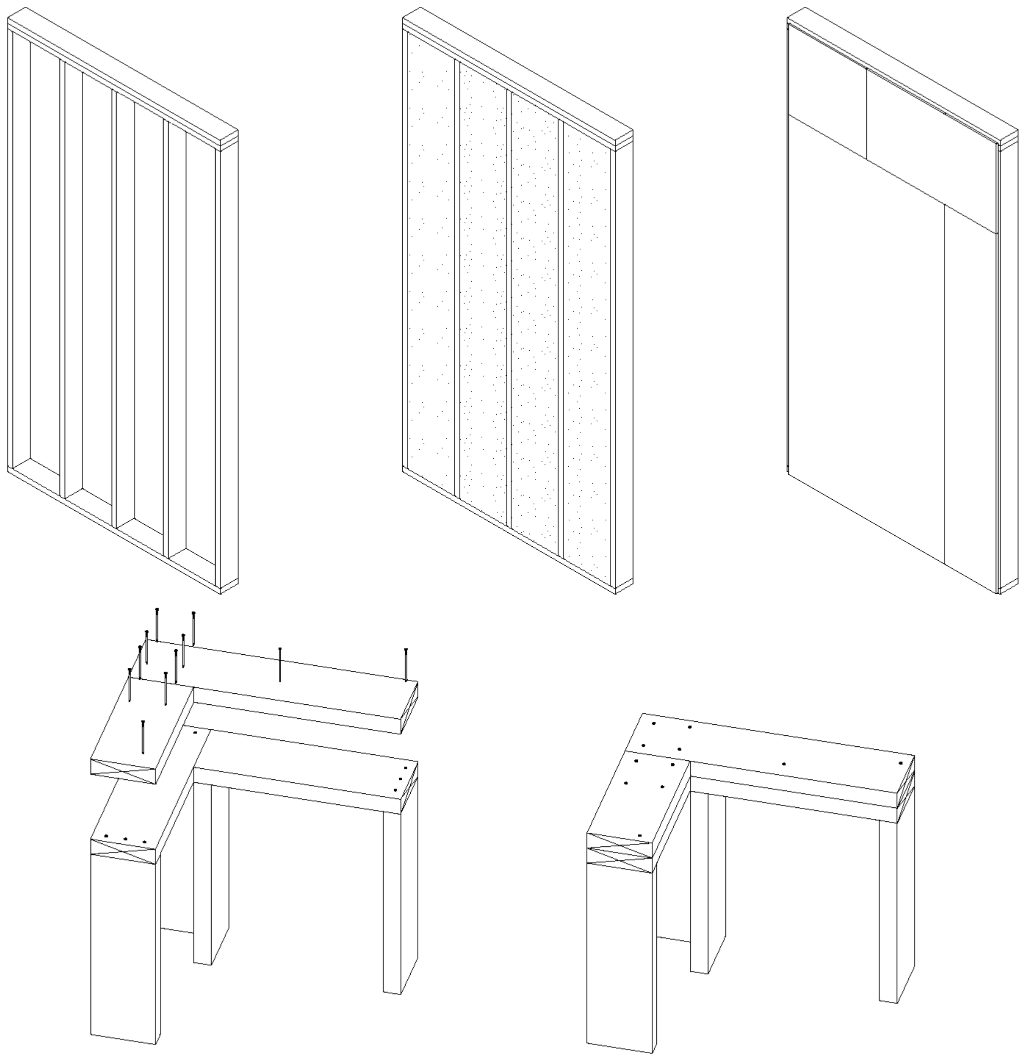

Figure 10: Light-frame Wall and Top Plate

Light-frame construction consists of vertical members spaced sixteen inches apart. This system depends on exterior sheathing and overlapping of top plates to create rigidity as the framing itself is not very stable. All the structural components of this system get covered by sheathing and siding leaving no exposed wood. Because of the number of vertical members that span the width of the wall, it is more susceptible to thermal bridging if not insulated properly.

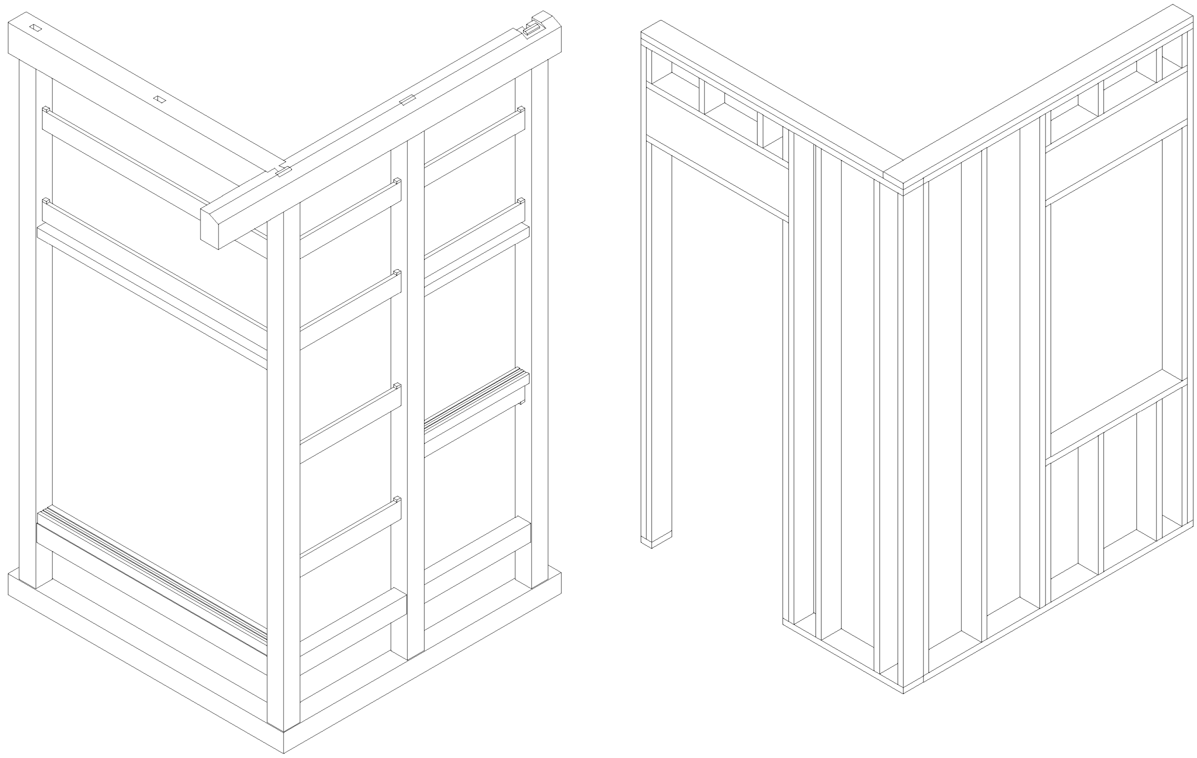

Figure 11: Door and Window Framing
Note: The assembly on the left is the traditional Japanese model while the one on the right is light-frame construction.

2.2.6. Framing Doors and Windows

Japanese walls incorporate a post and beam assembly allowing for the vertical load to be taken away from any doors and windows. The modern light-frame assembly needs additional headers and bracing to transfer that vertical load away from the top of doors and windows. Traditional Japanese doors and windows used a sliding system. This meant the frame incorporated two rails allowing doors and windows to slide past each other to open or close.

2.2.7. Roof

The roof structures of traditional Japanese and modern homes are assembled differently. The Japanese roof uses crossbeams, posts, purlins, and rafters. All these members are assembled separately unlike a truss that comes assembled from a manufacturer. Another key difference is the Japanese roof doesn't take advantage of triangulation which is very common in modern roof systems.

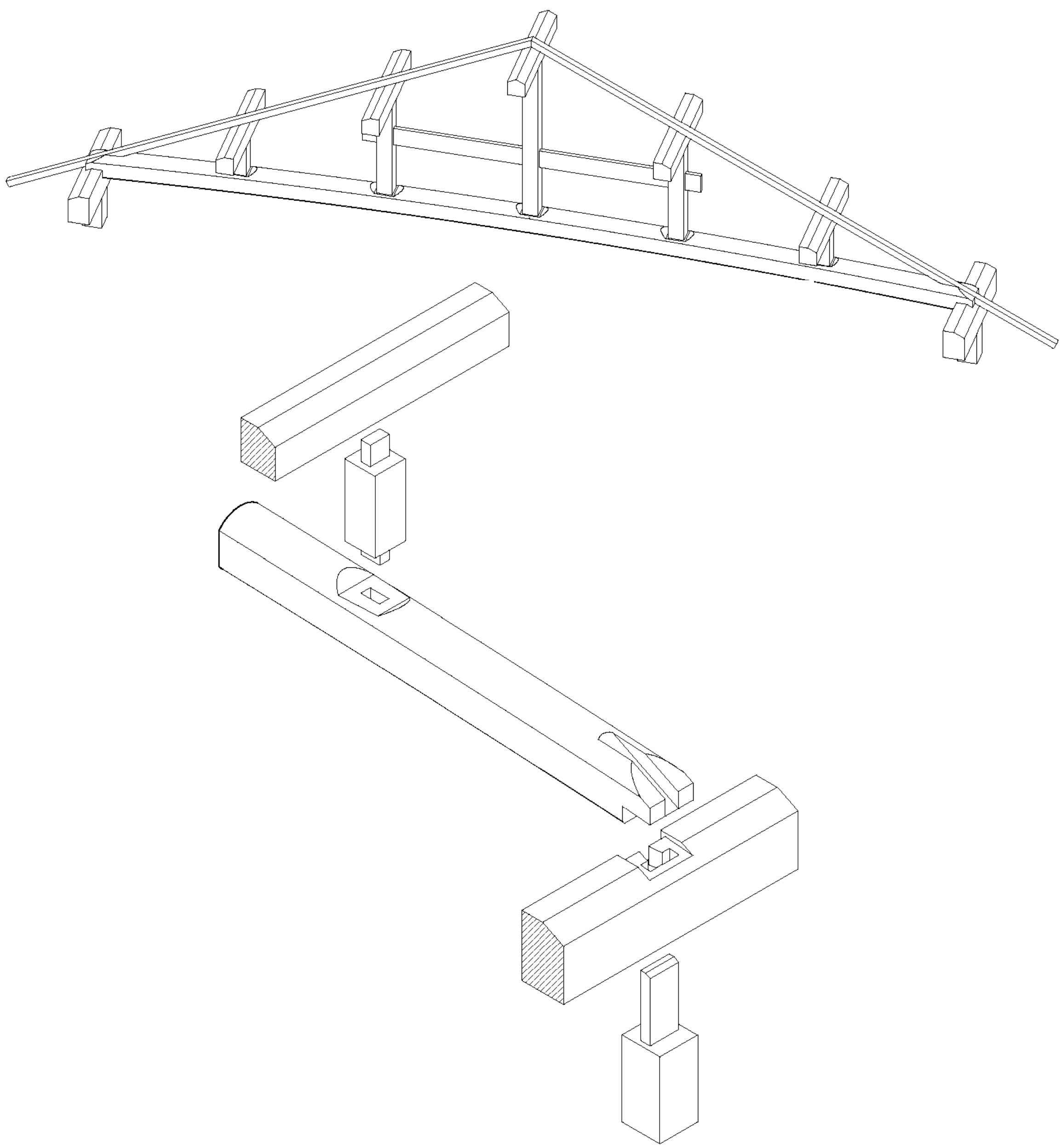

Figure 12: Traditional Japanese Roof

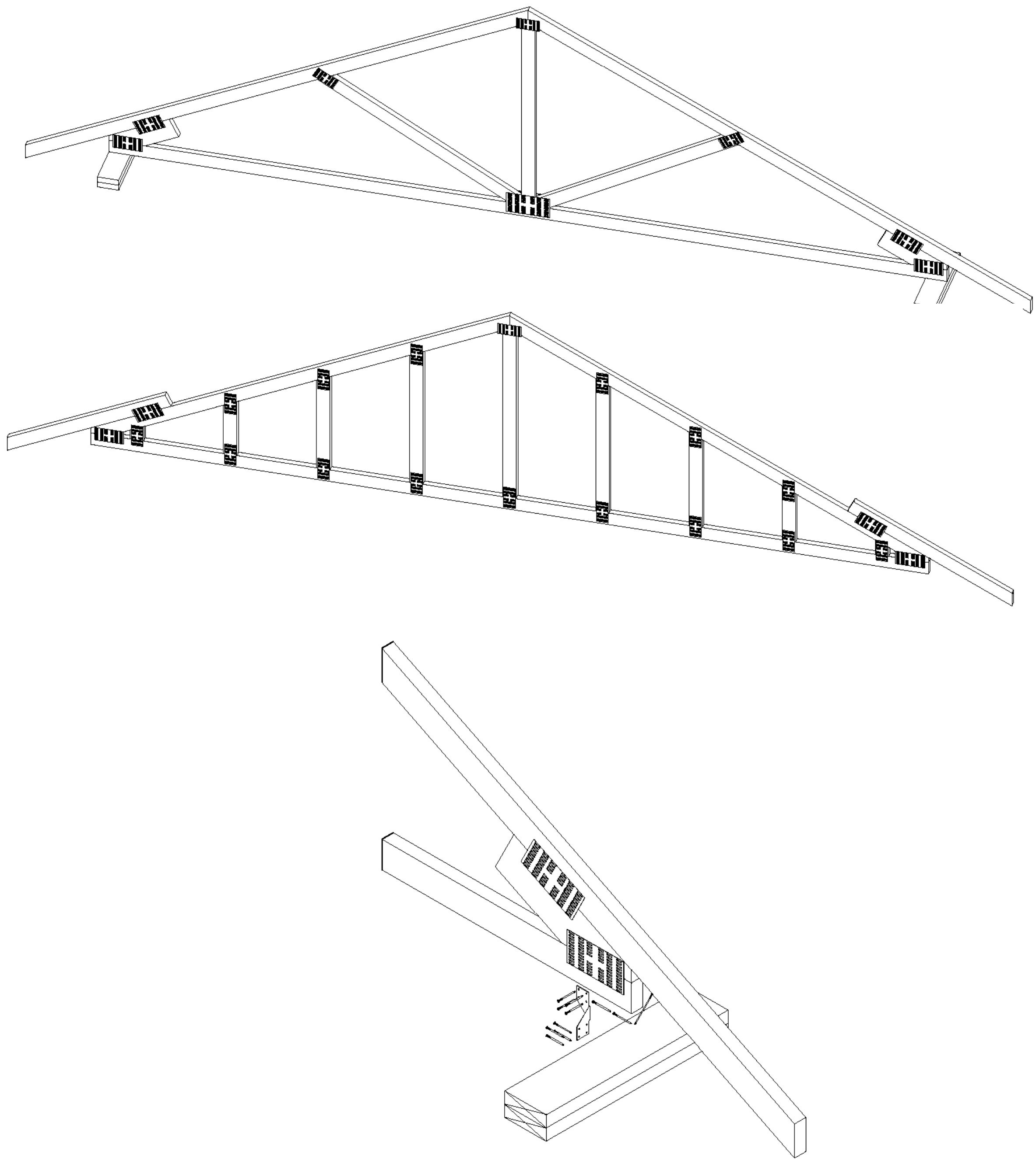

Figure 13: Light-frame Truss

The truss on the other hand is very light and uses mending plates instead of wood joints. Trusses are also fastened using nails and sometimes hurricane clips to prevent them from uplifting in heavy winds. The difficulty of placing trusses is lining them up and making sure the spacing is correct for roof sheathing.

2.3. Project Issues

When comparing the two structural systems there are strengths and weaknesses to both. The main issues to be addressed revolve around the light-frame construction method. It has problems with thermal bridging, reliance on metal fasteners, additional framing around doors and windows, additional blocking for mounting wall fixtures, and reliance on sheathing for structural rigidity.

3. METHODOLOGY

3.1. Approach

The approach for this project included analyzing and understanding how a traditional Japanese and modern home frame is constructed. It involved researching the structural systems to understand the assembly and connection of each member used to assemble a house. This information was then used to generate a model of each structural system to understand every detail. Both models were compared and assessed to create an adaptation of the two systems. This adaptation was then modeled in detail to understand its complexities and weaknesses.

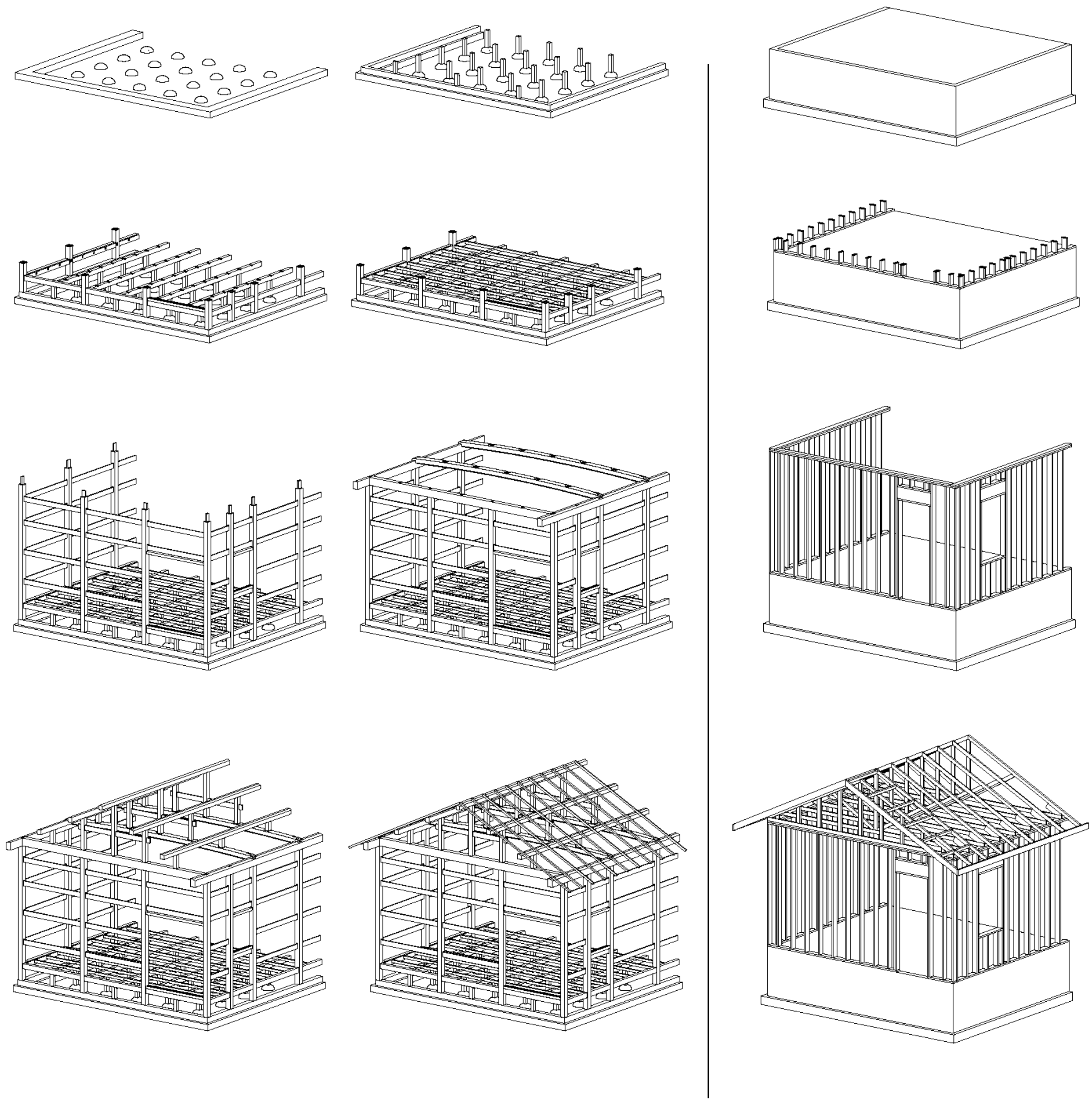

Figure 14: Structure Assemblies

3.2. Adaptation

3.2.1. Tools

The adapted construction method would use modern power tools to fabricate and assemble. This makes it easy to learn without any additional training. Any new joints would be simple straight cuts that could be performed with tools found on a typical job site.

3.2.2. Foundation and Sill Plate

The adapted foundation incorporated the same slab-on-grade construction we use today. This was kept the same to focus the project solely on the wood structure itself. This meant it still used anchor bolts, drive pins, and sill seal to fasten the sill plate to the foundation. One thing that

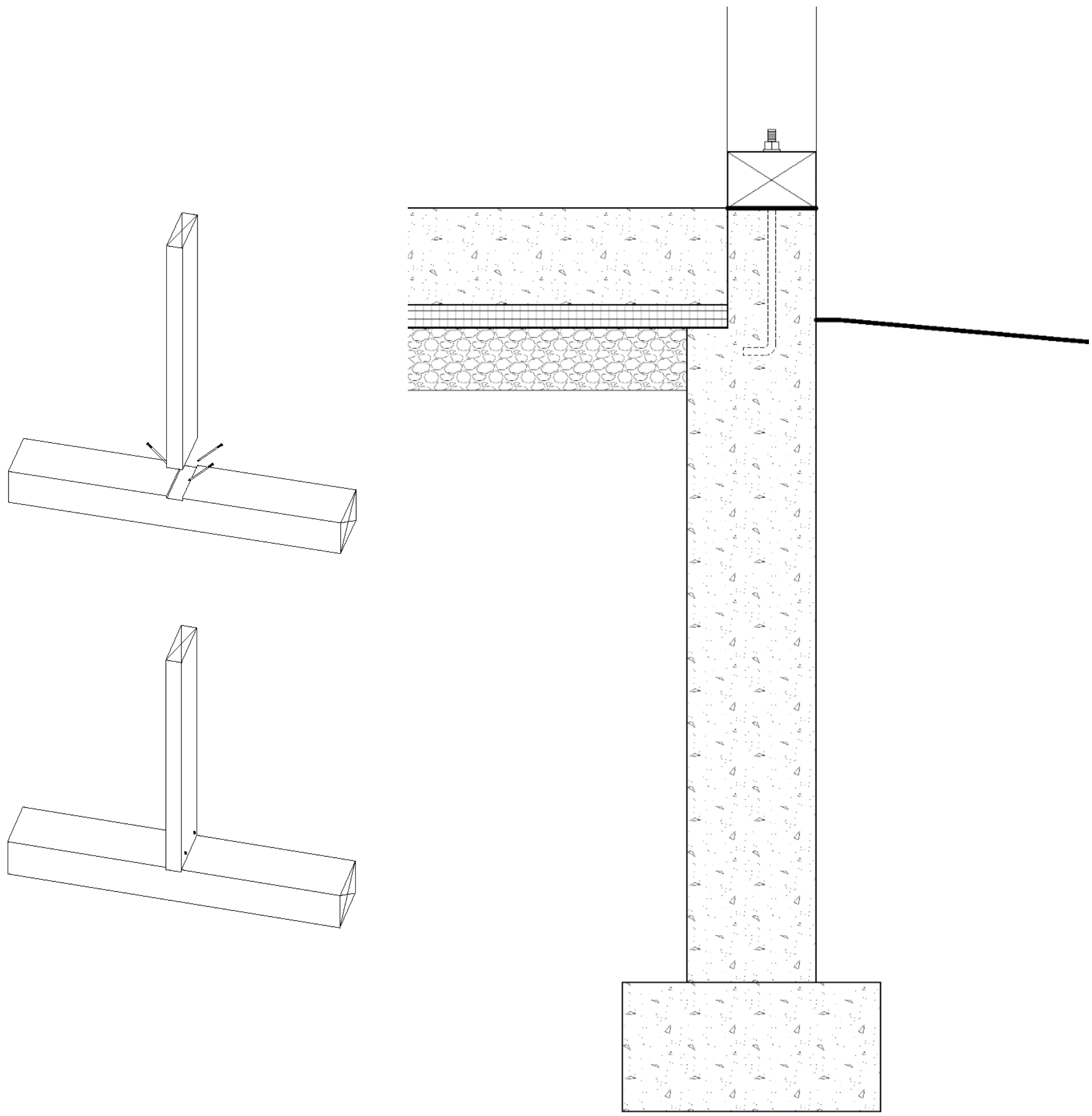

Figure 15: Adaptation Foundation and Sill Plate

changed was the thickness of the sill plate. Instead of a 2x6, it would use a 4x6. This allowed for a shallow groove to be cut in the sill plate keeping the vertical stud in place. It also allows the stud to be toe-nailed from the top which is a stronger connection. This also eliminates any metal or additional holes underneath the sill plate that could lead to rust or rot.

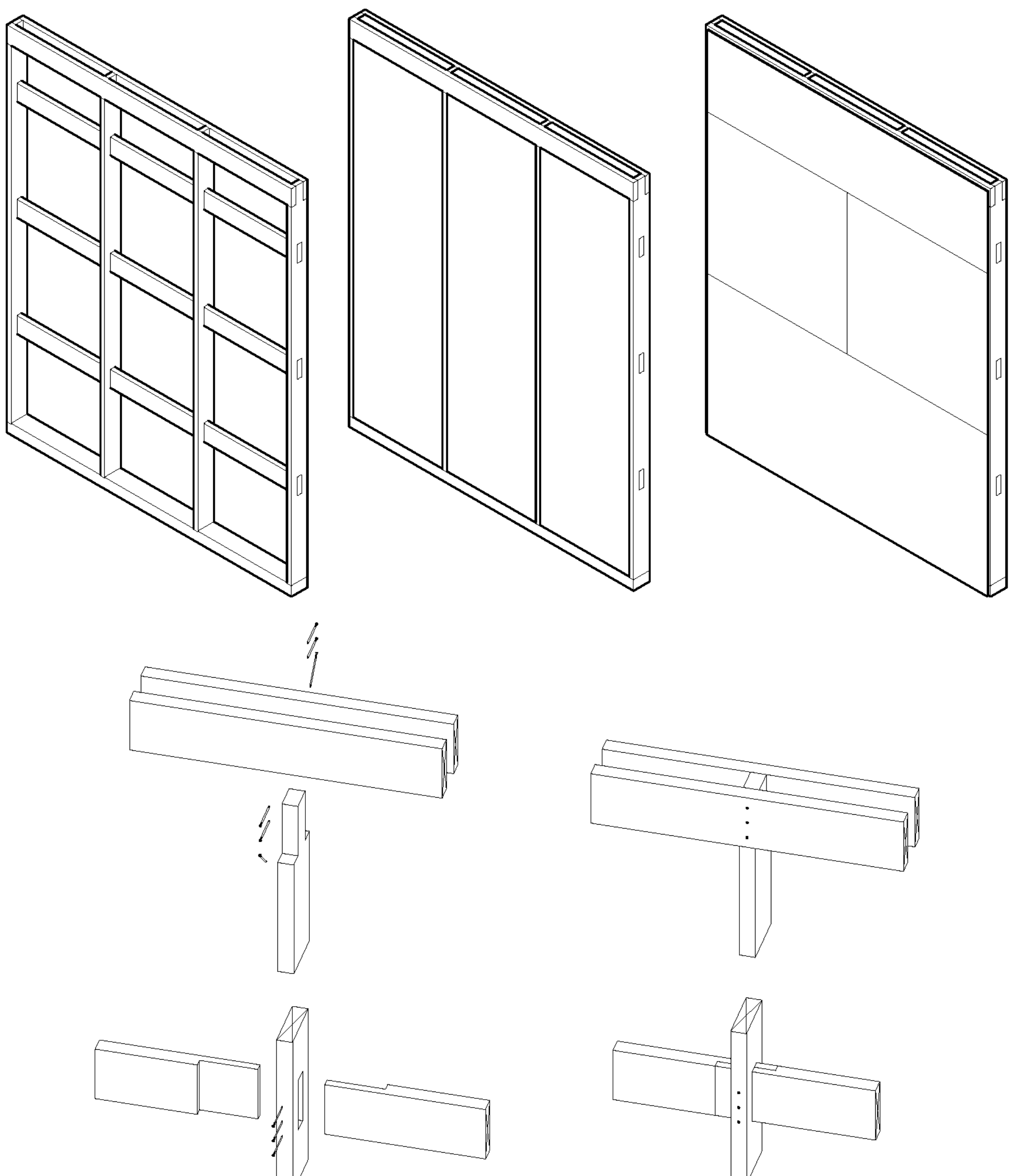

Figure 16: Adaptation Wall, Top Plate, and Horizontal Tie

3.2.3. Wall

The adapted wall assembly used a combination of dimensional lumber wall studs with the horizontal members used in Japanese construction. This means that the wall doesn't rely on exterior sheathing for rigidity. This allows more siding options that could either eliminate the use of sheathing or reduce its thickness as it would no longer be structural. Instead of the studs being 16 inches apart they are 32 apart. This allows for sheathing to still work when laid horizontally. This wall system would assemble similarly to a stud wall where it is assembled on the ground as one piece and then stood up.

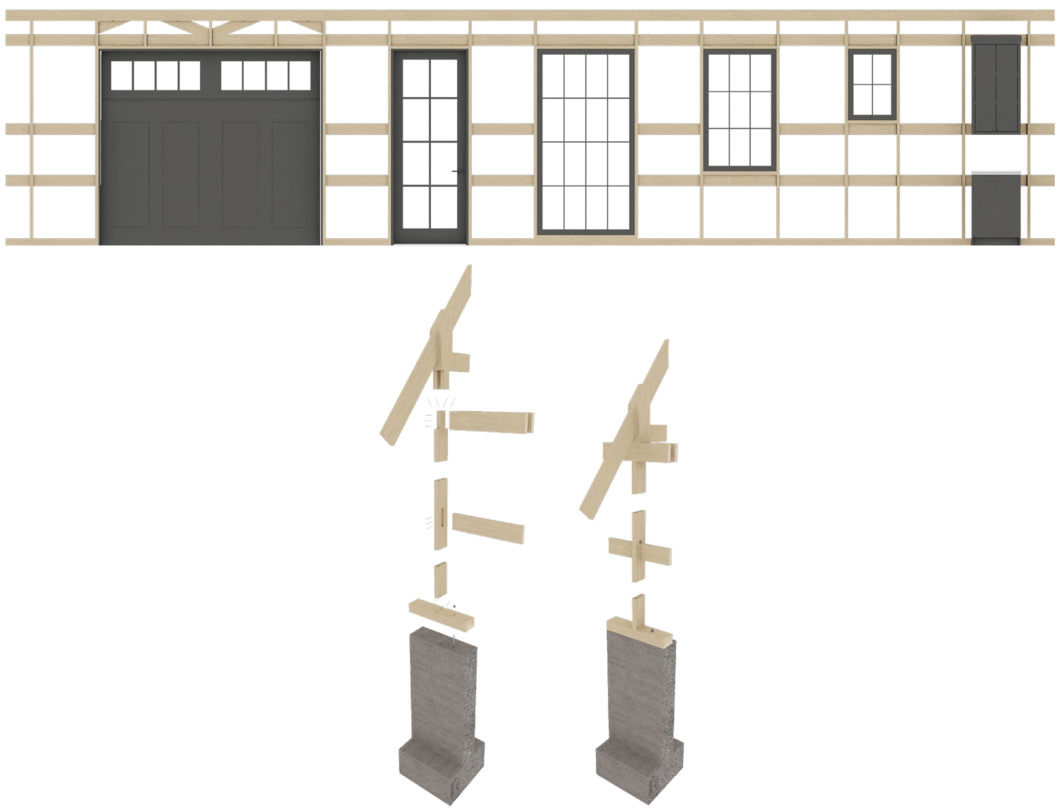

Figure 17: Horizontal Member Diagram

3.2.4. Framing Windows and Doors

Horizontal members are positioned at the header height of doors and windows and the average sill height of the windows. This allows for doors and windows to be moved around much easier without as much deconstruction. There are also no additional headers or bracing needed as there is no vertical load on the doors and windows. The middle horizontal member serves as additional support as well as blocking for mounting upper cabinets and other wall-mounted fixtures.

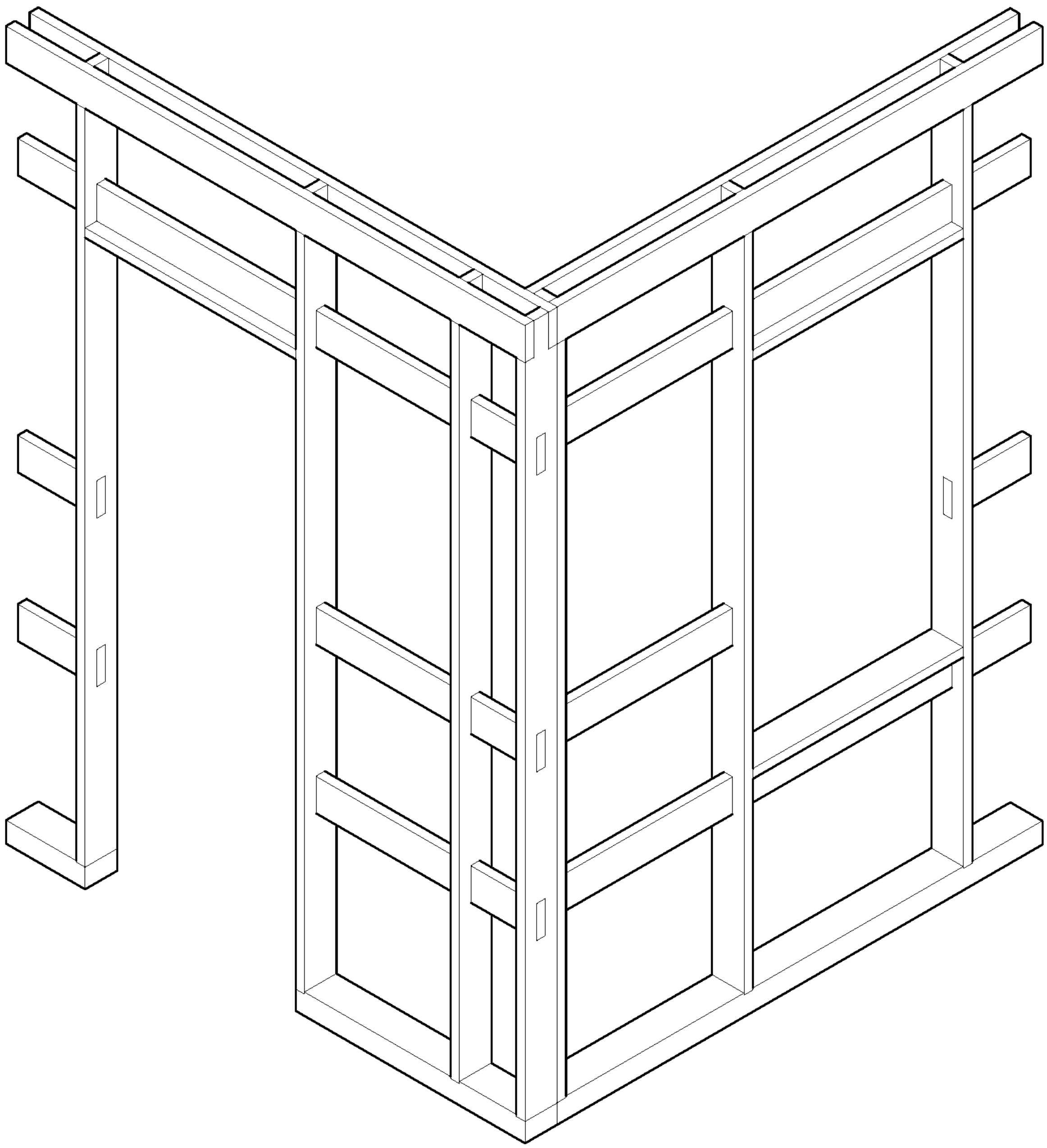

Figure 18: Adaptation Window and Door Framing

3.2.5. Roof

The roof system would work the same as a truss. In this case, it could come completely assembled or be constructed on-site to save space in transport. This truss doesn't rely on mending plates, however. It uses simple wooden joinery with nails to secure it. One benefit of

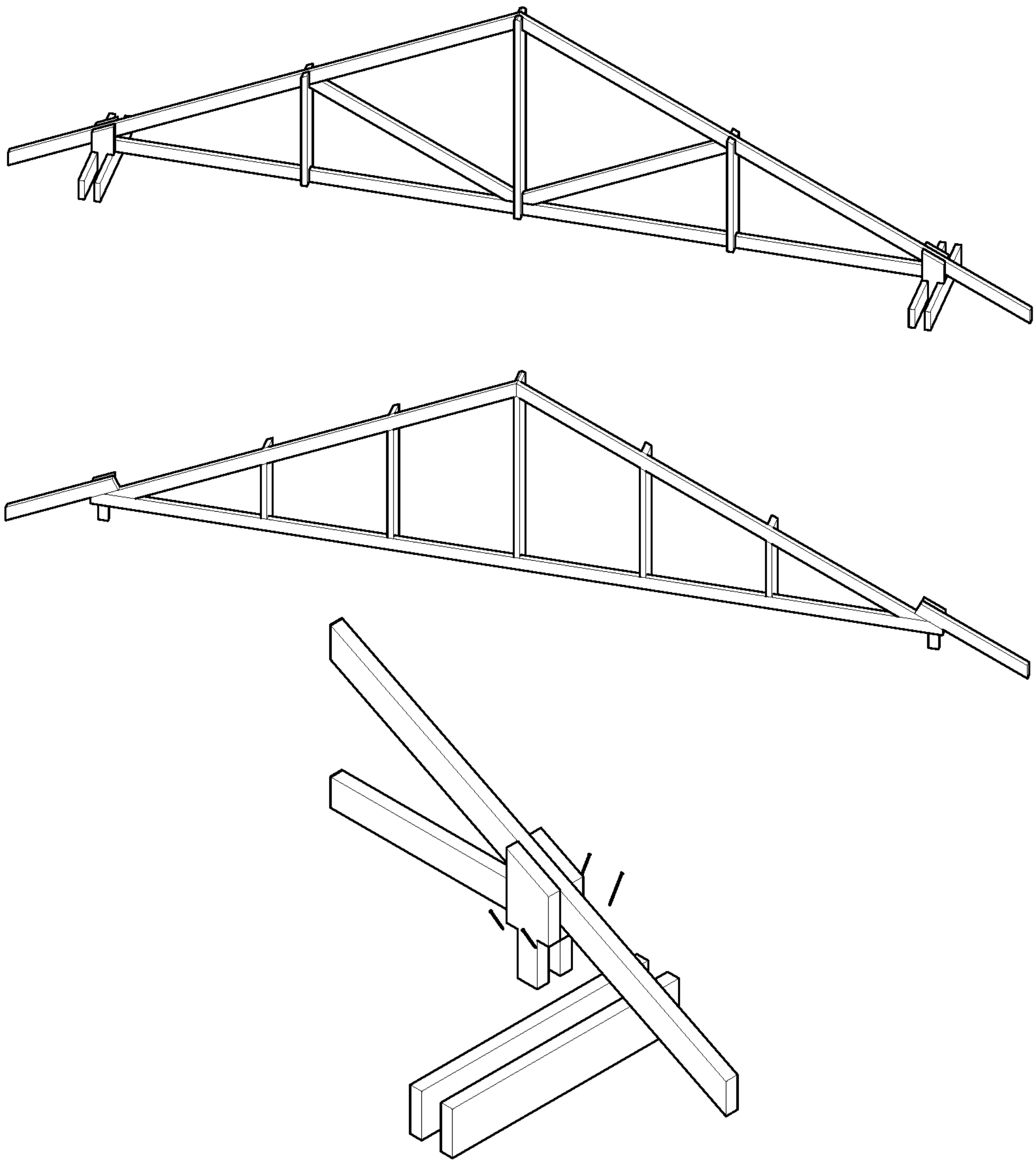

Figure 19: Adaptation Roof Assembly and Connection

the top plates being turned on their edge is that the trusses can easily slide into this opening making it much easier to align and secure the roof system.

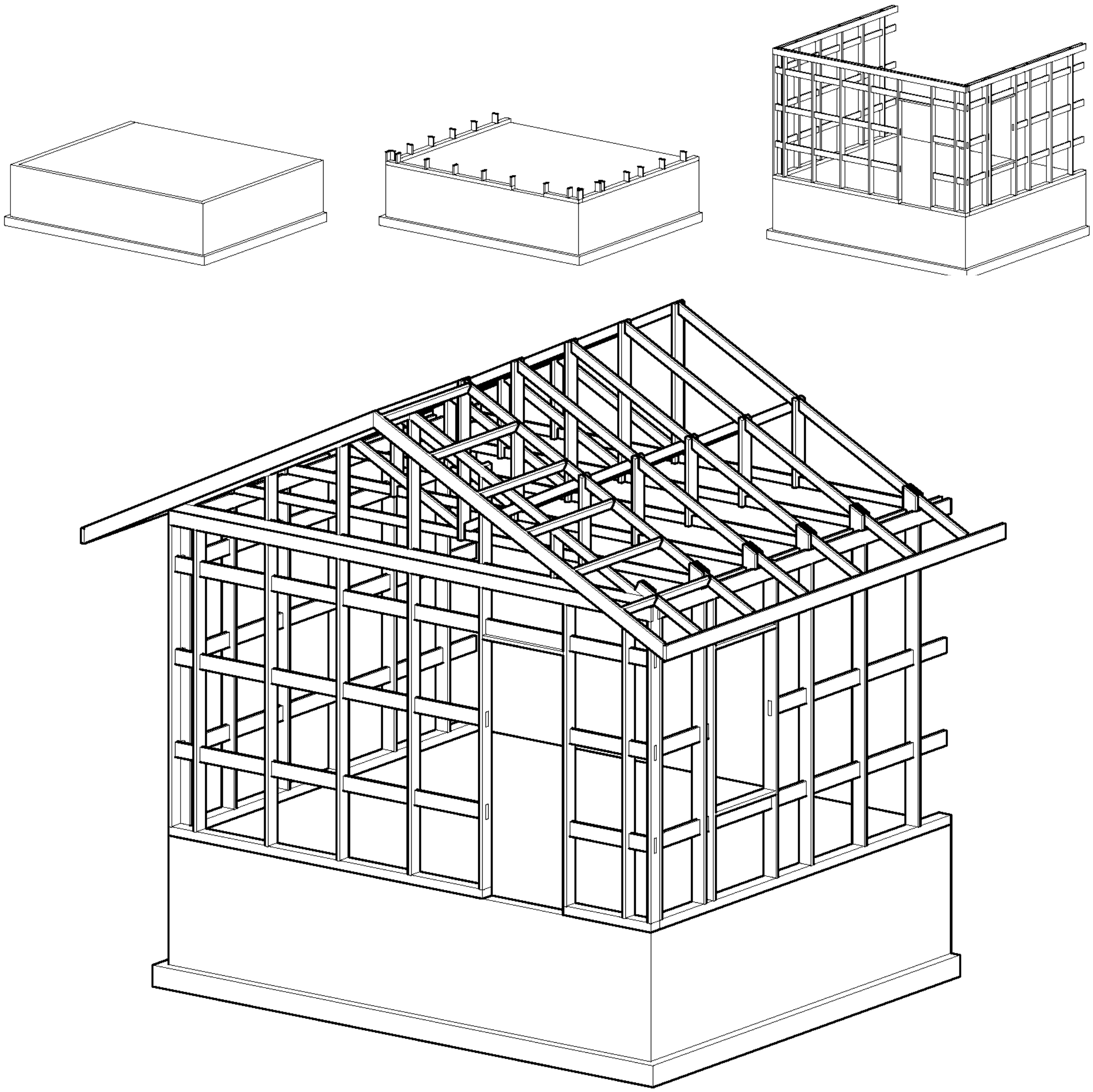

Figure 20: Adaptation Assembly

3.2.6. Analysis

Analyzing the two construction methods the goal was to combine positive aspects of both. I wanted to create redundancy using the traditional Japanese method of wooden joinery with modern metal fasteners' efficiency. It was clear to see.

3.2.7. Conclusion

In conclusion, this proposal lays the foundation to begin researching how the craftsmanship of traditional joinery can be adapted to today's construction methods. The importance of completing this research would result in a greater understanding of whether our current construction methods can achieve the same quality and craftsmanship as traditional joinery methods have done and if there are solutions to bringing this level of detail back in an efficient manner.

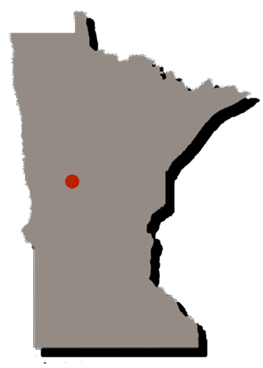

Figure 21: Project Location in Minnesota

3.3. Project Location (larger scale)

The site is in Becker County, Minnesota. Becker County's population is around 35,000. Located in Minnesota, this site experiences cold winters and hot, humid summers. A relatively rural location consisting of a lot of lakes. The county seat for Becker County is Detroit Lakes, Minnesota.

3.4. Project Location (smaller scale)

Located in Rochert, Minnesota northeast of Detroit Lakes and West of Tamarac National Wildlife Refuge. This site has very little elevation change and is near Rock Lake.

Figure 22: Site Location Near Rock Lake
Note: Google Maps. (n.d.)

3.5. Specific Site

This site is located on the east side of Rock Lake. It is located on the edge of a field surrounded by trees and protected from wind. The main access is a dirt path from the southeast with an even lesser path from the northeast. One of the main views from the site includes the sunset overlooking Rock Lake.

3.6. Pertinent Research (user experience)

I spent two summers working for a contractor in residential construction. This background knowledge allowed me to create a stick-frame model and understand its connections and assembly.

4. RESULTS AND CONCLUSIONS

4.1. Final Project Description

This project is a single-family home constructed using the adapted structural system. The house has roughly 3,000 square feet of finished space and has four bedrooms and two and one-half bathrooms. The main views from the kitchen, dining, and living room consist of a western view over Rock Lake to capture sunsets. A four seasons room was included to allow the family to enjoy their time by the fire without being interrupted by mosquitoes or weather. The overall design appears symmetrical but is rather balanced for aesthetics.

4.2. Project Objective

The intention behind this project was to test the adapted structure. This way I could adjust the construction system and find obvious pitfalls I might have missed creating the adaptation. This would allow me to have further knowledge of how the adaptation would be applied to a real-world project so I could analyze its strengths and weaknesses.

4.3. Project Design and Documentation

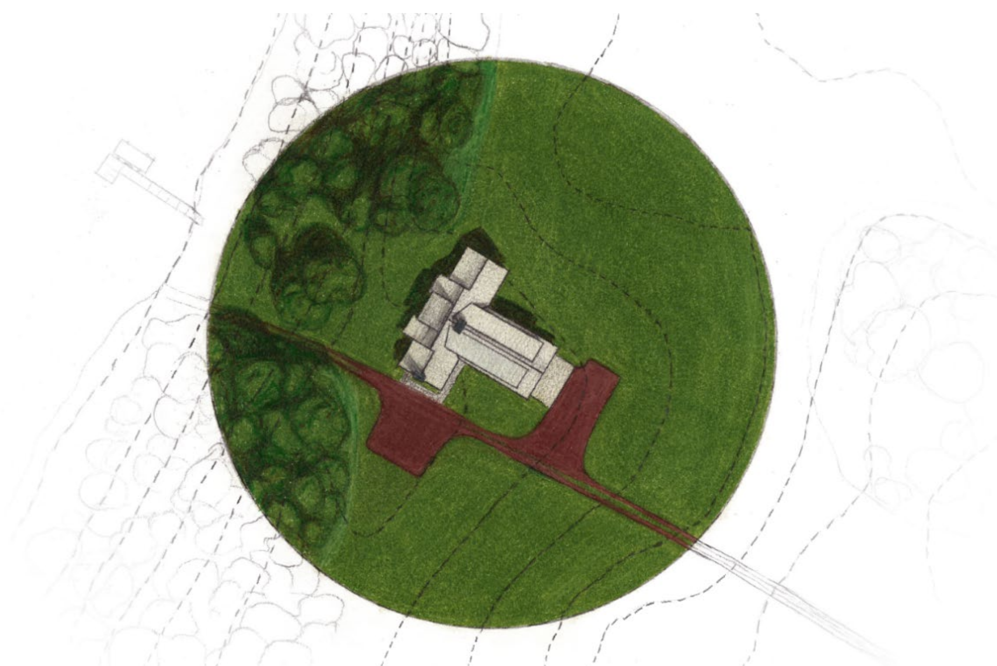

Figure 23: Site Plan

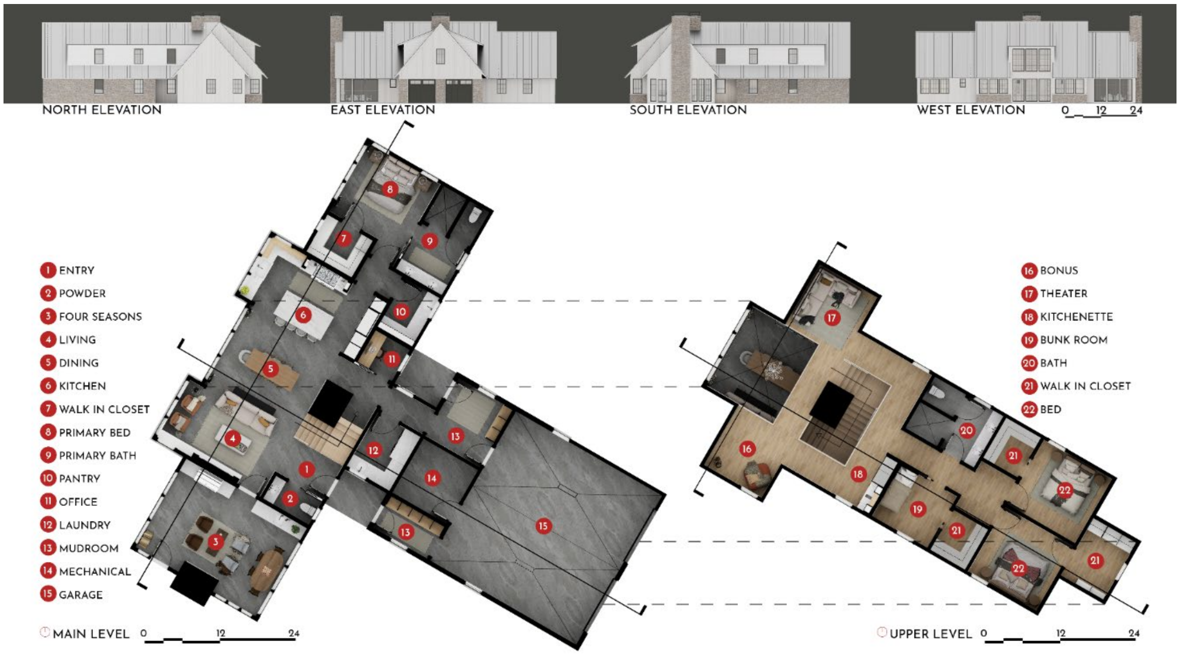

Figure 24: Elevations and Floor Plans

Figure 25: Section Perspective 1

Figure 26: Section Perspective 2

Figure 27: Exterior Perspective from Southwest

Figure 28: Entry Perspective

Figure 29: Living Room Perspective

Figure 30: Dining to Kitchen Perspective

Figure 31: Kitchen Perspective

Figure 32: Dining Room Perspective

Figure 33: Kitchen to Dining Room Perspective

Figure 34: Four Seasons Room Fireplace Perspective

Figure 35: Four Seasons Room Perspective

Figure 36: Exterior Perspective from Path

Figure 37: Exterior Perspective Sunset

4.4. Conclusions

Upon completion of the project, I discovered that the adapted construction system had solved problems while also creating new ones. It was successful at creating a rigid structure without the need for sheathing. This could open new possibilities for siding and other exterior materials. The adaptation incorporated wood connections backed up with metal fasteners for more redundancy. The horizontal members provide multiple purposes besides structural rigidity including headers, sills, and mounting wall fixtures. Some concerns found while designing the project are the open top plates that could allow the spread of fire. The additional horizontal members could offset that, but additional testing would need to be done. Load calculations would be beneficial to understand if the construction method is plausible or unstable. Testing the adaptation in seismic activity would be interesting as it may perform better than modern light-frame construction. Another concern would be the options for insulation since the wall cavities would not be standard light-frame construction today.

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