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Tiny Home Innovations: Alternative Uses and Designs with the San José Bridge Housing Community

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I HEREBY RECOMMEND THAT THE SENIOR DESIGN
PROJECT REPORT PREPARED UNDER MY SUPERVISION BY

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ENTITLED

Tiny Home Innovations: Alternative Uses and Designs with the San José Bridge Housing Community

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By
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Abstract

Homelessness is without question one of the most severe humanitarian crises in the Bay Area. Regardless of whether people think ending homelessness is feasible, the bottom line is that every human deserves the right to have a place they call home. Despite the simplicity of this right, achieving it in today's society is difficult because of the economic, social and political complexities which make homelessness appear to be a problem with no solution. Unfortunately, belief in the hopelessness of efforts to end homelessness dissuades many from taking action.

This project is not guided by the belief that ending homelessness is hopeless. The goal of this project was to provide organizations that counteract homelessness with more housing options because the project team valued their mission to provide the marginalized and forgotten with the rights they deserve. This project investigated, analyzed, and developed alternative tiny home uses for the City of San José's Bridge Housing Community (BHC) program. To accomplish this, a fully engineered, modular version of the existing BHC cabin was designed for if the BHC program is expanded, and appropriate retrofit modifications to the current cabin design were determined for if the program is discontinued.

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Chapter 1: Introduction

1.1 Homelessness in San José

Most who live in San José are aware of the current homelessness crisis. There are currently over 6000 people who experience homeless in San José (City of San José Housing Department 2019); 43% are experiencing homelessness for the first time, and 60% of the first time homeless have been homeless for over a year (City of San José Housing Department 2017 Census). The total number of homeless in San José has increased dramatically by nearly 50% in the past two years. This increase demonstrates a lack of services for individuals who have recently fallen into homelessness, including the inability to shelter 82% of San José's homeless every night (City of San José Housing Department, 2019). One of the other factors that has made it difficult to combat homelessness is the staunch position of San José and Santa Clara County residents who lobby against services for the homelessness. Any notion that housing is a right and that homelessness is usually a mark of unfortunate circumstances is marred by predispositions towards and the stigmatization of the homeless. So it is also important to note how many common beliefs about the unhoused are false. For example, many people believe that those who are homeless have been drawn to San José by fair weather or a lenient system. This notion is false, as 83% of the homeless in San José are native to Santa Clara County (City of San José Housing Department 2017 Census).

The City of San José has taken a major stake in combating homelessness. The City Council recently approved the allocation of 45% of the City's investments into permanent affordable housing for extremely-low-income residents. Santa Clara County as a whole has committed $234 million thus far to housing developments that serve, as one city council member put it, the "most vulnerable of our community" (City of San José Housing Department 2019). This funding has gone to a variety of projects in the City of San José. One such program is the Bridge Housing Community project.

1.2 Bridge Housing Community - San José

When the Santa Clara University (SCU) team began their project, the City of San José (SJC) was close to beginning construction of San José's first Bridge Housing Community (BHC) - a development of 40 "emergency cabins" to serve as a rapid re-housing support community for recently homeless individuals. The City intends for the BHC to serve as a model of interim housing solutions for homeless members of the community, and expects the program to grow beyond this first "village." The pilot program includes the construction of temporary housing structures on two plots of land owned by the city or other state agencies. The first set of cabins were expected to be completed shortly after the SCU team graduated in June 2019. Habitat for Humanity (Habitat), who served as the general contractor for the BHC project, had previously built a few prototypes to showcase different options. The cabins are intended to be a single room with a bed and some storage, and will initially house just individuals. Each cabin will have electricity, but not services for running water or sewer. There will instead be a separate facility on site that will house cooking and shower facilities, as well as a facility that provides personal and professional support services.

Figure 1.1 *- Initial conceptual designs of the emergency sleeping cabins created by Gensler (San Francisco) and published by the City of San José Housing Department in December, 2017.*

The SCU team was first introduced to this project in a meeting with James Stagi and Gabriela Banks, members of SJC Housing Office's Homelessness Response Team. They explained that the Bridge Housing Community project is a result of an Assembly Bill approved by the City Council called AB-2176. This bill, approved in 2016, temporarily amends the building code and zoning laws for the purpose of constructing emergency housing to address the aforementioned shelter crisis in San José (Assembly Bill No. 2176). This bill will expire on January 1, 2022, and the Homelessness Response Team has until then to prove that the BHC model can be successful in order to extend the bill or make it permanent. Based on meetings with SJC, Habitat, HomeFirst (who will operate the first BHC communities), and others involved with the BHC program and similar homelessness response efforts, it was determined that the BHC program has a good chance of being renewed. This confidence is due to the fact that the specific demographic which the program aims to serve are in position to get back on their feet quickly. All residents are required to maintain a full time job, and must adhere to policies that are intended to give them support such that when they move on from the program, they have a less likely chance of falling back into chronic homelessness.

Chapter 2: Project Scope Evolution

2.1 Meeting the City

Before determining the criteria that would be used in the design, the SCU project team made it a priority to seek advice from outside sources whose experience provided invaluable insight. The team used the feedback from these meetings to make key decisions throughout the design process.

The first group of people that provided insight was the City of San José (SJC). The Director of Programs and Partnerships at the Santa Clara Frugal Innovation Hub, Allan Baez Morales, reached out to his contacts at City Hall. These contacts put the SCU team in touch with James Stagi and Gabriela Banks from the Homelessness Response group. In June 2018, Mr. Stagi and Ms. Banks introduced the SCU team to a variety of projects and initiatives that SJC was employing to counteract homelessness. It was evident that SJC was focusing on projects that have the resources available to not just serve as temporary housing, but that work to return the homeless to permanent housing. These programs are referred to as "rapid re-housing approaches" (Housing Department 2018). One such program was the Bridge Housing Community (BHC) project.

There are many unique aspects of the BHC project. Among the most significant is the fact that the cabins used for the program do not have to be designed per the California Building Code (CBC). AB-2176 suspended the building code and typical zoning laws until 2022 as a part of the response to the "homelessness crisis" in San José (Assembly Bill No. 2176). The City had to write their own building code which follows structural guidelines and applicable safety measures (such as fire safety), but were allowed to take some breaks on non-structural requirements (such as minimum square footage and plumbing in each of the units). At the time of the first meeting in June 2018, the City had already received pro bono architectural renderings from Gensler in San Francisco and had secured a developer (Habitat for Humanity) and site operator (HomeFirst).

In September 2018, the SJC Homelessness Response group invited the SCU team to a meeting with Habitat for Humanity's team, including Kevin Elliot, Audrey Murray, Cameron Delaney, Hamid Taeb, and Ben Grubb. The SCU team then met with Ms. Murray, Mr. Delaney, and Mr. Grubb to discuss the work they had done thus far, and began to determine how the Santa Clara team could supplement the work done by Habitat.

After these initial meetings, it was determined that the ability to transport the BHC cabins was paramount, and that continuing to improve the current cabin's mobility could be very beneficial to the program. The second issue was that, at the time, the City did not have a plan for what to do with the cabins if the program is discontinued in 2022 when AB-2176 expires. If this were to happen (although it does not seem likely), there will be 80 cabins with no place to store and no planned future uses.

2.2 Reframing the Project Goal

By December 2018, the SCU project team had reframed their question from "how can we alter the design to provide value to Habitat and SJC?" to "how can we alter the design by addressing future needs that these organizations have not yet been able to consider?" This new guiding question led the team to reach out to more people and organizations that could provide insight on how an alternative design could meet the needs of not just the BHC program, but other, future needs beyond the BHC model. These individuals included Spencer Arnold, Director of the Miller Center for Social Entrepreneurship's Global Operations and friend of the SCU team's advisor, and René Ramirez, Chief Operating Officer of HomeFirst.

Mr. Arnold advised the team to ensure that whatever the team designed could be adapted to changing technologies. This included designing for the incorporation of technologies that could make the cabins entirely self sufficient. Though this feedback was taken into consideration, it was determined that such new technologies were not feasible due to their higher cost, and the difficulty maintaining mobility would be with these additional features.

The meeting with Mr. Ramirez confirmed the path that the team had already begun to focus on. The first thing that became apparent in this meeting was how receptive SJC had been to trying new methods of addressing homelessness. One example of this is the Overnight Warming Locations (OWL) program that SJC approved as a way of sheltering homeless in City-owned buildings (like public libraries) during cold and wet stretches in the winter. For Mr. Ramirez, programs like this show that the City is truly dedicated to being creative and open to new ideas for how to address homelessness. Mr. Ramirez also shared that Gensler, Habitat, and the City have continuously involved him and others at HomeFirst throughout the design process. He was also very confident that the BHC will be successful both economically and in its ability to serve the recently homeless in San José.

During this meeting, the current options available to families who are homeless in the City of San José and the broader Santa Clara County were also discussed. Mr. Ramirez admitted that it was difficult to find programs that were equipped to serve families and that families would trust. While the BHC program is currently set up for individuals, he said that if the program was modified to accomodate families, it could be very successful, and fill the current need for adequate options for housing families. The current cabin design is limited in the sense that it currently can only serve individuals, however, and could not meet this potential need.

With all this in mind, the SCU team was able to come to a finalized scope that satisfied the criteria developed above and incorporated the input brought up in these meetings. The project goal was to first come with an alternative redesign of the current cabin that improves versatility and mobility, and to second provide comprehensive and viable alternative future uses of the current cabin design.

2.3 Ethical Consideration

There were a number of ethical implications of the project. Since the intention of the project was to make a real humanitarian impact, it was important to consider whether the project achieves this from an ethical standpoint. Both parts of the project, the redesigned cabin and research of alternative uses, needed to be analyzed. The ethical analysis was performed through use of three criteria: humanitarian, environmental, and financial. Looking through these three lenses shed light on the strengths and weaknesses of the project and pointed the team in the direction of future improvement.

Modular Redesign Humanitarian Ethics:

It was imperative to both look into the direct user of the BHC cabins as well as those indirectly affected. Through use of the redesigned cabins, both individuals as well as families are able to move into a house. The safety and security of living in a home is incredibly empowering to human beings and provides a sense of self, home, and independence. The versatile aspect of the design implies that there are more potential future uses that the cabins could be put towards, meaning that the cabins could benefit more people over the course of their lifetime. The increased number of potential uses means that SJC could be able to serve families, and be able to help restore a sense of safety, security, and empowerment for the entire family. Those not living in the cabins, but in nearby communities, have already expressed discomfort with the current BHC model; however, the project team believes that the inclusion of families in the BHC design will actually remove a certain amount of that discomfort, lessening pushback from these communities. The redesigned, versatile design has a definite net positive impact on personal ethics.

Alternative Uses Humanitarian Ethics:

The alternative uses were designed with the purpose of solving the City's issue of where to store the cabins should the BHC program not be renewed. That being said, the uses were still chosen in an effort to have the cabins still be continuing to bring positive change. Using the cabins to fill different, current needs was paramount. The cabins would continue to empower individuals, as they would be used to provide space to those who are without. This empowerment again provides a net positive in personal ethics. There are fewer people indirectly affected by the alternative uses, as the cabins will no longer be included in the BHC program.

Modular Redesign Environmental Ethics:

The redesigned cabin, upon first glance, may seem to resemble other new tiny homes that are currently seen on the market. However, one significant difference when compared to these newer homes is that it doesn't make use of sustainable, self-sufficient technologies like recycled water or solar power. In an effort to the reduce the cost of the cabin, it is likely that lower cost and therefore lower grade lumber purchased is not sustainably grown and includes chemicals that are harmful to the environment. These factors increase the toll of building more cabins on the environment. However, keeping people off the streets and providing them with waste disposal, storage, and a bathroom space helps keep the City slightly cleaner. The environmental ethics of the redesigned cabin unit are therefore difficult to pinpoint, as there are contributed circumstances that could take a toll on the global environment, but the improved impact on the local area could offset this negative impact.

Alternative Uses Environmental Ethics:

Finding alternative uses of the cabins keeps them from winding up in a landfill sooner, and fills needs that might consume other resources should a greener solution not present itself sooner. By providing users with a pre-built space, they need not construct another one out of materials. The alternative uses are fantastic at reusing a structure to improve its life cycle, thus lowering it ecological footprint and improving its environmental ethical standing. This applies to the life of both the current cabin design that was used for the first two BHC villages, as well as that of the project team's redesigned cabin, should it be used in the future.

Modular Redesign Financial Ethics:

It is important to consider where taxpayer money goes and whether or not it is being used efficiently. The versatile cabin redesign costs more than the current BHC cabin unit; however the improved versatility and mobility associated with the redesigned cabin make the money worth spending. Once the BHC program has run its course, it will become clear whether or not the money spent has remedied enough homelessness to make the program worthwhile. That clarity will suggest whether or not it would be more productive to spend taxpayer dollars on other homelessness programs.

Alternative Uses Financial Ethics:

Using the cabins for longer than planned reduces the financial burden on others who would be constructing new cabins for their use. If the City is able to sell any cabins to alternative users, then the financial toll on San José is lessened and the funds can be put towards future homelessness programs. While there is a higher upfront cost to the cabins than other homelessness solutions, the implementation of alternative cabin uses increases the overall benefit-to-cost ratio.

Part 1 - Modular Unit Design

Chapter 3: Why Modular

3.1 Background on Modularization

The first part of the project focused on the goal of providing a versatile and mobile redesign of the City's current unit. It was determined that the best way to accomplish this goal was to pursue a modular method of design and construction. This idea is similar to concepts of panelization and prefabrication in civil engineering and other fields. For this project, the idea of modularization means that the cabin can be built in sections or components (on- or off-site). Once every section is complete, they are then assembled on-site. This allows for different sections to be used for the same purpose, and can potentially allow for sections of the unit to be switched out throughout the life of the structure.

Modularization is not a new concept in the world of tiny house construction, but engineered designs that employ it in tiny house construction are fairly new. Minneapolis-based Architects for Society is one such firm that has recently released conceptual designs for building a modular house (Architects for Society 2016). Architects for Society specifically intended their "hex-house" design to be useful for temporary refugee camps. Their design showcased some of the benefits of pursuing a modular design for a tiny house. These benefits include the increased versatility of the design, the ability to store the unit more compactly, the ability to transport more units at one time, and, most importantly for SCU team's project, the ability to create larger structures with the same wall, floor, and roof sections used in a standard sized unit. Even though architectural renderings are available with a price tag, they have not published engineered drawings of their concept.

There are several elements of the hex-house design and others like it that the SCU team sought to build upon. Each of these units is far more expensive than the design developed by the SCU team ($55k minimum compared to ~$7.5k, respectively), are more difficult to transport due to their larger size, and take longer to assemble the sections (estimated to take one week with five people) (Architects for Society 2016). It is also not clear whether these units can be repurposed or downsized after initial construction.

3.2 Modularization & Design Criteria

Before the project team applied the parameters of versatility and mobility to the idea of modularization, it was necessary to define what was implied by these terms. The idea of being able to make multiple home sizes from standard floor, wall, and roof sections was the best example of increasing versatility. Such a design allows for the final product to include a wide range of assembly options, a feature which adds a great deal of value to the cabins. The increased versatility that the various wall sections allow also improved the cabin's potential return on investment in the future. The lengthened life cycle of the structures that also results from the cabin's ability to be put towards multiple uses make the slight increase in cost well worth it. This feature of the modular cabin is explained in further detail later in Section (§) 4.2. Should the program be expanded to accommodate families, the modular design gives SJC the ability to house families with the same cabins that are used to house individuals in the current version of the BHC.

The mobility of the structure is a much more give and take process. The original units that the team redesigned are already capable of being moved from site to site. Habitat designed a structure whose building envelope fits the minimum dimensional constraints of a standard, Double Drop Deck truck. While this constraint ensured the cabins could be mobile, it also meant that the City can only fit two cabins on each semi-trailer. The SCU team's redesigned modular option allows for at least four (4) and as many as eight (8) units (depending on weight limitations and how the sections are packed) to be moved on one such trailer. This could decrease transportation costs by up to one-fourth. This improved mobile efficiency is particularly beneficial if the cabins need to be transported across long distances. These benefits of the modular cabin redesign align closely with the needs and vision of the BHC program, and increased the value of the cabins.

3.3 Financial Concerns with Modular Design

While a modular design has many benefits, it does introduce some potential shortcomings. The City and any others who wish to design with modular sections should be aware of these issues and address them prior to furthering their project. The first issue is that using modularization slightly increases the up-front cost of the units. The cost estimate for the modular cabin redesign can be found in Appendix G, page G2. This shows that the modular cabin costs around $7,500 (excluding labor). This is slightly higher than Habitat's rough cost estimate from February 2019 of $6,500. The higher cost of the modular units is largely due to the increased number of connections that enable the cabin to be disassembled and reassembled. While the increased cost can be worthwhile if an owner makes use of the option to create varying structures with the same sections, the higher investment will not see this particular return if the option is not utilized. There are still other elements of the modular option, however, that could still see a return on investment, such as the lower cost of transportation and storage.

The final concern with the modular design option is that, in order to capitalize on the investment in modularization at all, owners must follow the proper procedures of assembly, disassembly, and maintenance of the structures. If the modular units pass into new ownership, the new owner must be fully aware of the details of how to perform these three processes. If ownership does not know how to properly assemble, reassemble, and maintain the structure, then the greater investment could lose some of its value.

Despite these concerns, the project team continues to believe that modularization can be a very beneficial method for designing and building tiny homes, particularly for a situation with needs and constraints similar to the San José Bridge Housing Community program.

3.4 Design Constraints & Criteria

The primary geometric constraints on the design were the shipping limitations, which remain the same limitations as the current BHC cabin's dimensional constraints. The minimum cargo length, width, and height of a small Double Drop Deck truck are 41 feet (41'), eight foot six inches (8'-6"), and eleven foot six inches (11'-6"), respectively. The cabins must fit within these dimensions. The advantage of a modular house in this situation is that it is the broken down sections of the cabin that must fit within the envelope, not the entire assembled cabin. This allows for more flexibility with the redesign dimensions.

The structural demand constraints were determined using the American Society of Civil Engineering's 2010 Minimum Design Loads for Buildings and Other Structures (ASCE 7-10), the American Wood Council's 2015 National Design Specification for Wood Construction (AWC NDS 2015 or NDS 2015), and the 2016 California Building Code (CBC 2016). The design was based on the Allowable Stress Design (ASD) method, and the team choose to use a Factor of Safety (F.S.) of at least 2.0 for all calculations. In accordance with the standards set by the BHC program and AB-2176, exceptions were taken with regards to serviceability design factors, including minimum windows per exterior wall, minimum utility services, and minimum residential living space area.

In addition to these requirements, the SCU team established their own criteria for making decisions throughout the design process that aligned with the goal of the redesign: to develop a more versatile and mobile cabin design with an emphasis in resiliency and reusability. With this in mind, the following criteria were established: Firstly, each element of the design, primarily the sections and connections, needed to be reusable. Secondly, the design needed to be easily constructed, not just the first time, but with each process of disassembly and assembly. Thirdly, the design needed to be easy to replicate, both from a practical perspective and a financial perspective. To meet these three criteria, it was necessary to avoid complex assemblies and expensive specialized connections. Finally, the connections needed to be accessed for assembly and disassembly with minimal disruption to the finishes.

Chapter 4: Cabin Geometry

4.1 Original Cabin Geometry Design

The redesign dimensions were based on the cabin dimensions of a previous version of the cabin what was current when the SCU team began design. Figure 4.1, below, shows these approximate dimensions on a rough sketch received from Habitat in January 2019. Habitat's intention to use a single pitch roof with a 3:12 slope was also maintained.

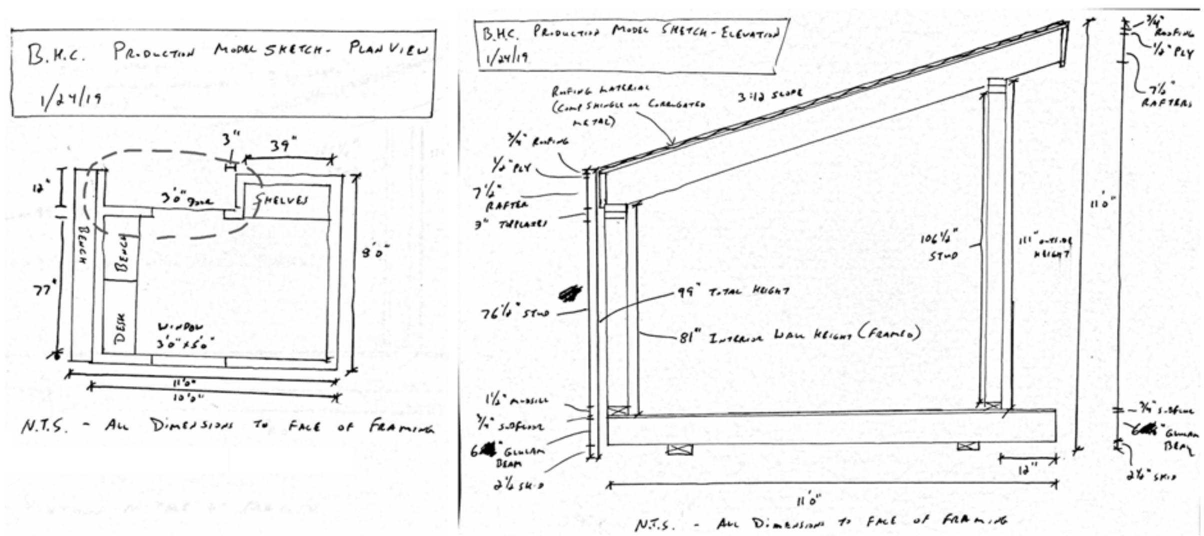

Figure 4.1 *- Plan and Elevation sketches of a previous BHC cabin version from January 2019. These are included as a reference for the initial cabin geometry.*

4.2 Modifications to Cabin Geometry

The floor plan of the original design was first modified by removing the small inset (shown in dashed circle on Figure 4.1) to make the walls span each edge of the floor. This would make the modular connections less complicated. The second change to the floor plan was with regards to the dimensions. Because the modular design is not limited by the building envelope dimensions but by the cabin section dimensions, the size of the sections could be increased. The interior floor size was changed from eight feet by ten feet (8'x10') to 10'x10'. The wall dimensions were also increased, but this is discussed later in the report.

To make the house modular, the walls would need to be connected to the floor at the bottom edge, to each other at the side edges, and to the roof on the top edge. This is shown in Figure 4.2. There were two options to make the walls themselves modular. The first option, shown in Figure 4.2, was to make four separate wall units for each side of the house. This option, however, limited the versatility of the wall sections, as each section can only be used in one location. To solve this issue, the SCU team came up with a second option, which was to use a base wall section with dimensions of ten feet (10') wide and eight feet (8') tall for each wall of the cabin. To make this option work with the sloped roof, height extensions were designed and built separately from the base wall and installed on top of any base wall to account for the tall and rake (triangular) wall faces. The house sections for this second and option are shown in Figure 4.3 below.

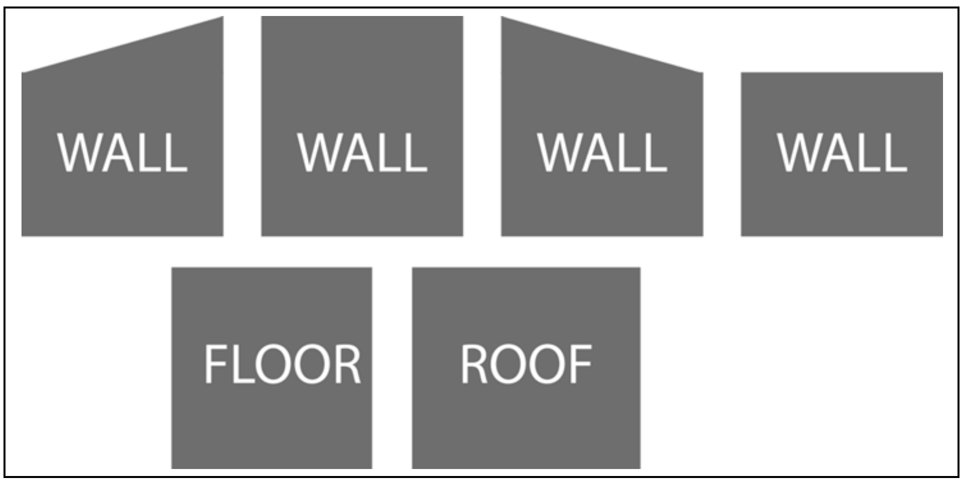

Figure 4.2 - *Original plan of modular wall designs, consisting of individual wall sections.*

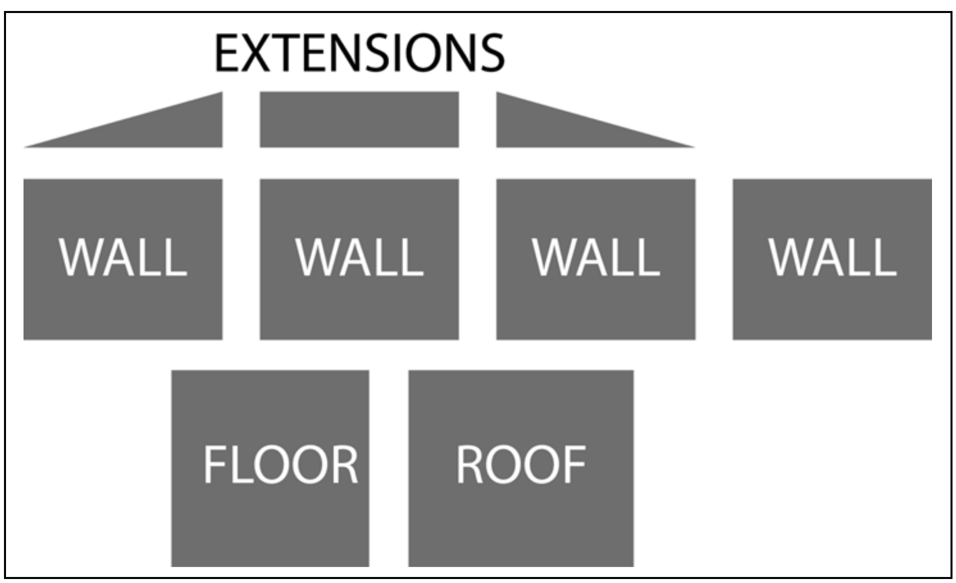

Figure 4.3 - *Second modular design, including wall extensions mounted to top of base wall sections for versatility.*

These height extensions account for a height difference of two feet, six inches (2'-6") (created by the 3:12 roof slope) between the base wall size and the tall wall size. Since the base wall was eight feet (8') tall, the tall wall had a height of ten feet, six inches (10'-6"). Breaking down the walls in this manner also allows for the wall sections to fit within the geometric constraints for transportation. One thing to note is that the increased width of the cabin means that the length and width of the roof and floor sections exceed the transportation width of eight feet six inches (8'-6"), and therefore they must be shipped sitting vertically on their edge. For the sake of consistency, it may be sensible to orient every house section in this manner for shipping and storage.

As mentioned in §3.2, one of the potential benefits of utilizing a modular design is that it allows for multiple units to be used as one larger unit. This potential is made possible by the fact that the walls on the cabins can be replaced. If the owner of two cabins wanted a structure twice the size of a single unit, he or she could make a larger unit using two modular cabins. All that would need to be done is to replace a window-wall or plain-wall section on each cabin with a doorway-wall section, and then push the cabins next to each other and install additional flashing. The new doorway allows for a person to walk from room to room between the two cabins. This concept could be used with any number of cabins, and is shown in Figure 4.4 below. For more information on the geometry plans, see Appendix A.

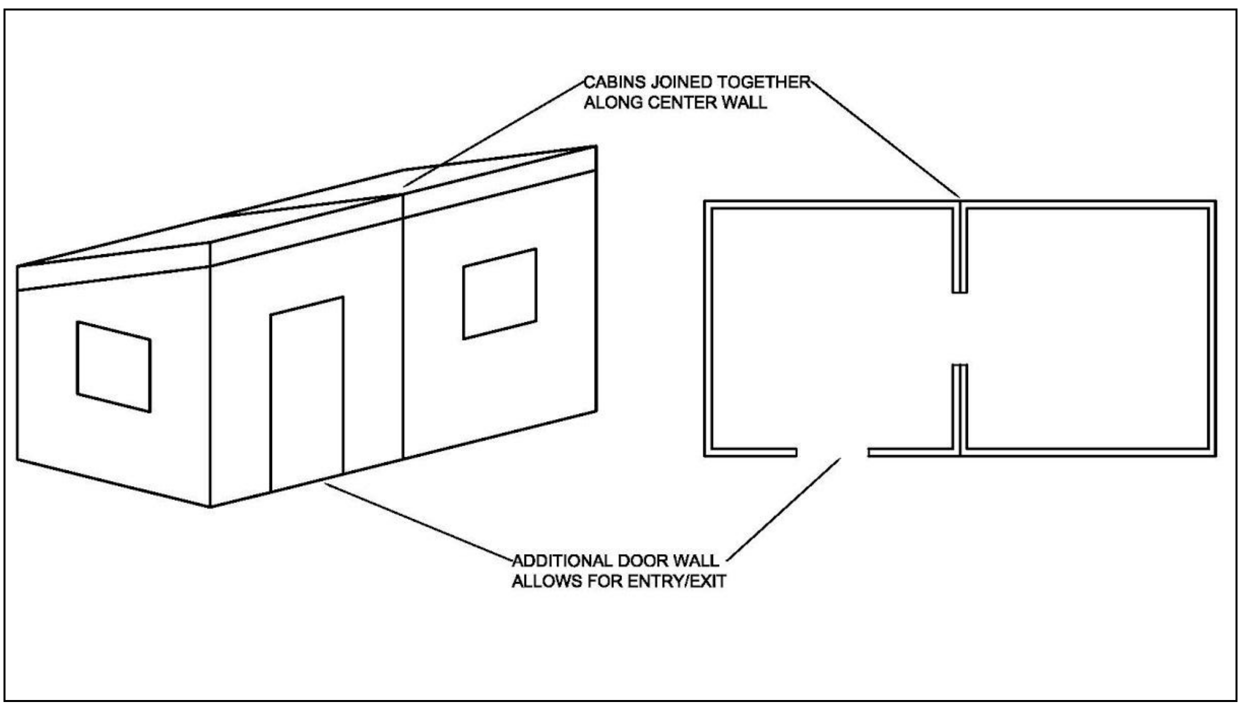

Figure 4.4 - *The house can be connected to another to create a two-room cabin unit.*

Chapter 5: Structural System Design

5.1 Load Paths

The idealized load paths were drawn based on the finalized geometry from Chapter 4. These idealized load paths are shown on the building envelope in Figures 5.1 and 5.2. Figure 5.1 shows the load path if the cabin is subjected to gravity loads only, and Figure 5.2 shows the load path for lateral wind loading.

The load transfer from cabin section to cabin section (i.e, wall-to-wall or wall-to floor) were located at what the project team determined would be the optimal position to transfer the load. Determining this load path was the first step in designing the structural components of the sections. Once the load paths had been determined, the governing load demand for the lateral and gravity structural systems design could be determined. The capacity of the framed sections could then be designed to meet this demand. The connection design was then based on the framed section designs.

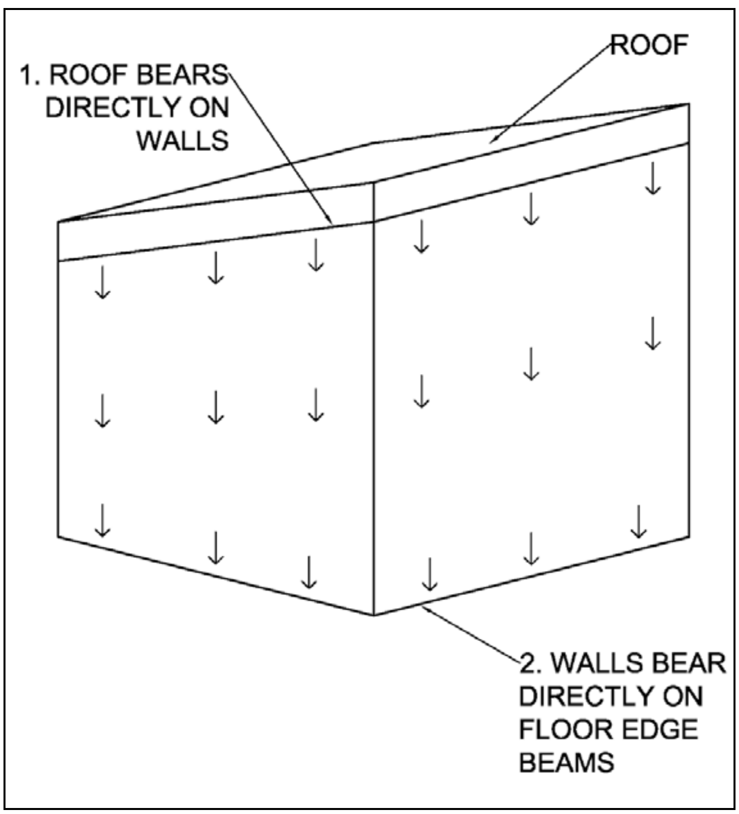

Figure 5.1 *- The load path for gravity load on the building envelope.*

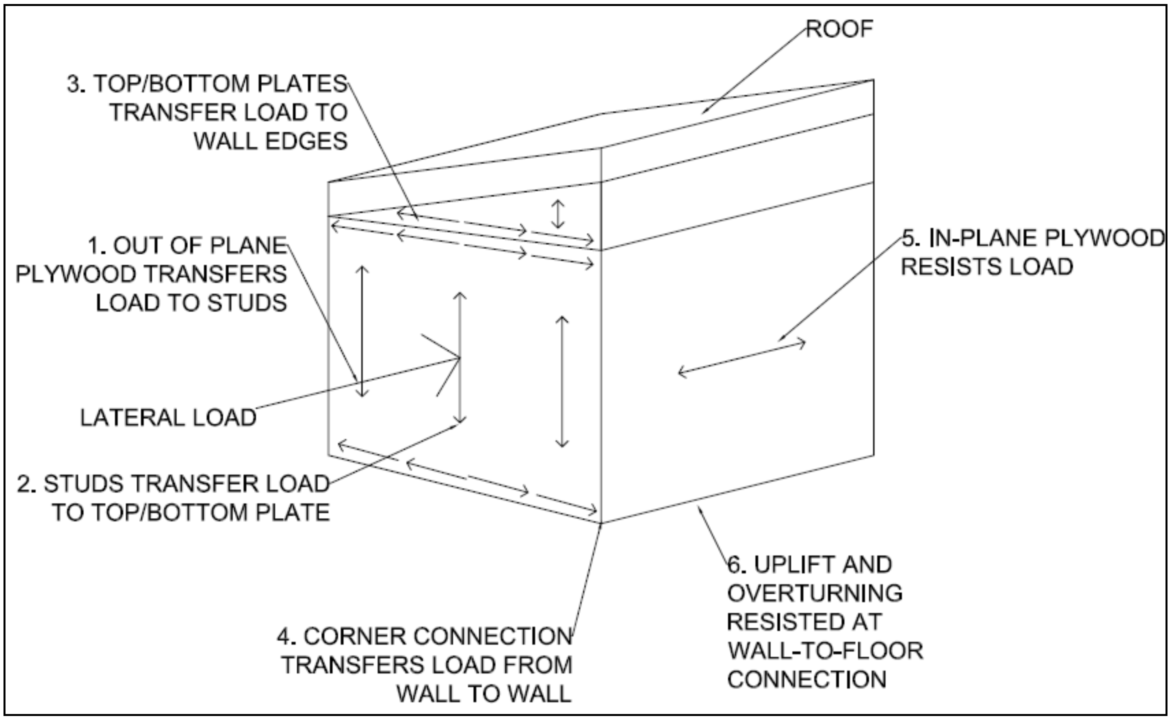

Figure 5.2 *- The load path for lateral wind load on the building envelope.*

5.2 Lateral System Demand

After a quick initial calculation, it was determined that wind governed the design. To find the wind demand, the team used the American Society of Civil Engineering's Minimum Design Loads for Buildings and Other Structures from 2010 (ASCE 7-10). This is the most recent version of the code that has been adopted by the City of San José and the California Building Code, which is also referenced in this report.

Table 27.2-1 from ASCE 7-10 was the primary reference for determining the Main Wind Force Resisting System (MWFRS) loads. The governing wind pressure was found to be 19 pounds per square foot (psf) on the walls and negative 22 psf (due to internal wind pressure) on the roof. The maximum base shear for each in-plane wall was found to be approximately 500 pounds (lb.). The overturning moment caused by the distribution of lateral forces and the base shear was also found. Based on these findings, it was determined that the weight of the cabin was enough to resist this overturning moment. The full calculations are located in Appendix B.

5.3 Gravity System Demand

The 2015 National Design Specification for Timber Construction (NDS 2015) Allowable Stress Design (ASD) method was used to find the demand of gravity loads on the structural system. The preliminary details for the cross-section of the wall, floor, and roof that were used to find the dead loads are shown below in Figure 5.3.

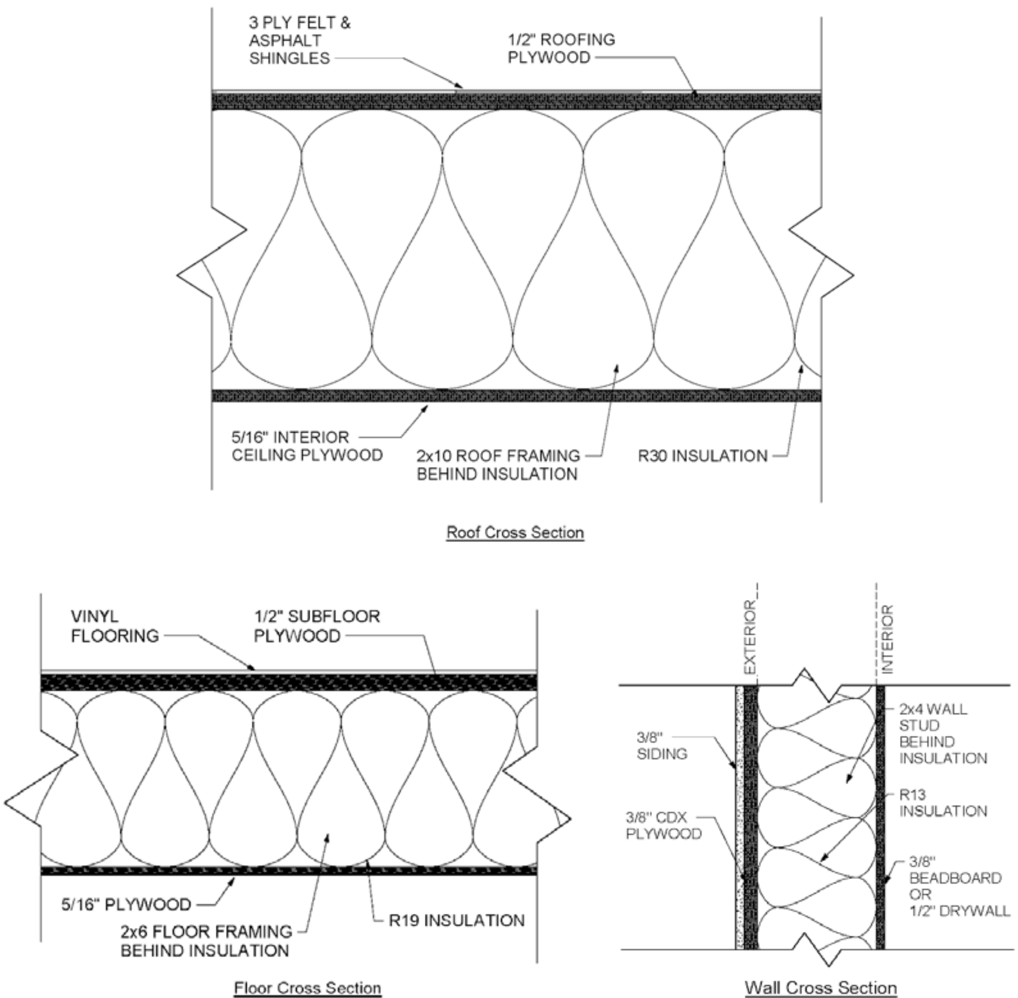

Figure 5.3 *- Cross-sections of the wall, floor, and roof details used to find dead loads.*

Design of Wood Structures, ASD/LRFD by Donald Breyer and others was used as a reference for the building material weights (Breyer et al. 2014). Table 1604.3 and Table 1607.1 of the California Building Code (CBC 2016) were used to find both the deflection requirements and live loads, respectively. The dead loads, live loads, and deflection requirements are summarized below in Table 5.1. The full calculations can be found in Appendix C.

Table 5.1 - Assumed design conditions and requirements used in gravity capacity design.

Cabin Section	Dead Load	Live Load	Deflection Requirements	
			D + L	L
Floor	6 psf	40 psf	$\Delta_{D+L} \leq \frac{l}{240}$	$\Delta_L \leq \frac{l}{360}$
Roof	9 psf	20 psf	$\Delta_{D+L} \leq \frac{l}{180}$	$\Delta_L \leq \frac{l}{240}$
Wall	7 psf	n.a.	n.a	n.a.

5.4 Lateral System Capacity

The team chose to use exterior grade plywood (CDX) along the walls as the primary lateral force resisting structural element. The capacity of the CDX was based on the thickness of plywood, and the spacing of both framing and fasteners. To find these requirements, the team used the NDS 2015 and referenced Chapters 3 and 4 from the Special Design Provisions for Wind and Seismic (AWC SDPWS 2015 or SDPWS 2015).

There were several requirements that the design needed to satisfy. Firstly, the CDX had to be able to transfer the wind load applied out of plane (when the load is perpendicular to the plywood itself). These requirements were detailed in SDPWS 2015 Tables 3.2.1 and 3.2.2 for the walls and roof respectively. The team then used SDPWS 2015 Table 4.3A to find the shear capacity of the plywood. Finally, SDPWS 2015 Tables 4.3.3.4 and 4.3.4 were used to ensure that the adjustment factors and aspect ratio requirements were also met. It was determined that using plywood with a thickness of ⅜ inches (in.), panel edge fasteners at 6 inch (6”) on center (o.c.) spacing, and unblocked wall framing at 16 inch (16”) o.c. spacing satisfied all requirements. These calculations are shown in Appendix D, and the findings are summarized below in Tables 5.2 and 5.3.

Table 5.2 - Summary of capacity design calculations for the plywood sheathing in both planes.

Design Element	Selected Variable	Capacity	Demand	Resulting F.S.
Out-Of-Plane Plywood	thickness (t) = ⅜”	For plywood grains parallel to studs: lateral pressure = 60/1.6 = 37.5 psf	19 psf	F.S.= $\frac{37.5}{19}$ = 2.0
	stud spacing = 16 ”			
In-Plane Plywood	t = ⅜”	Shear Capacity: V_S/1.6 = 280 pounds per linear foot (plf)	95 plf	F.S.= $\frac{280}{95}$ = 3.0
	edge nail spacing = 6”			

Table 5.3 - *Opening requirements based on ⅜" plywood with 16" o.c. framing and 6" o.c. edge fastener spacing.*

Design Element	Selected Variable	Capacity	Demand	Resulting F.S.
Opening Requirements (window)	Max Opening: h/2	$\frac{h}{2} = \frac{8'}{2} = 48"$	42"	n.a.
	Shear Adjustment Factor = 0.87	$V'_s = (0.87) * 280$ plf = 244 plf	95 plf	F.S.= $\frac{244}{95} = 2.6$
	Aspect Ratio: $\frac{h}{b_s}$	$\frac{h}{b_s} = \frac{8'}{42"} = 2.3:1$	3.5:1	n.a
Opening Requirements (door)	Max Opening: h	$h = 96"$	96"	n.a.
	Shear Adjustment Factor = 0.50	$V'_s = (0.50) * 280$ plf = 140 plf	95 plf	F.S.= $\frac{225}{95} = 1.5$
	Aspect Ratio: $\frac{h}{b_s}$	$\frac{h}{b_s} = \frac{8'}{38"} = 2.5:1$	3.5:1	n.a

It should be noted that, after applying the adjustment factor for the door opening requirement, the Factor of Safety is under 2.0. The SCU team still went ahead with the design, because of the conservative approaches taken when determining the wind demand and in selecting the adjustment factor. This conservative approach is due to the fact that, if the design was based off of ASCE 7-16 rather than ASCE 7-10, the maximum wind speed would have been 20 mph less for the design. This decrease in the design would have significantly reduced the maximum wind pressure.

5.5 Gravity System Capacity

The framing for the wall, floor, and roof were previously determined to have minimum nominal sizes of 2x4, 2x6, and 2x10, respectively, to accommodate fiberglass insulation with thermal factors of R13, R19, and R30. NDS 2015 was used to check that these sizes were sufficient for the gravity demands found in §5.3. The design values (F_b, F_v, F_c, E) for rough sawn, visually graded No. 2 Doug Fir lumber were taken from Table 4A of the NDS 2015 Supplement Design Values for Wood Construction. Chapter 4 was used to find the adjustment factors that were applied to the reference design values. The adjustments focused primarily on accounting for varying levels of moisture content and the effect of repetitive members. Finally, equations from Chapter 3 of NDS 2015 were referenced to determine the capacity of the floor and roof framing in bending, shear, and deflection, and of the wall studs in compression. It was determined that 2x4 and 2x10 unblocked nominal sizes could be used for the wall and roof, respectively. The floor framing sizes, however, may need to be increased from 2x6 to 2x8 nominal if the spacing of supports beneath the floor exceeds eight (8) feet. The full calculations can be found in Appendix E, and the findings are summarized below in Table 5.4. The full framing plans are included in Appendix G.

Table 5.4 *- Summary of design calculations for gravity structural system capacity. Deflection demands reflect the minimum factor of safety. The prototype built by the SCU team used 2x6 floor framing with a support at mid-span.*

Design Element	Selected Variable	Member Response	Capacity	Demand	Resulting F.S.
Floor Framing	2x6 supported at ends and mid-span, unblocked	Bending	$S_x = 7.56\ in^3$	$S_{x,\ min} = 2.91\ in^3$	F.S.= $\frac{7.6}{2.9}$ = 2.6
		Shear	$A = 8.25\ in^2$	$A_{min} = 1.5\ in^2$	F.S.= $\frac{8.3}{1.5}$ = 5.5
		Deflection	$\Delta = 0.167$ in	$\Delta_{min} = 0.026$ in	F.S.= $\frac{0.17}{.03}$ = 6.4
	2x8 supported at ends only, unblocked	Bending	$S_x = 13.44\ in^3$	$S_{x,\ min} = 10.5\ in^3$	F.S.= $\frac{13.4}{10.5}$ = 1.3
		Shear	$A = 10.9\ in^2$	$A_{min} = 3.0\ in^2$	F.S.= $\frac{10.9}{3.0}$ = 3.6
		Deflection	$\Delta = 0.33$ in	$\Delta_{min} = 0.185$ in	F.S.= $\frac{0.33}{.185}$ = 1.8
Roof Framing	2x10	Bending	$S_x = 21.4\ in^3$	$S_{x,\ min} = 6.24\ in^3$	F.S.= $\frac{21.4}{6.24}$ = 3.4
		Shear	$A = 13.9\ in^2$	$A_{min} = 1.63\ in^2$	F.S.= $\frac{13.9}{1.63}$ = 8.5
		Deflection	$\Delta = 0.55$ in	$\Delta_{min} = 0.055$ in	F.S.= $\frac{0.55}{.055}$ = 10
Wall Framing	2x4	Compression	P = 3600 lb	$P_{demand} = 303$ lb	F.S.= $\frac{3600}{300}$ = 12

Chapter 6: Connection Design

6.1 Connection Design Criteria

The connections were the most unique element of this project. Standard modular connection designs are not readily available because modular construction on a small scale is a relatively new and therefore specialized field. As a result of this specialization, connections in other modular construction projects were custom and therefore very expensive. Faced with this reality, the team had to start from scratch when designing the connections. The geometrical constraints for the connections were the dimensions of the cabin section designs finalized in §5.5. The design criteria continued to focus on reusability, constructability, ease of replication, and ease of access during the reconstruction process. As previously mentioned, it was also important to avoid specialized connections, as they would make the design expensive and challenging to replicate in the future.

One connection was fully designed out, and four Simpson Strong Tie (SST) standard connectors were found that could be used to meet the structural requirements and the above design criteria for the remaining three connections (Simpson Strong Tie 2019). Since these connectors were not designed for these uses, their capacity under the load conditions shown in §5.1 had to be evaluated. The four connections were as follows: 1) the wall-to-wall connection at the wall corners, 2) wall-to-floor connection, 3) the wall-to-height extension connections, and 4) the wall-to-roof connections. A diagram with these locations is shown in Figure 6.1, and a more detailed representation of connection locations can be found in Appendix A. The constructability of these connections was tested when the SCU team built a prototype of the modular cabin redesign.

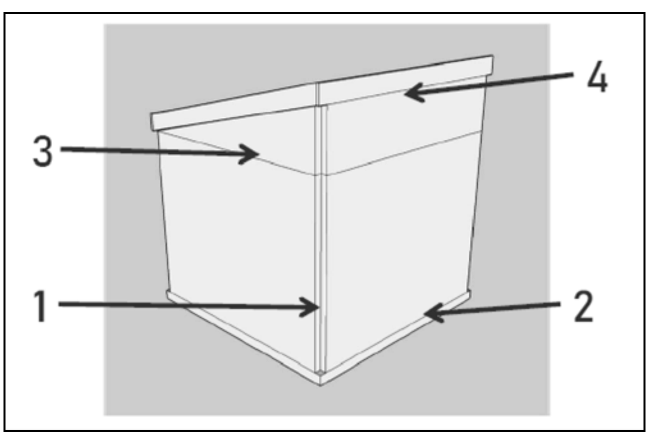

Figure 6.1 *- The four (4) connections designed for the design. The connections are 1: wall-to-wall corner, 2: wall-to-floor, 3: wall-to-height extension, and 4: wall-to-roof.*

6.2 Wall-to-Wall (corner)

The intent of the wall-to-wall connection was to make perpendicular walls act as one lateral force resisting system. This is particularly important when transferring the wind loading from the out-of-plane wall to the in-plane shear wall. As shown in Figures 5.1 and 5.2, the primary areas of load transfer will be the top and bottom corners of the wall section. The team choose to design an angle bracket that would fit into the corner of the wall, attaching the double edge stud of the out-of-plane wall to the in-plane wall. This lateral load demand at the corners was found using the wind pressure demand calculated in §5.2. The maximum demand was found to be approximately 120 pounds (lb.) at the corners of the height extension sections, and 380 lb. at the corners of the base wall sections. The team found that SST heavy angle brackets HL35-R and HL37-R adequately fit the geometric needs of the connection. Based on Chapter 12 of NDS 2015, the strength capacity of the HL-35R and HL-37R for the required loading was found to be approximately 410 lb. and 615 lb., respectively. Based on these findings, the design team chose the number of connections required at each location. This design is summarized in Table 6.1 below. The complete calculations are shown in Appendix F, pages F1-F9.

Table 6.1 *- Simpson Strong Tie (SST) Selections for the Wall-to-Wall connections. For the prototype, the SCU team used both the HL35-R and HL37-R for the base wall corners, but recommends using only HL35-R.*

Connection Location	Demand	SST Selection	Combined Capacity	Resulting F.S.
Base Wall Corners	380 lb.	(1) HL35-R & (1) HL37 - R	1015 lb.	F.S.= $\frac{1015}{380}$ = 2.67
		(2) HL 35-R	820 lb.	F.S.= $\frac{820}{380}$ = 2.16
Height Extension Corners	120 lb.	(1) HL35-R	410 lb.	F.S.= $\frac{410}{120}$ = 3.41

In addition to the corner connections, the SCU team recommends placing one HL35-R bracket at the midheight of the wall edge to help the connected walls act as one structural unit. Figures 6.2-6.4 below show the connection details, and include a picture of the connection in-use on the prototype.

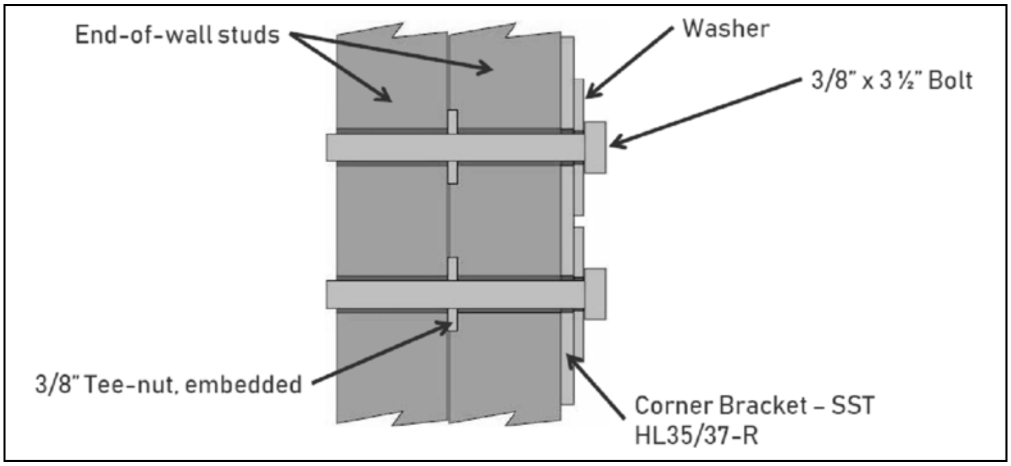

Figure 6.2 *- The assembled wall-to-wall corner connection detail, with components labeled.*

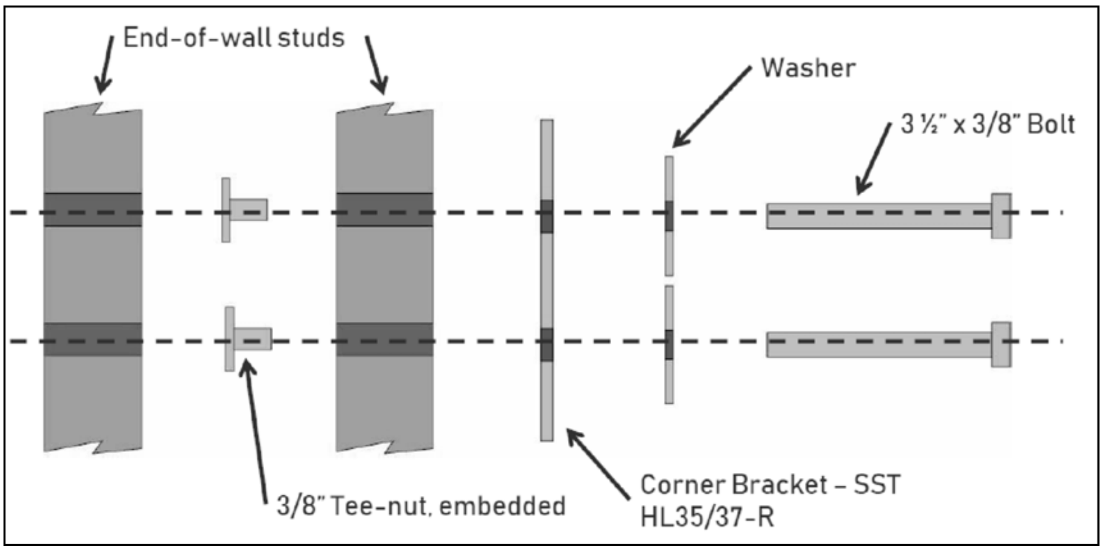

Figure 6.3 *- The exploded detail of a wall-to-wall corner connection.*

Figure 6.4 *- The wall-to-wall corner connection installed on the cabin prototype.*

The wall-to-wall connection includes several unique attributes. The connection needed to be reused multiple times, which meant that the connection needed to be bolted instead of nailed. The bolt also needed to screw into and unscrew out of the wood through multiple cycles without losing strength. This meant that bolts could not simply be screwed directly into the wood itself. To solve this, the team used a T-nut embedded in between the double end stud. The bolt would then screw into the thread of the T-nut, and the T-nut would not be dislodged because it is sandwiched between the double 2x4 studs. See Figures 6.2 and 6.3 for the full assembly.

6.3 Wall-to-Floor

The structural purpose of the wall-to-wall connections was to resist shear from the wind loading and prevent the wall from ripping out of the floor by resisting uplift and overturning moment. The team selected a SST elevated post base bracket intended to be used to connect a concrete foundation slab to a "4x" column. This item, technically referred to as EPD44PHDG, is shown below in Figure 6.5. The shear, uplift, and overturning demand forces on the connection were all found using the wind pressure demand calculated in §5.2. If two connections are used, the combined uplift force (including overturning moment) exerted approximately 705 lb. on each connection. Using Chapter 12 of NDS 2015, the uplift capacity of each connection was determined to be 3000 lb., far exceeding the demand. The shear demand on the bolt was determined to be a maximum of 1045 lb., and the shear capacity of the bolt was determined to be almost 6000 lb. The use of these connections, then, far exceeds the minimum factor of safety of 2.0. The calculations for each of these three forces is shown in Appendix F, pages F10-F12. Figures 6.6 and 6.7 below show the connection details, and include a picture of the connection in use on the prototype.

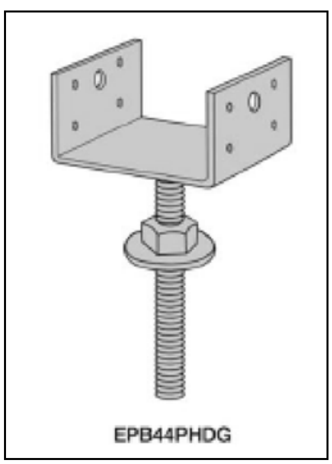

Figure 6.5 *- The SST post base product used for the wall-to-floor connection. (Simpson Strong Tie, 2019)*

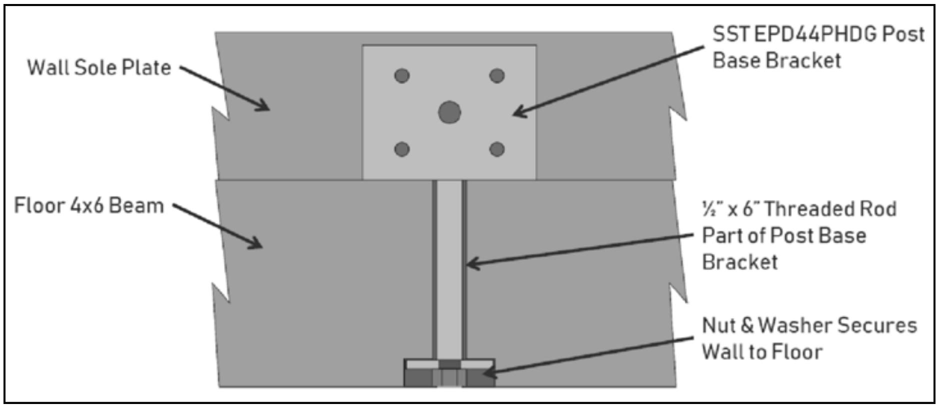

Figure 6.6 *- The details for the wall-to-floor connection, with components labeled.*

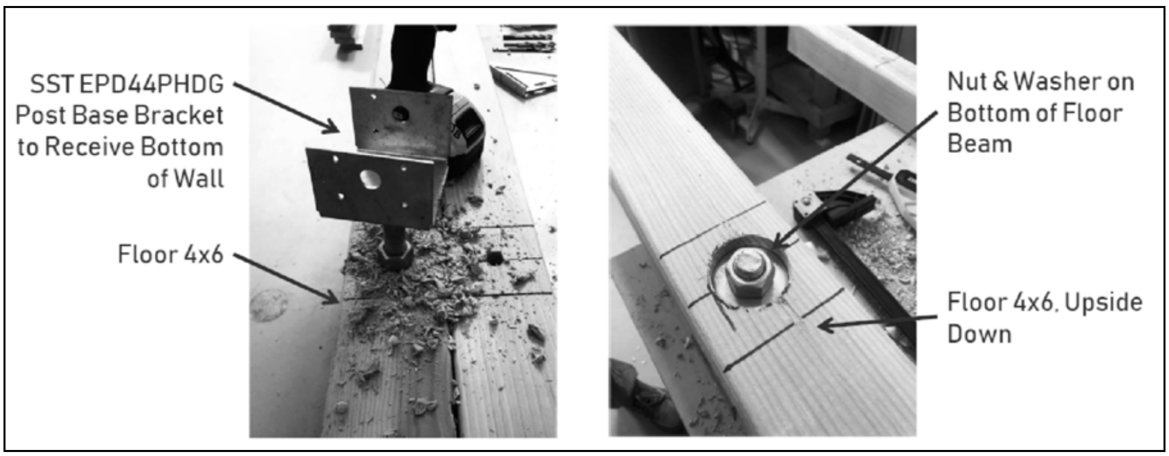

Figure 6.7 *- Images of the wall-to-floor connection being built for the prototype.*

6.4 Wall-to-Height Extension

This wall-to-height connection was the most difficult to design. The two main forces that needed to be accounted for were shear and uplift. The SCU team initially made a design that included multiple bolts that protruded from the bottom of a height extension, and were inserted into pre-drilled holes in the wall section below. Originally, it was thought that the same SST post-base connection that was used for the wall-to-floor connection could also be used for this connection as well. There was some concern, however, regarding the additional thickness of the post-base along the top of the wall. Instead of using the SST post-base, the installation and permanent embedment of a ⅜" diameter bolt was designed. Figures 6.8 and 6.9 below show this detail as a drawing and a photograph, respectively. The figure shows how the bolt is permanently attached to the height extension, and inserted into a pre-drilled hole in the top of the wall. There were also concerns about how to access the bolt in the wall after initial construction. To solve this problem, access panels need to be cut out of the interior beadboard later in the construction process to allow for a person to tighten the nut on the threaded bolt after insertion.

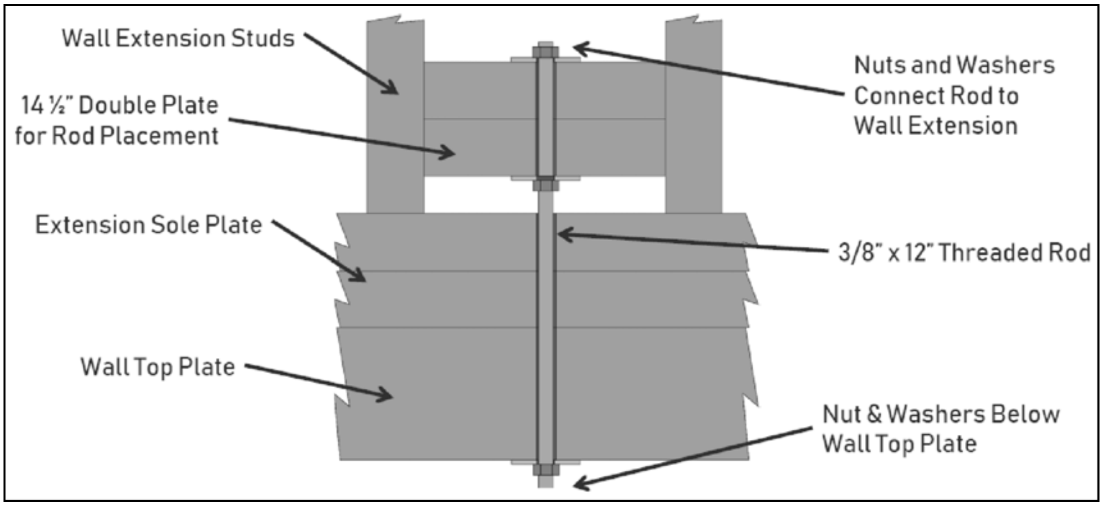

Figure 6.8 *- Detail of the wall-to-height extension connection, with components labeled.*

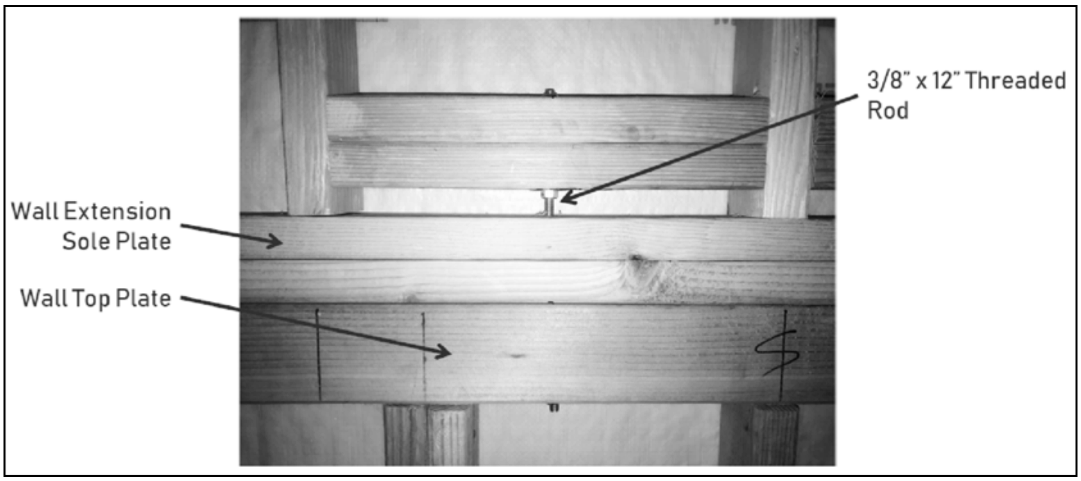

Figure 6.9 *- Photographs of the wall-to-height extension connection in the prototype.*

Like the wall-to-floor connection, this connection must resist shear, uplift, and overturning demand forces. These forces were found using the wind pressure demand calculated in §5.2, and Chapter 12 of NDS 2015 was also used to determine this connection's capacity. Table 6.2 summarizes two possible designs, each of which far exceeds the demand. The full calculations for each of these forces are shown in Appendix F, pages F13-F14.

Table 6.2 *- Simpson Strong Tie (SST) Selections for the Wall-to-Height Extension connections. For the prototype, the SCU team used four connections for the rectangular extension and two bolts for the rake extensions.*

Connection Location	Demand	SST Selection	Combined Capacity	Resulting F.S.
Rectangular or Rake Extension	705 lb	(4) Bolts	18000 lb.	F.S.= $\frac{18\ kip}{0.7\ kip}$ = 26
		(2) Bolts	9000 lb.	F.S.= $\frac{9\ kip}{0.7\ kip}$ = 13

6.5 Wall-to-Roof

The wall-to-roof connections not only help to align the roof during the assembly process, but assist in maintaining the structural integrity of the cabin as well. The main structural purpose of these connections was to resist uplift due to internal wind pressure. The uplift demand was found to exert a resultant force of 1270 lb. on top of each bearing wall. To resist this, the SCU team sought a connection similar to a hurricane clip, but that could be bolted rather than nailed. Another SST angle connector, A24, was determined to be suitable. A detail drawing and photograph of the connection is shown below in Figures 6.10 and 6.11, respectively.

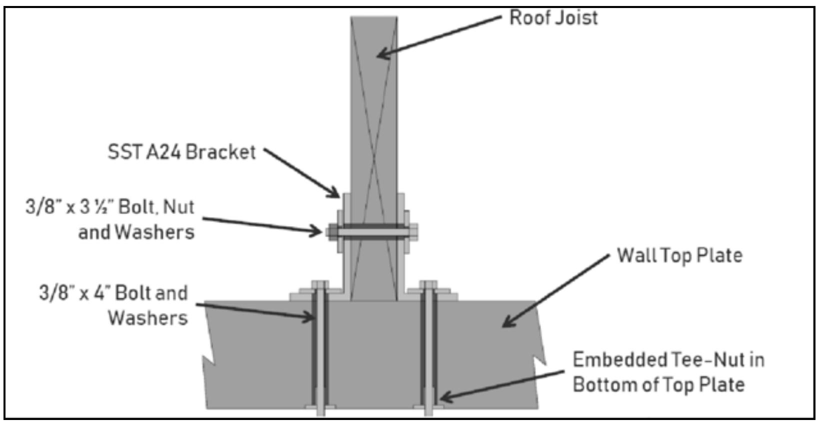

Figure 6.10 *- Detail of the wall-to-roof connection, with components labeled.*

Figure 6.11 *- Photographs of the wall-to-roof connection in the prototype.*

The brackets are installed used T-nuts that are installed similarly to the wall end double studs. Each A24 clip is attached with an T-nut that it embedded within the top plate of the wall, and all A24 clips are used in pairs, with one each side of a roof joist (see Figure 6.10 and 6.11). The combined uplift capacity of the two (2) T-Nut's in each pair of A24 clips was found to be 900 lb. If three (3) pairs of T-Nuts are used at the top of these walls, the total uplift capacity is therefore 2700 lb, giving the connection a Factor of Safety of 2.1. The full calculations are shown in Appendix F, pages F15-F17.

Chapter 7: Building Prototype

7.1 Reason for Building a Prototype

It was important to the SCU team that they be able to build a prototype of the redesigned modular unit. For any project, building a prototype makes the work much more tangible, and allows the design team to be able to experience the intersection of theory and practice. Understanding this intersection was particularly critical for this project. Since the design and method of construction of the redesigned cabin were so unconventional, it was important to determine the realistic feasibility of the designed connections. As stated in Chapter 6, almost all the connections used in this project were quite unconventional, and it would have been negligent to assume the connections work without building them. The design team also wanted to document this unconventional construction process in order to include a construction plan in the final design report.

7.2 Construction Schedule & Method

The construction process started on April 15, 2019 and lasted a total of just under four weeks, ending on May 8, 2019. There were 15 total days that work was performed. The expedited construction schedule was a necessity as material acquisition dictated the start date, and the end date of May 9, 2019, when the Senior Design Conference was scheduled to take place, could not be pushed back. The result was a construction process centered on efficiency.

The construction process was broken out into the following five general steps:

1. Framing Preparation: Each wall consisted of standard wood framing, but the modular connections required the use of T-nuts in order to utilize reusable bolts as opposed to single-use nails and screws. The preparation included drilling holes in studs and sole plates and installing T-nuts where necessary.
2. Floor and Wall Framing: Once all wood members were ready to be framed into place (T-nuts embedded where necessary), then the floor section, four wall sections (plain wall, door wall, and two window walls), and three wall extensions (two rake extensions and one full extension) were framed. These were framed in a standard manner, but separately from one another.

3. Roof Framing and Finishing: The roof installation plan involved placing the roof on top of the house and not allowing workers to stand on it once placed (for safety reasons). So all roof framing and finishing (flashing, paper, and shingles) were installed on the ground before the roof was placed.

4. Transfer to Conference Site: The wall sections and roof were transported to the conference site so that the prototype would be more accessible for guests to view (transport occurred on April 29, 2019). The transfer consisted of loading the sections on a flatbed pickup truck, driving them to the site, and then unloading and erecting the sections. After all walls were secured, the roof was placed on top and fastened down.

5. Finishes: Once all walls were structurally sound and in place and windows were installed, the exterior house wrap and sheathing was hung. Then the interior wall and floor plywood was placed. Finally, the exterior and interior of the house was painted. Once vinyl flooring and trim was placed, the house was ready for the conference.

Step one took approximately one week, steps two, three, and four took two weeks, and step five took place in the final remaining days before the conference.

7.3 Challenges that Arose in Schedule

Most of the issues with the design came up during the construction of the cabin sections themselves. During this pre-construction process, the use of 4x4 headers and footers rather than double 2x4 was found to be unnecessary. The intent was to leave room for the elevated post-base bracket to be connected to the wall footers. It was determined, however, that the elevated post-base bracket could still be connected using a double 2x4. It also became clear that using 4x4 headers and footers made framing the walls excessively tedious, as these larger sizes required either toe-nailing or the use of 40d nails directly through the bottom and top plate. Toe nailing is difficult for inexperienced workers, and the use of 40d nails proved to be very tedious when building the prototype.

The second recommendation when preparing the wall sections is to ensure that every T-nut is embedded between two 2x4 members, instead of tacked to the outside of the beams. While this may seem tedious, it prevents the t-nuts from being dislodged throughout multiple cycles of use. This was another problem that arose due to using a 4x4 instead of a double 2x4 as the headers of walls. As a result of these complications, SCU team highly recommends against using 4x4's in favor of using double 2x4's.

The final recommendation for the wall section design is to change the vertical location of wall-to-wall corner angle brackets to be offset about 6" more away from the bottoms and top edges of the walls. This is to avoid overlap with framing nails that go through either the bottom plate or top plate and into the studs. When the team was nailing the header and footer to the studs, it proved difficult to avoid getting the nails in the holes that had been pre-drilled for the corner brackets. Slightly increasing the distance between the edge of the brackets and the ends of the studs would eliminate this challenge.

The team strongly recommends that the members intended to be used for the header and footer be kiln dried lumber with minimal knots. The team designed the structural systems with the assumption that it would be Grade No. 2 Doug Fir, but ended up using No.1 or better due to a generous donation. Even though it was higher grade lumber, the fact that some of the headers and footers were green made it extremely challenging to nail with the precision this framing required.

Once the pre-construction of the framed sections was completed, the most significant alterations to the design process were when the team had to make decisions about how to change the order of construction to accommodate the expedited construction time. Due to being behind schedule and encountering difficulties acquiring materials, the team was not able to begin the construction process until April 15, giving 22 total days to build the cabin before the Senior Design Conference. While the prototype was completed in time, some elements of the cabin design were not included. For example, no electrical equipment or insulation was installed. Neither of these were necessary, as the intended use of the prototype cabin was to be a storage shed.

The expedited time for construction also impacted when the team transported the cabin from Alameda Hall (where construction began) to the Kenna Trellis (where the team intended to showcase during the Senior Design Conference). The team had originally planned to hang at least the exterior plywood and possibly the interior beadboard on the framed wall sections before assembling the house near Kenna. Due to being behind schedule though, the team was not able to hang the plywood before needing to make the move across campus. While it appeared that waiting to install the plywood would not be a problem, it later proved to be an issue when installing the roof. The roof was installed with a forklift. Since there was no lateral support resisting the forklift as it backed away after dropping the roof on the house, the force of the forklift racked the house, meaning the walls were no longer square. This problem was not fully realized until later that day, at which point it was too difficult to make the walls square again due to the high weight of the roof. If the plywood had been attached, it would have kept the walls square as the forklift backed away. As a result of this error, the SCU team recommends that the plywood should always be installed before placing the roof.

For the wall-to-roof connection, the initial construction method used one (1) pair of A-24 clips at the end of every roof joist along the top of the walls. This meant that there were seven (7) total pairs of A24 clips at the top of each bearing wall. While this was intended to help align the roof framing during assembly of the cabin, the construction of the prototype showed that this repetition made it more difficult to set the house down during assembly. Section 6.5 shows that not every roof joist needed to have an A-24 clip in order for the cabin to be structurally sound. As a result, the SCU team recommends that future uses of the design use only three (3) pairs of A24 clips at the top of each bearing wall.

Also due to the shortened construction time, the team did not have enough time to completely waterproof the cabin before the conference. When it rained a few days before the conference after the house was mostly completed, the team did not have any unexpected leakage throughout the house, save above the window on the wall that did not yet have flashing installed. This demonstrated not only how important it was to place flashing at every possible location, but how successful flashing could be to prevent leakage in the house.

Chapter 8: Conclusions - Modular Design

8.1 Final Remarks on Prototype:

In general, being able to build the prototype was the most educational element of the project. Because the design is so unconventional, there were important details regarding the construction process that were completely unexpected, and it would have been nearly impossible to find these errors and conflicts without the opportunity to build the prototype. Most importantly, the team was able to conclusively determine that the modular design was constructable and can be a feasible method of building emergency cabins for the Bridge Housing Community program if the City and Habitat choose to pursue this design further.

8.2 Future of the Prototype:

The first Monday after the conference (May 13, 2019) the cabin was fully removed from the conference site and moved to a temporary storage area in the SCU University Operations Facilities yard. The prototype was intended to be used as a storage shed for the Alameda Hall Structural and Materials Testing laboratory. The day between disassembly and reassembly, however, the SCU team was notified by the lab manager that they could no longer use the prototype in the laboratory space due to space constraints. Due to the late nature of this notification, the SCU team had extremely limited time to find an alternative solution. After searching for other possible uses around campus, the team was informed a week before graduation that the university was enforcing a policy of not keeping student projects on campus permanently. Due to the inefficient cost to ship just one cabin, and the additional time and resources it would take require to assemble the prototype cabin off site, the SCU was left with no choice but to demolish the cabin, and donate whatever materials could be reused to Habitat for Humanity's ReStore location in Santa Clara.

Part 2 - Alternative Uses

Chapter 9: Alternative Use Design Process

9.1 Steps Taken for Idea Development

The alternative use ideas were formulated using a standard process of idea development. It began with general brainstorming, followed by evaluation based on set criteria. The ideas were then proposed to professionals with knowledge in the area of study similar to that of the idea, and then finally the ideas were refined and sorted based on generalized categories of alternative uses. Each part of these steps is broken out below.

9.2 Idea Formulation and Brainstorming

The first step in brainstorming alternative cabin uses was to gain a comprehensive understanding of the current cabin design and its strengths and weaknesses. This aided in pointing the SCU team to which areas of implementation might most play into those strengths. The main strength of the cabins is the mobility. The cabins can be transported in twos on the bed of a truck, allowing for them to be taken wherever there is a need. Furthermore, they are built durably to withstand this constant movement and they leave very little trace of where they have been due to their designed nature of being placed on the ground with no foundation. The most prominent weakness of the cabins is their lack of versatility. Once built, their size is unchangeable, so any future user would have to fit within the eight feet by ten feet space.

The initial brainstormed ideas were evaluated based on five criteria: feasibility, constructability, estimated cost, how well it fills a need, and amount of additional modifications required to the current cabin to be able to properly implement it in its alternative use. Once the list of ideas was created and ideas evaluated based on the five criteria, the SCU team refined the list in order to bring the best ideas in front of professionals to continue the alternative use design process.

9.3 Design Meetings with Professionals

Several meetings were held throughout the alternative use design process. Table 9.1 shows a list of meetings held, who the professionals were that the SCU team met with, and what the goal of the meeting was. Through these meetings, the ideas were further developed through use of the professionals' comprehensive understanding of genuine needs in the community related to the initially designed alternative uses. The meetings with professionals were mixed with several meetings with the City to maintain a line of communication to run through ideas as they were developed. The SCU team was then able to alter the ideas as needed to fill these newfound needs. Once done, a well-formed list was made of all the ideas, and the SCU team moved on to the organization and further development of those ideas.

Table 9.1 *- List of meetings held with professionals throughout alternative use design development.*

Date	Professional	Subject
1/21/2019	Sean Lanthier *Palo Alto Fire Department*	Re-use cabin for emergency responders. Work on discerning needs and desired implementations.
1/22/2019	René Ramirez *C.O.O., HomeFirst*	Develop ideas involving future use to continue combatting homelessness in the Bay Area.
1/30/2019	Spencer Arnold *Director of Global Operations, SCU Miller Center for Social Entrepreneurship*	Gain a wider understanding of possible modifications to make to current cabin design.

Chapter 10: Conclusions - Alternative Uses

10.1 Alternative Use Results

The final step in design development was organizing the newly refined ideas in a structured manner for communication with the City. The SCU team created a table to sort the ideas into six categories: community use (sleeping), community use (non-sleeping), disaster relief, consumer use, full redesign, and education. Each of these categories then had the individual items sorted based on feasibility. This table can be found in Appendix I. Three main encompassing categories were used in the Senior Design Conference Presentation, and allowed for a simplified understanding of the best alternative uses. These three categories were 1) community use, 2) emergency responder housing, and 3) consumer use. For more on these three categories and all the formulated alternative uses, reference the sections below and Appendix I, respectively.

10.2 Community Use

The section on community uses includes all ideas related to using the cabins for continued service to the community. The two main areas of organization within this category are education and housing. There are many schools in the Bay Area that would benefit greatly from having a tutor space for teachers to instruct students or hold office hours. Furthermore, there are several universities with insufficient student housing, so the cabins could be used to house those who need a place to live. Housing is needed throughout San José, not just in schools. Upon meeting with René Ramirez from HomeFirst, he expressed a need for individual housing space within the shelters HomeFirst operates. Finally, there are several individual needs that the cabins can fulfill within the community, such as serving as a miniature library, community garden shed, art center, shower unit, and more.

10.3 Emergency Responder Housing

Sean Lanthier, a firefighter from the Palo Alto Fire District, was instrumental in developing the emergency responder housing alternative use. He explained that frequently firefighters sleep in tents, on the ground, or on the fire trucks while fighting wildfires. An actual cabin would significantly improve the lives of emergency responders while on site. Sean explained that a wi-fi hub cabin could allow firefighters to communicate with family and friends throughout their time fighting the fire. This is all made possible by the mobility of the current cabin design.

In addition, due to the high living costs of San José, many local firefighters do not actually live nearby, but rather commute into the City for lengthy shifts at their stations. Sean explained that having additional housing at the station could allow for more firefighters to live on site should there be a large fire nearby and more than a normal amount of responders need to stay at the station.

This idea requires some redesign work, as there will need to be systems put in place to keep the homes stable on unlevel ground and reusable by different users. Overall, though, both Sean and the SCU team were very interested about using the cabins for emergency responder housing.

10.4 Consumer Use

Any idea involving selling the cabins to individuals for personal use was sorted under consumer use. If a homeowner wanted a shed, art studio, short term rental, retreat center housing, etc. in their backyard, then they could potentially buy the cabins from the City. This would benefit San José in two ways: one, San José would be able to free up city spaces by finding other uses, and two, there would be money coming back into the City, lessening the financial burden of the Bridge Housing Community program.

Chapter 11: Future of the Project

11.1 Feedback from the City of San José

A project debrief meeting between the SCU team and James Stagi from the City of San José's Homelessness Response Team (SJC) was held on Tuesday, May 28, 2019. The purpose of the meeting was to break down the City's feedback on the Senior Design Conference Presentation as well as discern The SCU team's next steps for the end of the school year to ensure that SJC would receive a satisfactory deliverable.

Mr. Stagi was very grateful for the time and effort that the SCU team spent working on the project. He pointed out how the BHC Project frequently moves too quickly for SJC's team to spend time analyzing the project at the level of detail that the SCU team was able to. The main area in which this was helpful was the alternative uses portion of the project. One of the most significant findings from the meeting was when Mr. Stagi noted that AB-2176 will be extended in the coming months to expire in 2025, prolonging the life of the BHC program; however, there will nevertheless be a need for alternative cabin uses, as SJC does not have the space nor resources for long term storage of cabin units. Mr. Stagi was very impressed with the modular cabin design, but as the current cabin design is nearing the final stages of its completion, transitioning to a new design altogether for the first two communities remains not feasible.

This meeting helped the SCU team discern the next steps to take in order to provide SJC with the highest value deliverable. The City needs as much help as possible in creating alternative uses for the cabins come the expiration of the BHC program. In addition, SJC preferred the ideas relating to community service, emergency responders, providing public service, etc. and not as much towards consumer use (SJC is not overly concerned with recouping costs associated with the BHC Project). The SCU team worked to fine tune the existing table of alternative uses to best fit SJC's desires. SJC, while not being as receptive to the modular design as the alternative uses, still wanted the design plans. It also asked that the SCU team provide a breakdown of not just the specifics of the modular design, but how the overarching ideas and lessons that came from the design could be applied to the most current cabin design and help the work that Habitat for Humanity was doing. These ideas include making the cabins more efficient, easier to build, adaptable for reuse, and compatible with differing communities (including combined units).

San José plans to open the first BHC community in July of 2019. The SCU team was and is beyond grateful for SJC's support and willingness to involve the SCU team throughout the entire Senior Design process, and the SCU team is excited to see the BHC program become a reality.

11.2 Possible Expansion to the Project Scope

One potential area of project scope that was discussed very early on in project was the possibility of incorporating renewable technologies such as solar into the cabin design. Due to time constraints and an effort to keep the cabin cost low, these designs were not pursued. This will certainly be, however, an area that can be built on in the future by either the City or future SCU project teams. This project was also not able to address how to add water and sanitary utilities to the cabin with the modular design. This aspect is something that could be important, however, given the nature of the current BHC program and the difficulty of attaching wet utilities to each cabin on site, the SCU team choose not to pursue such designs. If the cabins were reused as individuals separate from the overall community, the ability to add water utility services to the cabin would be important. The team did, however, come up with a rough concept for how to install electrical services for the modular cabin redesign. While they are not fully designed, the idea is shown in the construction drawings in Appendix G.

11.3 Concluding Remarks

Homelessness in the Bay Area is a problem that is only getting worse, despite housing being a basic human need and right. This project set out to support the organizations working to counteract homelessness. This led the SCU team to the Bridge Housing Community program. Working with San José, the scope of the project was narrowed to designing a modular cabin version of the current cabin design and providing appropriate retrofit modifications to the current cabin design to best suit it for post-BHC alternative uses.

Throughout the duration of the project, the SCU team obtained a comprehensive understanding of the issue of homelessness in the Bay Area and the efforts being put in place to address both root causes and surface consequences. Additionally, much was learned about other programs in San José that could make use of the cabin in a manner that would benefit the communities that these programs serve. Finally, the SCU team gained valuable experience through designing the modular cabin to best fit the current and future needs of the BHC program, and learned how to improve the construction process by building a prototype of the modular cabin redesign. Overall, this project was incredibly educational and the SCU team is grateful for the support provided and the relationships built throughout the process.

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<u>Appendix A</u>
Extra Geometry Plans

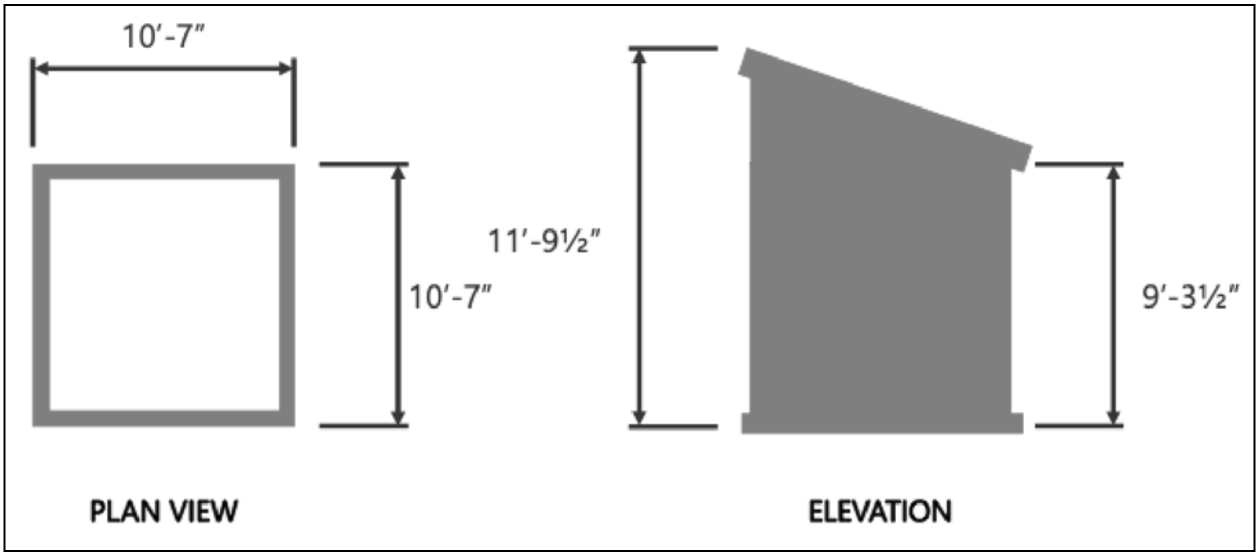


Figure A.1 - *Prototype overall dimensions.*

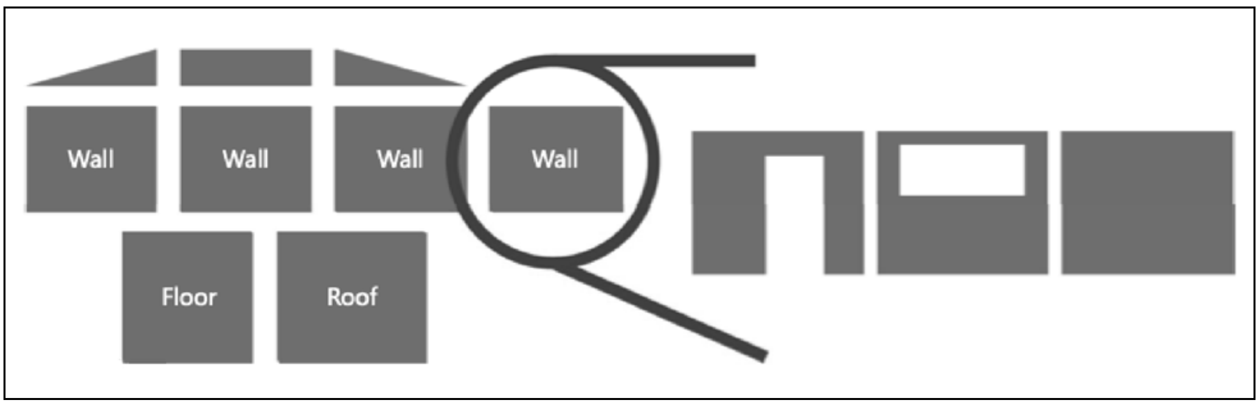


Figure A.2 - *Prototype wall, floor, roof, and height extension section breakdown. Wall section options shown for reference.*

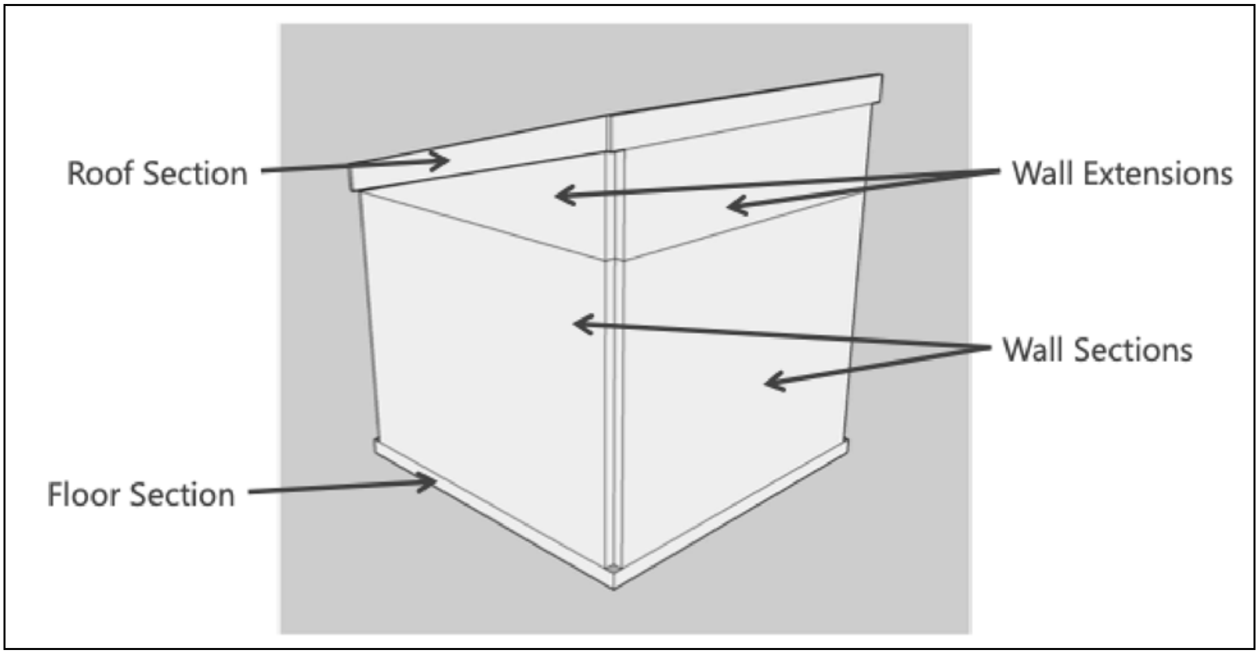


Figure A.3 - *Prototype assembled model with sections labeled for reference.*

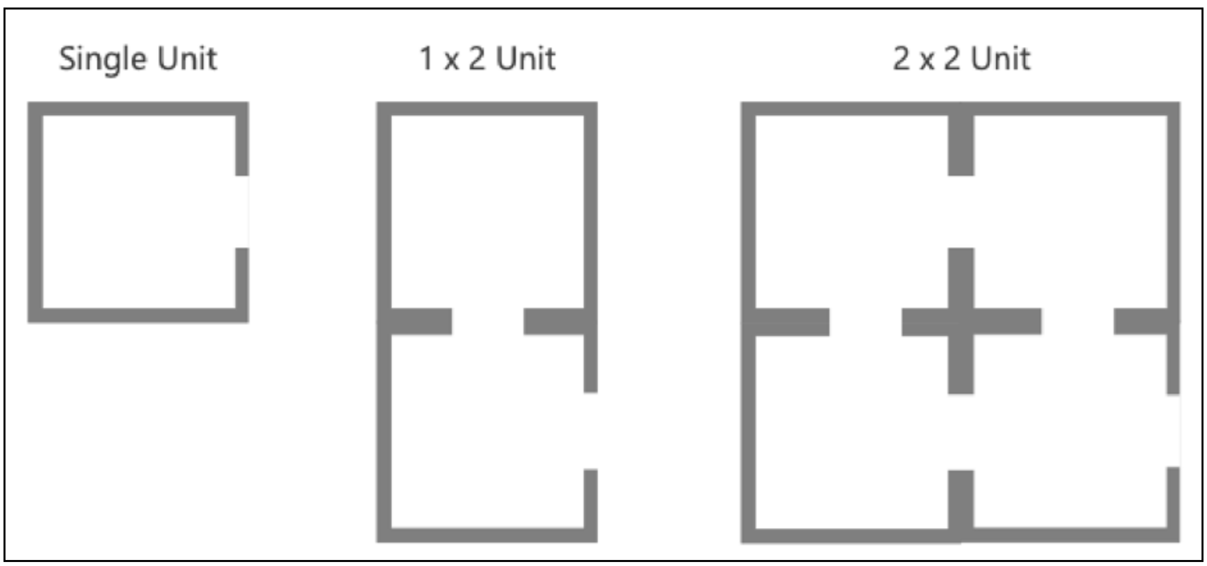


Figure A.4 - *Possible combined cabin units to have 1, 2, or 4 rooms.*

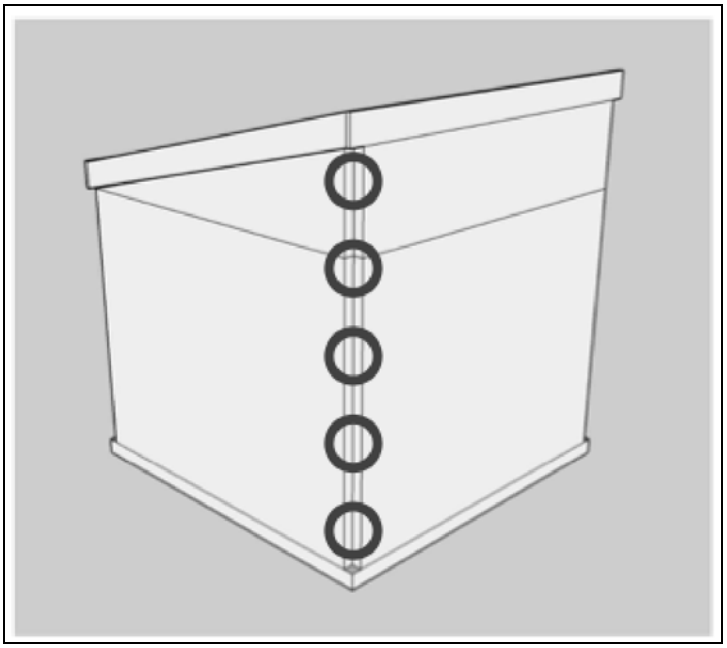


Figure A.5 - *Locations of the wall-to-wall corner connections.*

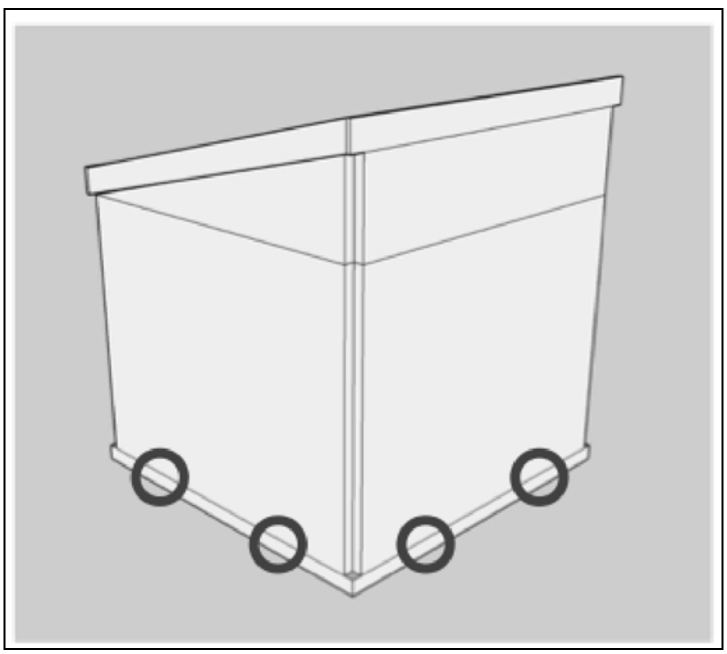


Figure A.6 - *Locations of the wall-to-floor connections.*

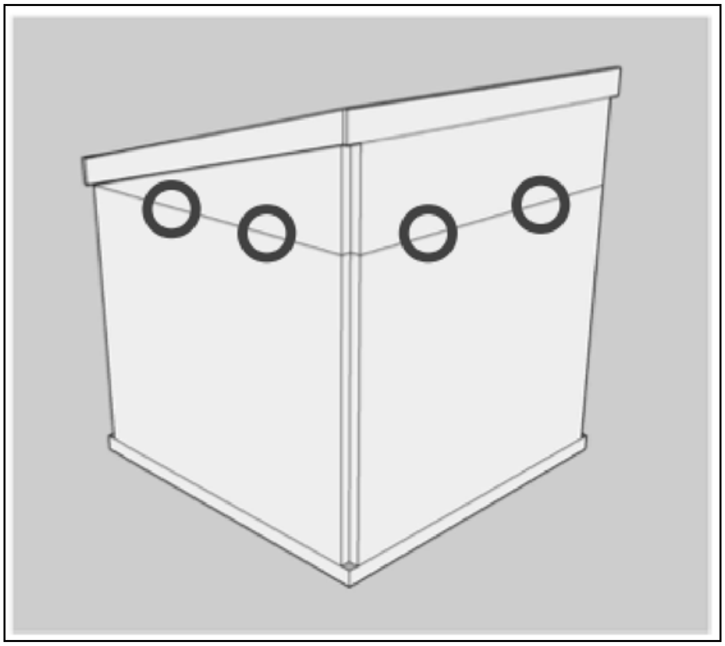


Figure A.7 - *Locations of the wall-to-height extension connections.*

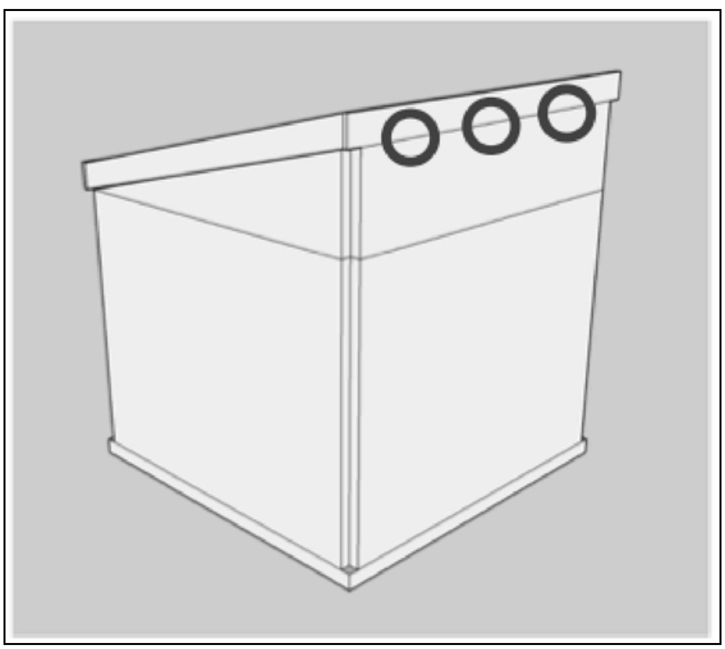
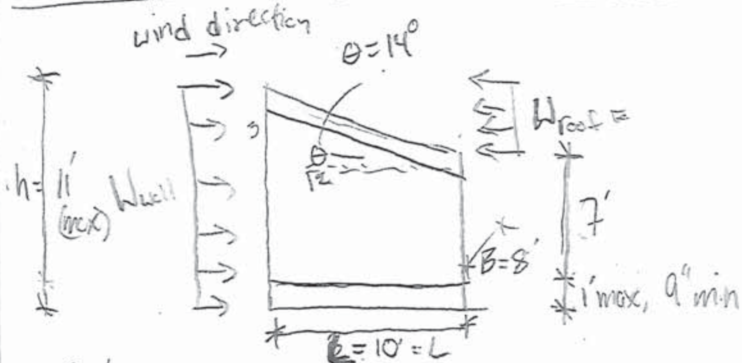


Figure A.8 - *Locations of the wall-to-roof connections.*

<u>Appendix B</u>
Lateral Demand Calc

WIND DESIGN → SENIOR DESIGN → See ASCE 7-10, ☆ TABLE 27.2-1 (Steps)



MINIMUM WIND PRESSURE:

W_{wall} = 16 psf
W_{roof} = 8 psf
→ ASCE 7-10, SECTION 27.4.7

① / RISK CATEGORY:

② ↳ RISK CATEGORY II → V = 110 mph

③ / WIND LOAD PARAMETERS:

④ ↳ WIND DIRECTIONALITY K_d

↳ $K_d = 0.85$

↳ EXPOSURE CATEGORY:

↳ SURFACE ROUGHNESS "B" → CATEGORY B

$h_{max} < 30'$

↳ VELOCITY PRESSURE COEFFICIENTS ($h < 15'$)

↳ $K_z = 0.57$

↳ $K_h = 0.57$

↳ TOPOGRAPHIC EFFECT (K_{zt}):

↳ $K_{zt} = [1 + K_1 K_2 K_3]^2$ → Assumed to be 1.0

$K_{zt} = 1.0$

☆ → check

↳ GUST EFFECT FACTOR (G):

↳ G = 0.85 → ALL RIGID STRUCTURES

↳ ENCLOSURE CLASSIFICATION:

↳ PARTIALLY ENCLOSED

partial: openings exceed 4 ft² or openings in 1 wall exceed balance (26.2 definition) / positive external pressure

↳ INTERNAL PRESSURE COEFFICIENTS: → If FULLY ENCLOSED, $GC_{pi} = \pm 0.18$

↳ $GC_{pi} = \pm 0.55$ → PARTIALLY ENCLOSED BUILDINGS

WIND DESIGN (cont.):

⑤ VELOCITY PRESSURE (q_z, q_h)

$K_z = K_h$, so $q_z = q_h$

$q_h = 0.00256 K_z K_{zt} K_d (V^2)$

$q_h = 0.00256 (0.57)(1.0)(0.85)(110)^2$ → No C_p fact

$q = q_z$
$q_i = q_z$

$q_h = q_z = 15.01$ psf → MINIMUM IS 15 psf for WALLS (calc after C_p)

⑥ EXTERNAL PRESSURE COEFFICIENTS (C_p or C_N)

↳ WALL, MONOSLOPE ROOF → FIGURE 27.4-1

roof → ↳ q_z → $C_p = 0.8$ → WINDWARD Wall (positive)

↳ q_h → $L/B = \frac{10}{8} = 1.25$ → $C_p = -0.45$ → Leeward Wall

with q_h { ↳ Side Wall → $C_p = -0.7$

↳ Windward → $\frac{h}{L} = \frac{11}{10} \geq 1.0$ → $\theta \approx 14°$ → $C_p \approx -1.05, -0.18$ (design for both)

⑦ FIND DESIGN PRESSURES:

↳ EXCEL SPREADSHEET

$P = q_z G C_p \pm q_z G C_{pi}$

Wind Loads

Variables:	
V	110
kd	0.85
kz	0.57
kh	0.57
kzt	1.0
G	0.85
GCpi	0.55

Calcs:		
qh	15.01	psf
qz	15.01	psf

Cp values				impacts
for qh	windward	-1.05	-0.18	roof
	leeward	-0.45		wall
	side	-0.7		wall
for qz	windward	0.8		wall

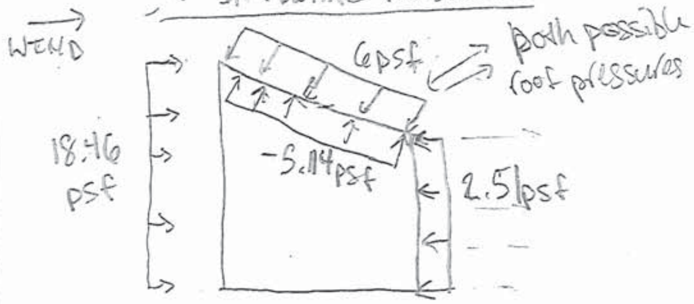
FINAL DESIGN PRESSURES

		qzGCp		qzGCpi	Positive Internal Pressure (+GCpi)	Negative Internal Pressure (-GCpi)	Notes
Wall	Windward	10.21		8.25	18.46	1.95	
	Leeward	-5.74		8.25	2.51	-13.99	
	Side	-8.93		8.25	-0.68	-17.18	
Roof	Windward	-13.39	-2.30	8.25	-5.14 & 5.96	-21.65 & -10.55	choose max

Negative –> away from wall/roof, Positive –> towards wall/roof (inside to outside)

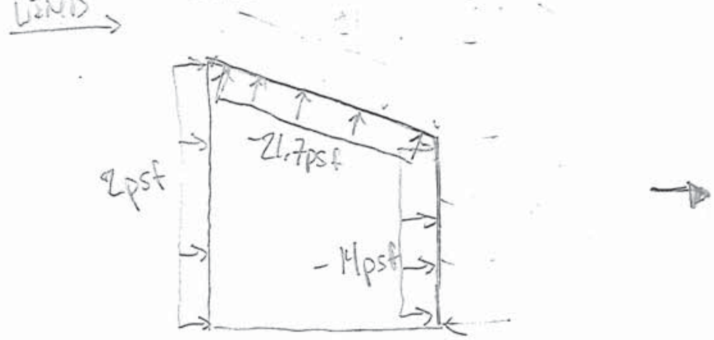
WIND DESIGN (cont):

+ INTERNAL PRESSURE



SIDE: -0.68 psf

- INTERNAL PRESSURE:

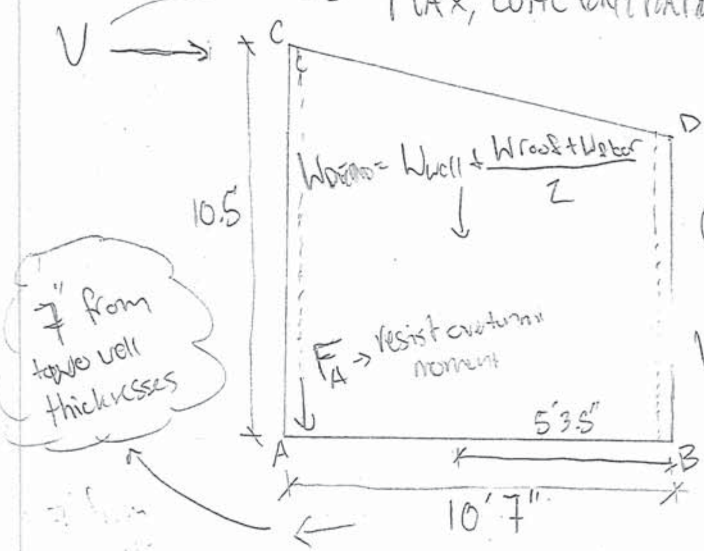


SIDE: -17.2 psf

WIND DEMAND → OVERTURNING MOMENT

MAX, CONCENTRATED POINT LOAD → $V = 95\,\text{plf}\left(\frac{10.5'}{2}\right)$

① $V = 498.7 \approx 500\,\text{lb}$



② W_{DEAD} → from Gravity Demand ESTIMATES,

$$W_{DEAD} = (7\,\text{psf})(8')(10.5') + \frac{(6\,\text{psf} + 9\,\text{psf})(100\,\text{ft}^2)}{2}$$

$W_{DEAD} = 588\,\text{lb} + 750\,\text{lb}$

$W_{DEAD} = 1330\,\text{lb}$

$$\circlearrowleft + \sum M_B = 0 = W_{DEAD}\left(5\tfrac{3.5}{12}\right)' + F_A\left(10\tfrac{7}{12}\right)' - V(10.5')$$

$$F_A = \frac{(500\,\text{lb})(10.5') - \left(5\tfrac{3.5'}{12}\right)(1330\,\text{lb})}{\left(10\tfrac{7}{12}\right)'}$$

$$F_A = \frac{5250 - 7037.9}{\left(10\tfrac{7}{12}\right)'} = -169\,\text{lb}$$ → NEGATIVE, NOT PULLING UP

↓

OVERTURNING NOT A CONCERN → FOR CONSERVATIVE REASONS, DESIGN CONNECTIONS WITH

OVERTURNING FORCE OF 200 lb per wall

<u>Appendix C</u>
Gravity Demand Calc

GRAVITY LOAD CALCS ⇒ LOADING DEMAND

DEAD LOADS:

DEAD LOADS TAKEN FROM DESIGN OF WOOD STRUCTURES (BREYER) APPENDIX A & B

WALL:

- ↳ 1/2" DRYWALL → 2.5 psf
- ↳ R13 FIBERGLASS INSULATION → 0.35 psf
- ↳ 2x4 DOUG FIR, 16" O.C. → 1.2 psf
- ↳ 3/8" PLYWOOD → 1.15 psf
- ↳ 1/2" SIDING ≈ 1.5 psf

→ $D_{WALL} \approx (2.5 + 0.35 + 1.2 + 1.15 + 1.5)$ psf

$D_{WALL} \approx 7$ psf

FLOOR:

- ↳ R19 FIBERGLASS INSULATION → 0.4 psf
- ↳ 2x6 FRAMING → 2.2 psf
- ↳ 1/2" SUBFLOOR PLY. → 1.5 psf
- ↳ FLOORING MAT. → 1.4 psf

→ $D_{FLOOR} = (0.4 + 2.2 + 1.5 + 1.4)$ psf

$D_{FLOOR} = 6$ psf

ROOF:

- ↳ 1/2" DRYWALL → 2.6
- ↳ R30 INSULATION → 0.6 psf
- ↳ 1/2" PLYWOOD → 1.5 psf
- ↳ 3 PLY FELTS ASPHALT SHINGLES → 3.5 psf

→ $D_{ROOF} = (2.6 + 0.6 + 1.5 + 3.5)$ psf

$D_{ROOF} = 9$ psf

LIVE LOADS:

FLOOR ("ALL OTHER AREAS"):

$L_{FLOOR} = 40$ psf

ROOF (ORDINARY, NOT OCCUPIABLE):

$L_{ROOF} = 20$ psf

→ TABLE 1607.1 CBC 2016

DEFLECTION LIMITS:

- ROOF: $\Delta_{D+L} \le \frac{l}{180}$: $\Delta_L \le \frac{l}{240}$; $\Delta_W = \Delta_E = \frac{l}{240}$
- FLOOR: $\Delta_{D+L} \le \frac{l}{240}$: $\Delta_L \le \frac{l}{360}$

→ TABLE 1604.3 CBC 2016

Appendix D
Lateral Capacity Calc

LATERAL CAPACITY

WIND LOADS → APPLYING TO 5 DIFFERENT WALLS

↳ basing on **19.0 psf max wind pressure in any direction**

↳ SEE EXCEL SPREAD SHEET (WIND LOADS) →

↳ OUT-OF-PLANE CAPACITY (WALL)

↳ NDS, SPECIAL DESIGN PROVISIONS FOR WIND & SEISMIC, 2015 (SDPWS) → TABLE 3.2.1

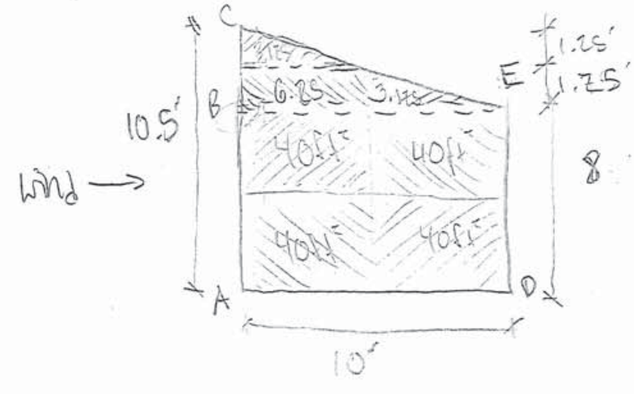
↳ PARRALEL TO SUPPORTS, 16 O.C. wall stud spacing,

↳ SPAN RATING 24/0, $t_{min} = 3/8''$ → $P_{max} = 50\,psf > P_{w} = 19\,psf$ ✓ → WORKS WITH FACTOR OF SAFETY = 2.6

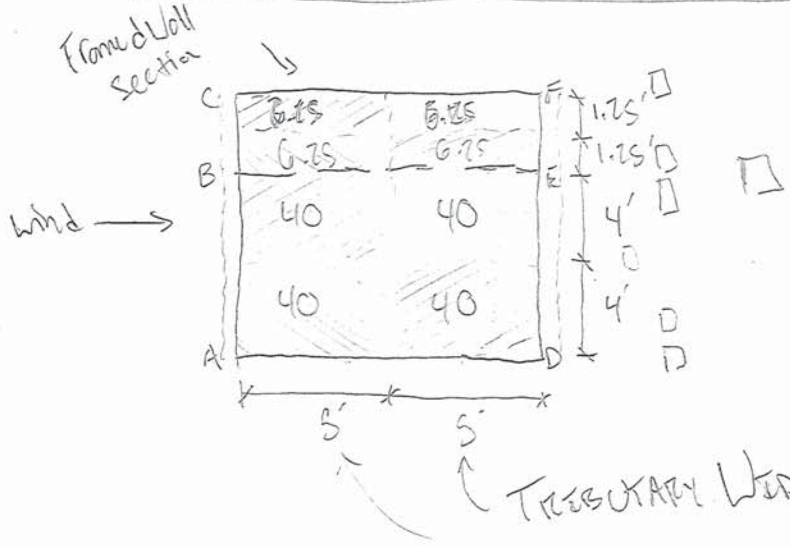
(nominal, will be fine with adjustment factors)

↳ IN-PLANE CAPACITY (WALL):

↳ BREAKDOWN OF FORCES DISTRIBUTION FOR RAKE WALL:

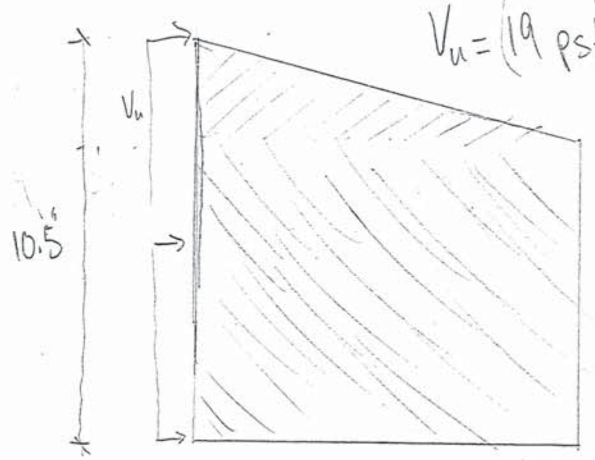


↳ BREAKDOWN OF FORCES ON TALL WALL:



IN-PLANE LATERAL CAPACITY (cont.):

↳ BASED ON FORCE DISTRIBUTION DIAGRAMS, CORNER BETWEEN RAKE & TALL WALL GOVERNS:



$V_u = (19\ psf)(5') = 95\ plf$

↓

MDS SDPWS 2015

↳ TABLE 4.3A:

↳ PLYWOOD SIDING, $t = 3/8"$, PANEL EDGE FASTENER SPACING = 6"

↓

WIND → $V_{max} = 450\ plf$

SEISMIC → $V_{max} = 320\ plf$

FOR OUT OF PLANE & IN-PLANE REQUIREMENTS,

↳ PLYWOOD SIDING, $t = 3/8"$ WITH FASTER SPACING OF 6" IS STRUCTURALLY SUFFICIENT (F.S. = 3.3)

· WIND LOADS (cont.)

↳ OPENINGS IN SHEAR PANELS (SDPWS 2015 TABLES 4.3.3.4 & 4.3.4)

↳ **WINDOW:**

↳ USE 36" x 36" (ROUGH OPENING)

① ↳ FOR 8' WALL, MAX OPENING height IS LESS THAN 4'0" (OR $h/2$, WHERE $h = 8'$)

② THE PERCENTAGE OF WALL WITH FULL HEIGHT SHEATHING IS $\left(\frac{7'}{10'}\right) * 100\% = 70\%$, SO SHEAR ADJUSTMENT FACTOR (C_o) IS $C_o = 0.87$

↳ APPLIED TO TABLE 4.3A → $V_s = C_o V_s = 0.87(280\,plf)$

$V_s' = 243.6\,plf$ → ε

↳ STILL FAR ABOVE $V_u = 95\,plf$ ✓

③ ASPECT RATIO:

↳ PER TABLE 4.3.4 → $\frac{h}{b_s} \equiv \frac{\text{(shear wall height)}}{\text{(minimum shear wall length)}} \leq 3.5:1$

↳ FOR WINDOW: $\frac{h}{b_s} = \frac{8'}{3'6"} = \frac{8'}{3.5'} = 2.3:1 \leq 3.5:1$ ✓

↳ **DOOR:**

① ↳ 40" x 86" ROUGH OPENING

↳ MAX OPENING HEIGHT = $\frac{7'2"}{8'} \approx \frac{9h}{10} < h = 8'$ → USE h

② PERCENTAGE OF WALL WITH FULL HEIGHT: $\frac{6'6"}{10'} \approx 65\%$ → USE 60%

↳ BASED ON TABLE 4.3.3.4, $C_o = 0.50$

↳ $V_s' = C_o V_s = 0.5(280) = 140\,plf \geq V_u = 95\,plf$ ✓

③ ASPECT RATIO: $\frac{h}{b_s} = \frac{8'}{32"} \approx 2.5:1 \leq 3.5:1$ ✓

Appendix E
Gravity Capacity Calc

STRENGTH OF WOOD:

↳ ASSUME USING DOUG FIR, No. 2 GRADE

- F_b = 900 psi
- F_v = 180 psi
- $F_{c\parallel}$ = 850 psi (stud grade, conservative)

E = 1,600,000 psi

→ NDS SUPPLEMENT: DESIGN VALUES FOR WOOD CONSTRUCTION, TABLE 4A

ADJUSTMENT FACTORS (ALL = 1.0 EXCEPT THOSE NOTED):

- ROOF:
  - ↳ BEAMS: USE C_M = 0.85 (EXPOSED AROUND EDGES) → ROOF BEAM NOT BEARING, BUT IN CASE...
  - ↳ JOISTS: USE C_r = 1.15 (REPETITIVE MEMBER) → only for F_b
- FLOOR:
  - ↳ BEAMS: C_m = 0.85
  - ↳ JOISTS: C_m = 0.85 ; C_r = 1.15 → only for F_b
- WALL:
  - ↳ STUDS: C_r = 1.15 → only for F_b
    C_m = 0.85
    C_F = 1.15 → size fact → only for F_c

$F_b' = F_b$ * ADJUSTMENT FACTORS

$F_v' = F_v$ * "

$E' = E$ * "

DEFLECTION EQN → simply supported, uniform distributed load

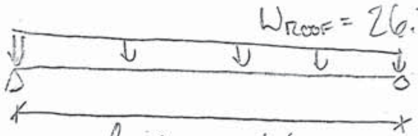
$$\Delta_{max} = \frac{5wl^4}{384EI}$$

ROOF DESIGN → JOIST

↳ Choose 16" o.c. framing (tributary width = 16" = $1.\bar{3}'$)

$D+L = 6.7\,psf + 20\,psf = 26.7\,psf$

$W_{ROOF} = 26.7\,psf(1.\bar{3}') = 35.6\,plf$



$l_{roof,max} = 11'$

> NOTE
> • DEMAND EQUATIONS BASED ON NDS BEAM FORMULA MANUAL (2015)
>
> • $F_b' = 1.15(900psi)$
> • $F_v' = F_v$
> • $E' = E$

DEMAND:

MOMENT

↳ $M_{max} = \frac{wL^2}{8} = \frac{35.6plf(11')^2}{8} = 538.5\,lb\cdot ft$

↳ $M_{max} = 538.5\,lb\cdot ft$

SHEAR:

↳ $V_{max} = \frac{wL}{2} = \frac{35.6plf(11')}{2} = 195.8\,lb.$

$V_{max} = 195.8\,lb$

DESIGN CAPACITY:

↳ 2x10 NEEDED FOR INSULATION REQUIREMENTS

↳ $A_{2x10} = 13.9\,in^2$ // $I_{x_{2x10}} = 98.9\,in^4$ // $S_{x_{2x10}} = 21.4\,in^3$ // $C_r = 1.15$ (only for F_b)

↳ Moment Capacity Check:

$F_b' = \frac{M_x}{S_x} \rightarrow S_x = \frac{M_x}{F_b'} = \frac{538.5\,lb\cdot ft}{(1035psi)}\left(\frac{12in}{1ft}\right) = 6.24\,in^3$

$S_x = 6.24in^3 < S_{x_{2x10}} = 21.4\,in^3$ ✓ → WORKS WITH F.S. = 2.0 ☆

↳ SHEAR CAPACITY → Don't use Repetitive Member FACTOR

$F_v' = \frac{3}{2}\left(\frac{V}{A}\right) \rightarrow A = \frac{3}{2}\left(\frac{V}{F_v'}\right) = \frac{3}{2}\left(\frac{195.8lb}{180\,psi}\right) = 1.63\,in^2$

$A = 1.63in^2 \leq A_{2x10} = 13.9\,in^2$ ✓ → WORKS WITH F.S. = 2.0

↳ Check DEFLECTION (next page)

Roof Joist (cont.):

↳ Deflection:

$$\Delta_{max} = \frac{5wl^4}{384EI}$$

$W_{d+l} = 35.6\ plf$

$W_l = 20psf(1.\bar{3}') = 26.7plf$

$$\Delta_{D+L} \leq \frac{l}{180} = \frac{11'(12'')}{180(1')} = 0.733''$$

$$\Delta_{D+L} = \frac{5(35.6)\,lb\left(11'\left(\frac{12''}{1'}\right)\right)^4 in^4}{384(1600{,}000)\frac{lb}{in^2}(98.9 in^4)(1ft)(12)} = 0.074''$$

$$\Delta_{D+L} = 0.074'' \leq \frac{l}{180} = 0.733'' \checkmark$$

$$\Delta_L \leq \frac{l}{240} = \frac{11(12')}{240(1')} = 0.55''$$

$$\Delta_L = \frac{5(26.7\frac{lb}{ft})(11' * 12''/1')^4\ 1ft}{384(1.6E6\frac{lb}{in^2})(98.9 in^4)\ 12''} = 0.055''$$

$$\Delta_L = 0.055'' \leq \frac{l}{240} = 0.55'' \checkmark$$ → WORKS WITH F.S. = 2.0

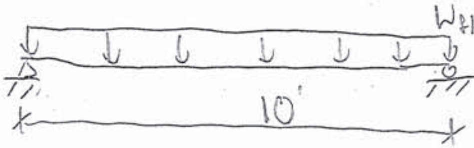
ROOF JOIST WORKS WITH 2x10 LUMBER

FLOOR DESIGN (JOISTS):

↳ Choose 16" O.C framing (1.33̄')

D+L = 6 psf + 40 psf = 46 psf

$W_{floor} = (46\,psf)(1.3\bar{3}') = 61.33\ plf$



→ SUPPORTS MAY BE CLOSER TO MIDDLE, THIS IS MAX POSSIBLE

DEMAND:

MOMENT:

↳ $M_{max} = \frac{wL^2}{8} = \frac{(61.3\,plf)(10')^2}{8} = 766.7\ lb\cdot ft$

$M_{max} = 766.7\ lb\cdot ft$

↳ SHEAR (V): $\frac{wL}{2} = \frac{(61.3)(10)\,lb}{2} \approx 307\,lb$

$V_{max} = 307\,lb$

DESIGN CAPACITY:

↳ 2x6 NEEDED FOR INSULATION

↳ $A_{2x6} = 8.25\,in^2$ // $I_{2x6} = 20.8\,in^4$ // $S_{x2x6} = 7.56$

↳ $F_b' = (1.15)(0.85)(900\,psi) = 879.8\ psi = F_b'$

↳ $F_v' = (0.85)(180\,psi) = 153\ psi = F_v'$

↳ $E' = (0.85)(1600000\,psi) = 1360000\,psi = E'$

F.S < 2.0
↳ acceptable ☆

↳ Moment Cap:

$F_b' = \frac{M_x}{S_x} \rightarrow S_{x,min} = \frac{M_{max}}{F_b'} = \frac{766.7\,lb\cdot ft\ in^2\ (12")}{(879.8\,psi)\,lb\,(ft)} = 10.45$

$S_{x2x6} \ngeq 10.45$ → NEED TO USE 2x8 ($S_x = 13.14\,in^3$) ✓

↳ 2x8: $A_{2x8} = 10.9\,in^2$ || $I_{2x8} = 47.64\,in^4$ || $S_{x2x6} = 13.14\,in^3$

FLOOR DESIGN (cont.):

↳ DESIGN CAP (cont.):

↳ SHEAR CAP:

$$F_v' = \frac{3}{2}\left(\frac{V}{A}\right) \rightarrow A_{min} = \frac{3}{2}\left(\frac{V_{max}}{F_v'}\right) = \frac{3}{2}\left(\frac{307\,lb}{153\,lb}\right)in^2 = 3.0\,in^2$$

$A = 10.9\,in^2 \geq A_{min} = 3.0\,in^2 \rightarrow$ ✓ $\rightarrow F.S > 2.0$

↳ DEFLECTION:

$$\Delta_{max} = \frac{5wl^4}{384EI} \rightarrow W_{D+L} = 61.3\,plf \;;\; W_L = 40(psf)(1.\bar{3}) = 53.\bar{3}\,plf$$

$$\hookrightarrow \Delta_{D+L} \leq \frac{l}{240} = \frac{10'(12''/1')}{240} = 0.5''$$

$$\Delta_{D+L} = \frac{5\left(61.3\frac{lb}{ft}\right)\left(10'\left(\frac{12''}{1'}\right)\right)^4\left(\frac{1 ft}{12 in}\right)}{384(1{,}360{,}000\,psi)(47.64\,in^4)} = 0.21''$$

$\Delta_{D+L} = 0.21'' \leq 0.5''$ ✓ $\rightarrow FS > 2.0$

$$\hookrightarrow \Delta_L \leq \frac{l}{360} = \frac{10'(12''/1')}{360} = 0.3\bar{3}''$$

$$\Delta_L = \frac{5\left(53.3\frac{lb}{ft}\right)\left(10'\left(\frac{12''}{1'}\right)\right)^4\left(\frac{1 ft}{12''}\right)}{384(1360000\,psi)(47.64\,in^4)} = 0.185''$$

$\Delta_L = 0.185'' \leq 0.33''$ ✓ $\rightarrow F.S. \approx 2.0$

2x8 WORKS FOR FLOOR JOISTS ☆

☆ ↳ TOO USE 2x6, REQUIRED DISTANCE B/L SUPPORTS IS:

$$S_x = 7 \rightarrow M_{max} = S_x(F_b') = 7(879.8\,psi)\left(\frac{1 ft}{12 in}\right) = 513.2\,lb\cdot ft$$

$$M_{max} = \frac{wL^2}{8} \rightarrow L_{max} = \sqrt{\frac{M*8}{w}} = \sqrt{\frac{(513.2\,lb\text{-}ft)(8)}{61.33\,lb/ft}} = 8.2'$$

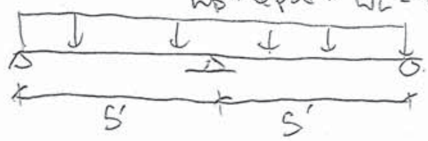
NOTE:
↳ THE DESIGN PROTOTYPE USED 2x6, WITH A SUPPORT IN MIDDLE OF FLOOR. THIS WORKS, BUT ONLY BECAUSE OF ADDITIONAL SUPPORT ☆

GRAVITY CAPACITY

FLOOR FRAMING:

↳ FACTOR OF SAFETY WHEN USING 2x6 FRAMING, WITH SUPPORT @ MIDDLE :→ 16" o.c. Spacing

$W_D = 6psf$; $W_L = 40psf$ → TW



$W_{floor} = 46psf\left(\frac{16''}{12''}\right) = 61.33plf$

DEMAND → treat like 2 seperate beams ☆

↳ $M_{max} = \frac{wL^2}{8} = \frac{(61.3plf)(5')^2}{8} = 191.7\ lb\text{-}ft = M_{max}$

↳ $V_{max} = \frac{wL}{2} = \frac{61.3plf(5)}{2} = 153.3\ lb = V_{max}$

CAPACITY → 2x6 ($A = 8.25in^2$ // $I = 20.8in^4$ // $S_x = 7.56in^3$

↳ $S_{x,min} = \frac{M_{max}}{F'_b} = \frac{191.7\ lb\text{-}ft}{879.8\ lb/in^2}\left(\frac{12in}{1ft}\right) = 2.61in^3 \leq S_x = 7.56in^3$

↳ WORKS WITH F.S. > 2.0

↳ $A_{min} = \frac{3}{2}\left(\frac{V_{max}}{F'_v}\right) = \frac{3}{2}\left(\frac{153.3lb}{153psi}\right) = 1.5in^2 \leq 8.25in^2$

↳ WORKS WITH F.S. > 2.0

↳ DEFLECTION (I):

$\Delta_{D+L} \leq 0.25 \rightarrow \Delta_{D+L} = \frac{5(61.3\frac{lb}{ft})(5')^4}{384(1360000psi)(20.8in^4)} = 0.030in$

$\Delta_{D+L} = 0.03in \leq 0.25in$ → WORKS WITH F.S. ≥ 2.0

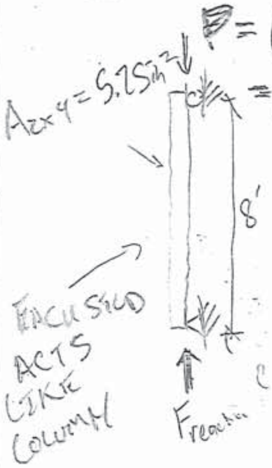
$\Delta_L \leq 0.167in$

$\Delta_L = \frac{5(53.3\frac{lb}{ft})(5')^4}{384(1360000psi)(20.8in^4)} = 0.026in$

$\Delta_L = 0.026in \leq 0.167in$ → WORKS WITH F.S. > 2.0

WALL FRAMING:

↳ WALL STUDS SUBJECTED TO COMPRESSION LOADING...



P = (Roof Live + Roof Dead + Wall Dead) tributary Area

$= [(20psf) + (8.5psf)](A_{trib,roof}) + 7.0(A_{trib}(wall))$

↳ $A_{trib,roof} = \left(\frac{\text{Length of Roof}}{2}\right)$(spacing of wall studs)

↳ $A_{trib,wall} = (10')$(spacing stud)

↳ Spacing of stud:

↳ BASED ON CBC 2016, TABLE ______ 16" SPACING FOR 2X4 IS ACCEPTABLE

↳ $A_{tributary} \left(\frac{11'(12")}{2(1')}\right)(16") = 1056 in^2 = 7.3 ft^2$

↳ $A_{trib,wall} = (10')(16")\left(\frac{12"}{1'}\right) = 1920in^2 = 13.3 ft^2$

$P_{DEMAND} = (28.5psf)(7.3ft^2) + 7.0psf(13.3ft^2) = \boxed{302.3 lb}$

↳ CAPACITY

↳ UNBRACED HEIGHT

↳ $l_x = 7.5'$ → no blocking

↳ $l_y = 6" = \frac{1}{2}'$ → nail spacing of plywood

↳ K-factor: 1.0 (pinned top & bottom)

↳ r:

↳ $r_x = \sqrt{I_x} = \sqrt{5.36in^4} = 2.31in^2$

↳ $r_y = \sqrt{I_y} = \sqrt{0.98} = 0.99in^2$

↳ Y-DIRECTION GOVERNS; → $F_{c||} = 850psi$

↳ $\frac{Kl_y}{r_x} = \frac{1.0(90")in^2}{0.99in^2} = 90.7$

↳ $F_{ec} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = \frac{\pi^2(1600,000)(0.85)\frac{lb}{in^2}}{(90.7)^2} = 1668.2 psi$ (applied to E)

↳ $\frac{l_y}{r_x} = 90.7 \leq 4.71\sqrt{\frac{F_{c}}{E}} \approx 180$ → $F_{cr} = \left(0.658^{\frac{F_{c||}}{F_{ec}}}\right)F_{c||}$

↳ $F_{cr} = \left(0.658^{\frac{850}{1668.2}}\right)(850 psi) = 686 psi$

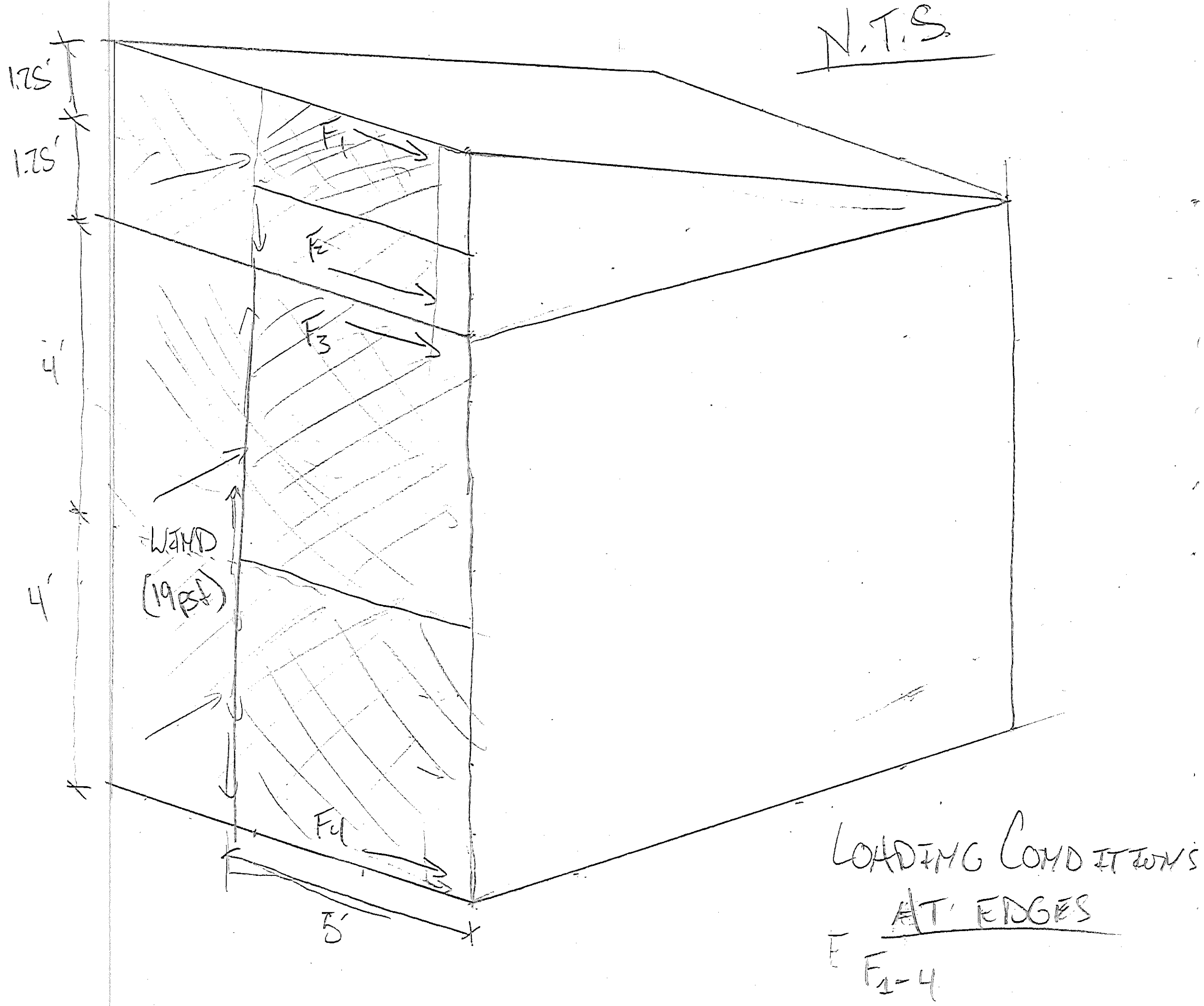
↳ $P_{capacity} = (686 psi)(5.25in^2) = \boxed{3605 lb = P_{cap}}$

GOOD WITH → F.S. >> 2.0

Appendix F
Connection Design Calcs

WALL-TO-WALL CONNECTION:

↳ LOCATIONS OF LOADING:



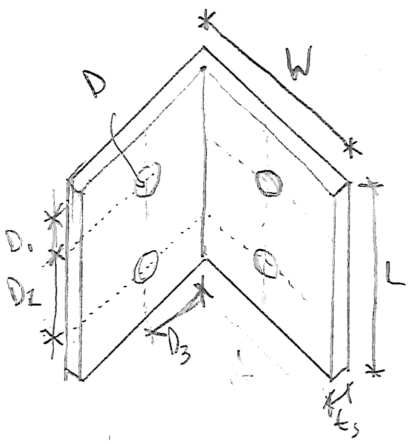
$F_1 = F_2 = 19psf(1.25')(5') = \boxed{118.75 lb}$

$F_3 = F_4 = 19psf(4')(5') = \boxed{380 lb}$

CONNECTION CALC:

① CONNECTION DETAIL (SST-HL35) ICC

↳ SST HL35 & HL37 (not shown):



$W = 3.25''$
$L = 5''$
$D = 0.5''$
$D_1 = 1.25''$
$D_2 = 2.5''$
$D_3 = 2''$
$t_s = 0.1875''$

→ GOING WITH THIS DESIGN

↳ SAME VALUES FOR t_m, F_{em}, F_{es}, R_d, R_t, F_{yb}

DESIGN DECISIONS:

↳ ~~CHOOSE ANGLE TO GRAIN (θ) TO BE θ = 30° → somewhat conservative~~ θ = 90° (load is 100% perp to grain) ☆

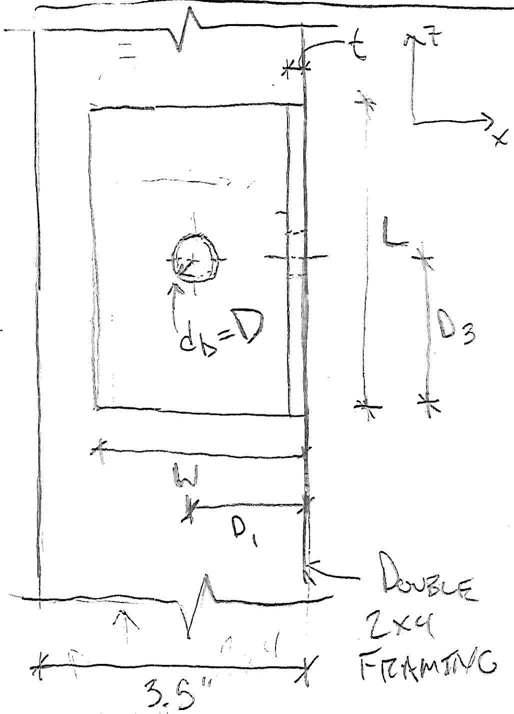
↳ GOING TO USE BOLT SIZE (d_b) OF 3/8" (0.375") ☆ ✓

CONNECTION CALCS:

t_{s} = t_{side} bearing member (steel)

t_m = t_{main} bearing member (wood)

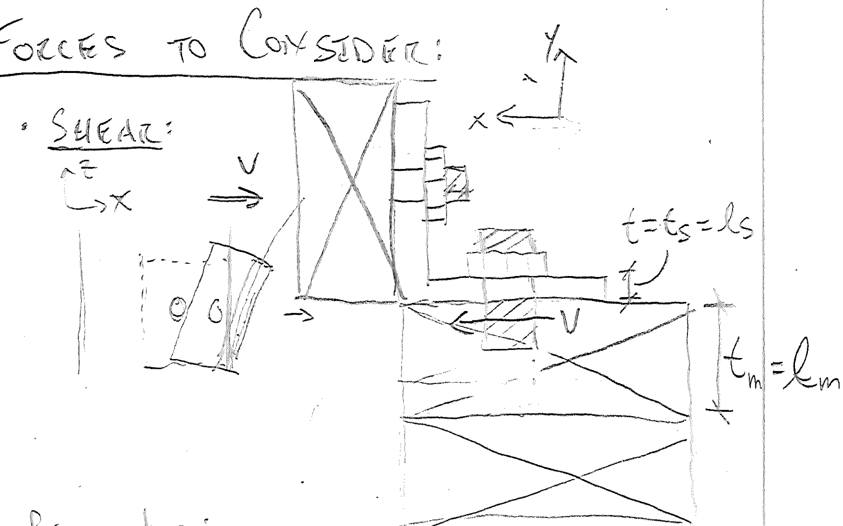
① CONNECTION 1 (WALL-TO-WALL):



-note: D_2 & D_4 used if more than 2 bolts on each face

FORCES TO CONSIDER:

· SHEAR:



from calcs:

↳ V_{max} = 95 plf

NDS DESIGN EQUATIONS:

(NDS 2005 § 11.3) / NDS 2015 § 12.3)

6 YIELD MODES (TABLE 11.3.1A):

MAIN MEMBER:

Dowel bearing failure (uniform) → $I_m \rightarrow Z = \frac{D\, l_m F_{em}}{R_d}$

Plastic hinge located near shear plane → $III_m \rightarrow Z = \frac{k_2 D\, l_m F_{em}}{(1+2R_e)R_d}$

SIDE MEMBER:

$I_s \rightarrow Z = \frac{D\, l_s F_{es}}{R_d}$

D.B.F. (Non-uniform) → $III_s \rightarrow Z = \frac{k_3 D\, l_s F_{es}}{(2+R_e)R_d}$

EITHER:

2 plastic hinges near shear planes → $II \rightarrow Z = \frac{k_1 D\, l_s F_{es}}{R_d}$

$IV \rightarrow Z = \frac{D^2}{R_d}\sqrt{\frac{2 F_{em} F_{yb}}{3(1+R_e)}}$

VARIABLES:

θ → Grain Angle (from direction of force) in degrees

$D = d_b$ → bolt diameter

F_{yb} → bending yield strength of bolt (psi)

F_{em} → MAIN MEMBER BEARING STRENGTH (psi)

F_{es} → SIDE MEMBER BEARING STRENGTH (psi)

R_d → Reduction term

$R_e = F_{em}/F_{es}$

$R_t = l_m/l_s$

Z → FORCE AT YIELD, USE MINIMUM FOR DESIGN

CONNECTION CALCS:

① (CONT.):

↳ IF USING SIMPSON STRONGTIE (SST) HL33

↳ $t = t_s = 3/16" = 0.1875"$

↳ $d_{b,hole} = 0.5"$ ⇒ Use bolt size of 3/8"

↳ L = 2.5"

↳ W = 3.25"

↳ $D_1 = 1.25"$

↳ $D_3 = 2"$

↳ $F_{es} = F_u$ OF A36 STEEL

$F_{es} = 87$ ksi = 87000 psi

BOLT STRENGTH:

↳ F_{yb} ⇒ FROM COMMONLY REFERENCED IN NDS TABLES 12A-12E.

↳ SEE NDS APPENDIX I.4

↳ FILLING IN VARIABLES:

· WOOD DIM./PROP.:

↳ $t_m = 1.5"$ · $G_s = 0.50$ → NDS TABLE 12.3.1A

↳ $F_{em} = F_{e\perp}$ → LOADING PARALLEL TO GRAIN — NDS TABLE 12.3.3

· R-VALUES:

↳ $R_e = \frac{F_{em}}{F_{es}} = \frac{5600 psi}{36000 psi} = 0.156$

↳ $R_t = \frac{t_m}{t_s} = \frac{1.5"}{0.1875"} = 8$

↳ R_d → DEPENDENT ON YIELD MODES:

- I_m, I_s → $R_d = 4K_\theta$
- II → $R_d = 3.6K_\theta$
- III_m, III_s, IV → $R_d = 3.2K_\theta$

↳ When D > 0.25", AND WHERE $K_\theta = 1 + 0.25(\theta/90)$

Appendix Table L1

For SST HL33

↳

CONNECTION CALCS:

① (cont):

K-factors:

↳ FROM NDS TABLE 11.3.1A:

$$k_1 = \frac{\sqrt{Re + 2Re^2(1+Rt+Rt^2) + Rt^2 Re^3} - Re(1+Rt)}{(1+Re)}$$

$$k_2 = -1 + \sqrt{2(1+Re) + \frac{2F_{yb}(1+2Re)D^2}{3F_{em}l_m^2}}$$

$$k_3 = -1 + \sqrt{\frac{2(1+Re)}{Re} + \frac{2F_{yb}(2+Re)D^2}{3F_{em}l_s^2}}$$

↳ FOR SST HL33:

$k_1 =$

$k_2 =$

$k_3 =$

↓

GET Z VALUES ON EXCEL (

→ SEE NEXT PAGE FOR HL-33, HL-35, HL-37

↓

REPEAT Process for other connect types.

↳ POSSIBLE CHANGES TO THIS CALC

↳ D (diameter)

↳ Use smaller bolts?

↳ θ (grain angle) → be conservative

↳ Need to consider Reduction FACTORS (table 10.3.1 in 2005 NDS)

NOTE:

FOUND THAT DOWEL BEARING FAILURE (NONUNIFORM) WOULD GOVERN

↓

SEE EXCEL

CONNECTION CALCS

↳ WALL-TO-WALL → ADJUSTMENT FACTORS → NDS 2015 TABLE 11.3.1

↳ LOAD DURATION FACTOR (C_D):

· WIND LOAD → $C_D = 1.6$ → APPLY TO Z → TABLE 2.3.2

↳ WET SERVICE FACTOR (C_M):

· $C_M = 1.0$ → 2+ FASTENERS IN ROW PARALLEL TO GRAIN → TABLE 11.3.3, NOTE 2

↳ USE $C_M = 0.7$ to be conservative → wet in service

☆ ↳ NO GROUP ACTION FACTOR B/C ROW IS NOT PARALLEL TO WIND LOADING ☆

↳ GEOMETRY FACTOR:

↳ SEE NEXT PAGE

↳ TEMP FACTOR (C_T)

↳ $C_T = 1.0$ → no extremes expected

① CONNECTION 1:

↳ SPACING REQUIREMENTS: (from center of holes)

↳ SPACING BETWEEN BOLTS:

↳ FOR $C_\Delta = 1.0$

↳ $S = 4D = 4(0.5") = 2"$ (← mess possible)

↳ USING HL35

↳ $S = D_3 - D_{max} = 2.5" - 0.5" = 2"$

→ WORKS ✓

↳ EDGE DISTANCE:

see note?

↳ MINIMUM EDGE DISTANCE IF DIRECTION OF LOADING IS...

- PARALLEL TO GRAIN → 1.5D
- PERP. TO GRAIN → 4.D

If D = 0.375" = 1.5"

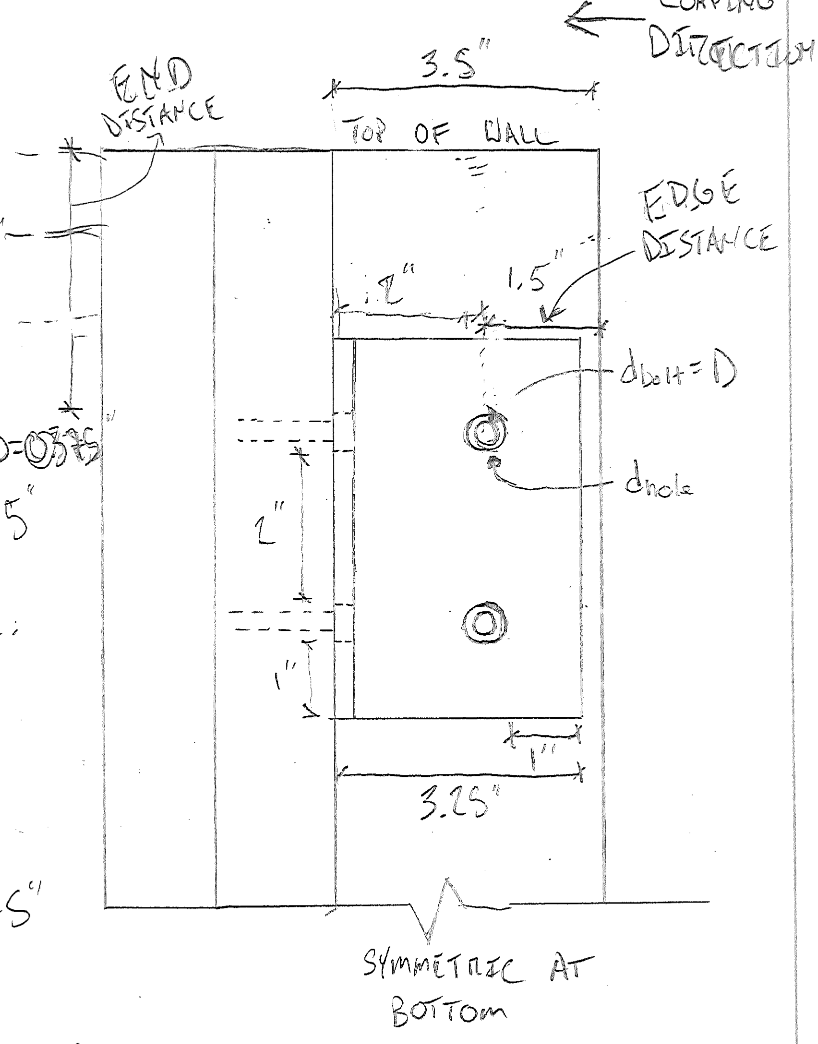
Check this, book figure 13.11 vs. 13.12

↳ MIN END DISTANCE:

↳ 2D

↳ If D = 0.5" = 1"

↳ If D = 0.375" = 0.75"



~~DEFLECTION ADJUSTMENT FACTOR (C_Δ)~~

Single Shear Calcs					
		Calc 1 (HL 33)	Calc 2 (HL 35)	Calc 2 (HL 37)	
		L bracket, one hole each side	L bracket, two holes each side	L bracket, 3 holes each side	
	ts (in)	0.1875	0.1875	0.1875	
	tm (in)	1.5	1.5	1.5	
	D (in)	0.375	0.75	1.125	
	Fes (psi)	36000	36000	36000	
	Fe(parallel, 0)	5600	5600	5600	
	Fe(perpindic, 90)	3650	3650	3650	
(from direction	Grain Angle (deg.)	90	90	90	
of force)	Fem (psi)	7436.6	7436.6	7436.6	
	K(angle)	1.25	1.25	1.25	
	Rt	8	8	8	
	Re	0.207	0.207	0.207	
	Fyb (psi)	45000	45000	45000	
	k1	0.652	0.652	0.652	
	k2	0.772	1.306	1.991	
	k3	8.178	16.374	24.780	
Yield Modes					
I_m	Rd	5.0	5.0	5.0	
	Z (lb)	410.6	821.3	1231.9	
I_s	Rd	5.0	5.0	5.0	
	Z (lb)	506.3	1012.5	1518.8	
II	Rd	4.5	4.5	4.5	
	Z (lb)	366.8	733.6	1100.4	
III_m	Rd	4.0	4.0	4.0	
	Z (lb)	280.3	948.6	2169.6	
III_s	Rd	4.0	4.0	4.0	
	Z (lb)	1269.9	5085.7	11544.6	
IV	Rd	4.0	4.0	4.0	
	Z (lb)	334.9	1339.7	3014.2	
Adjust. Factors					
	Cd	1.6	1.6	1.6	
	Cm	0.7	0.7	0.7	
	CΔ	0.5	0.5	0.5	
	Z DESIGN	157.0	410.8	616.2	lb

WALL-TO-WALL CONNECTIONS

↳ WHERE TO PLACE CONNECTIONS, AND HOW MANY? :

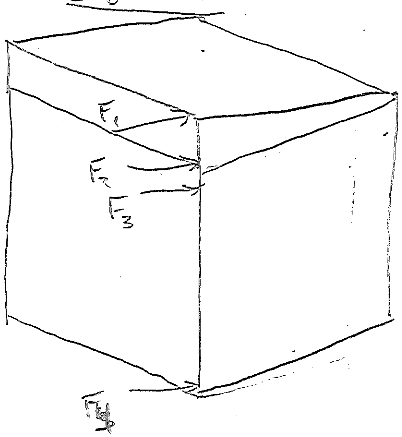
RECAP:

· CAPACITY OF BRACKETS:

↳ HL-35 → Z = 4101b

↳ HL-37 → Z = 6161b

· **DEMAND:**



$F_1 = F_2 \approx 1200$ lb → USE (1) HL-35 EACH (F.S. = 3.4)

$F_3 = F_4 \approx 3801$b → USE (1) HL-378 (1) HL-35 EACH

↳ TOTAL CAP = 10321b

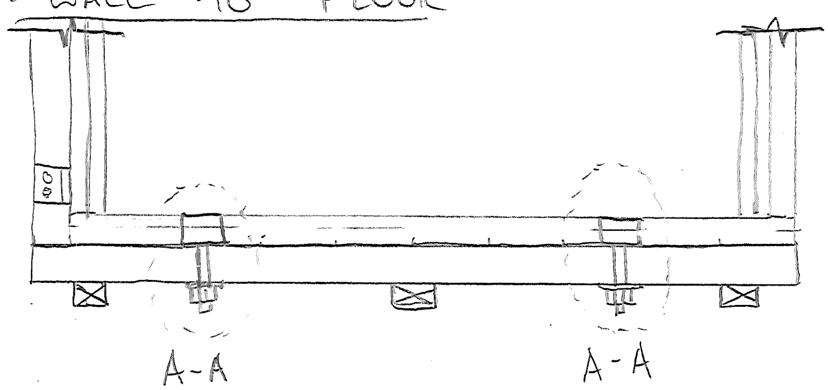
(F.S. = 2.71)

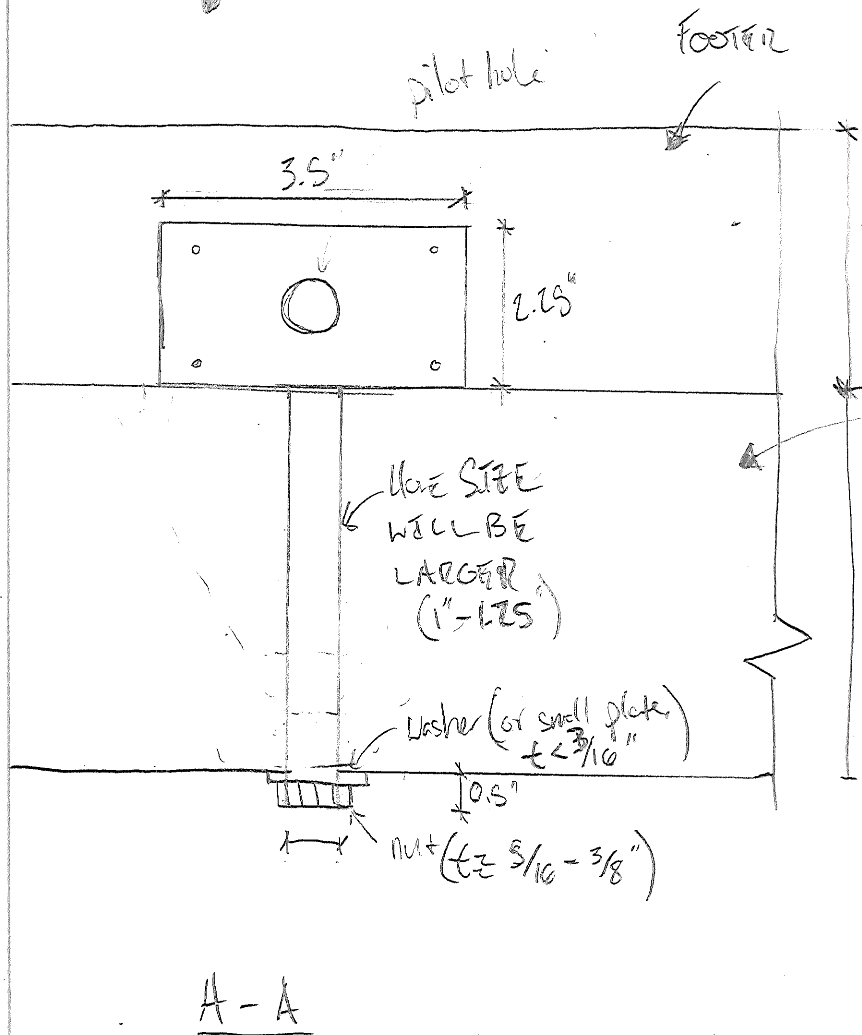
↓

COULD ALSO USE 2 HL-35 INSTEAD (F.S. = 2.15)

CONNECTION DESIGN (CONT.)

↳ WALL TO FLOOR:





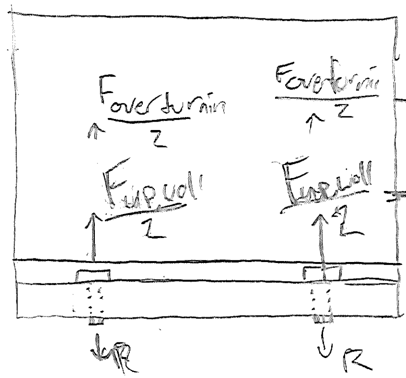
? can you put bolts through pilot hole?

· DESIGN FOR:

- SHEAR PERP. TO GRAIN
- crushing (area of washer)

UPLIFT CALCULATIONS (cont)

↳ WALL-TO-FLOOR CONNECTION



→ divided by 2 because only two (2) connections transfer overturning force

→ divided by 2 because there are two (2) wall-floor connections per load bearing wall

WHERE

- $F_{overturning}$ IS FOUND ON APPENDIX PAGE ___ TO BE = 200 lb FOR 1 wall
- $F_{up,wall}$ IS FOUND ON APPENDIX PAGE ___ TO BE (121 plf)(10') = 1210 lb for 1 WALL → ROOF UPLIFT CALC (1,2,1)

$$R = \frac{F_{overturning}}{2} + \frac{F_{wall}}{2} = \frac{200}{2} + \frac{1210\,lb}{2} = 705\,lb = R$$

DESIGN → based on Doug Fir with $G_s = 0.5$ & $D_{washer} = 2"$

- PULL OUT STRENGTH:

↳ ACCORDING TO NDS COMMENTARY (2005) → NDS 2005 § C11.2.4:

$W = 1200\,G^2(D)$ → lb/in of penetration

Use D of WASHER (in.)

↳ $W = 1200(1/2)^2(2\,in)(5"\text{ penetration})$

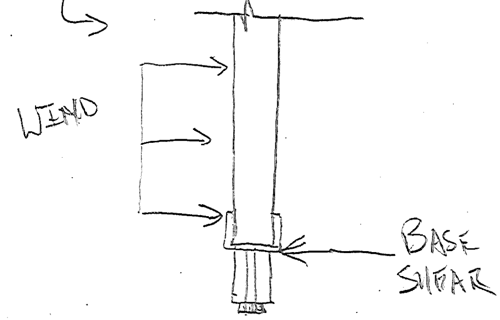
$= 3000\,lb$ → WORKS ☆ → 1/2 Ø 4"x6" WITH 2" DIAMETER WASHER

↳ USE TWO CONNECTIONS PER WALL (DISTRIBUTE)

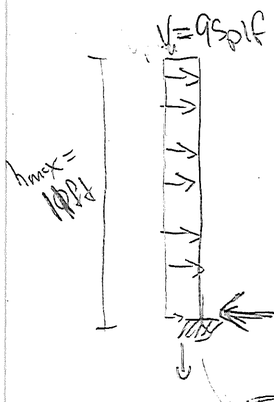
↳ F.S. ≥ 2.0

WALL-TO-FLOOR

↳ SHEAR → MAX LOADING CONDITION



→ 19 psf WIND CREATES $V_{wind} = 95$ plf FOR HALF WALL (per connection)



$V_{base} = (95 \text{ plf})(11') = 1045$ lb.

1 3/4" BOLT NEEDS TO BE ABLE TO RESIST 1045 lb of shear force → $\frac{r_n}{\Omega}_{minimum} = 5.97^K = 5970^{\#}$

AISC TABLE 7-1
($\Omega = 2.0$) → F.S.

ASSUMES CONVENTIONAL A307 BOLT

$\frac{r_n}{\Omega} = 5970^{\#} \geq 1045$ ✓ → F.S. DEFINITELY WORKS

WALL-TO-HEIGHT EXTENSION

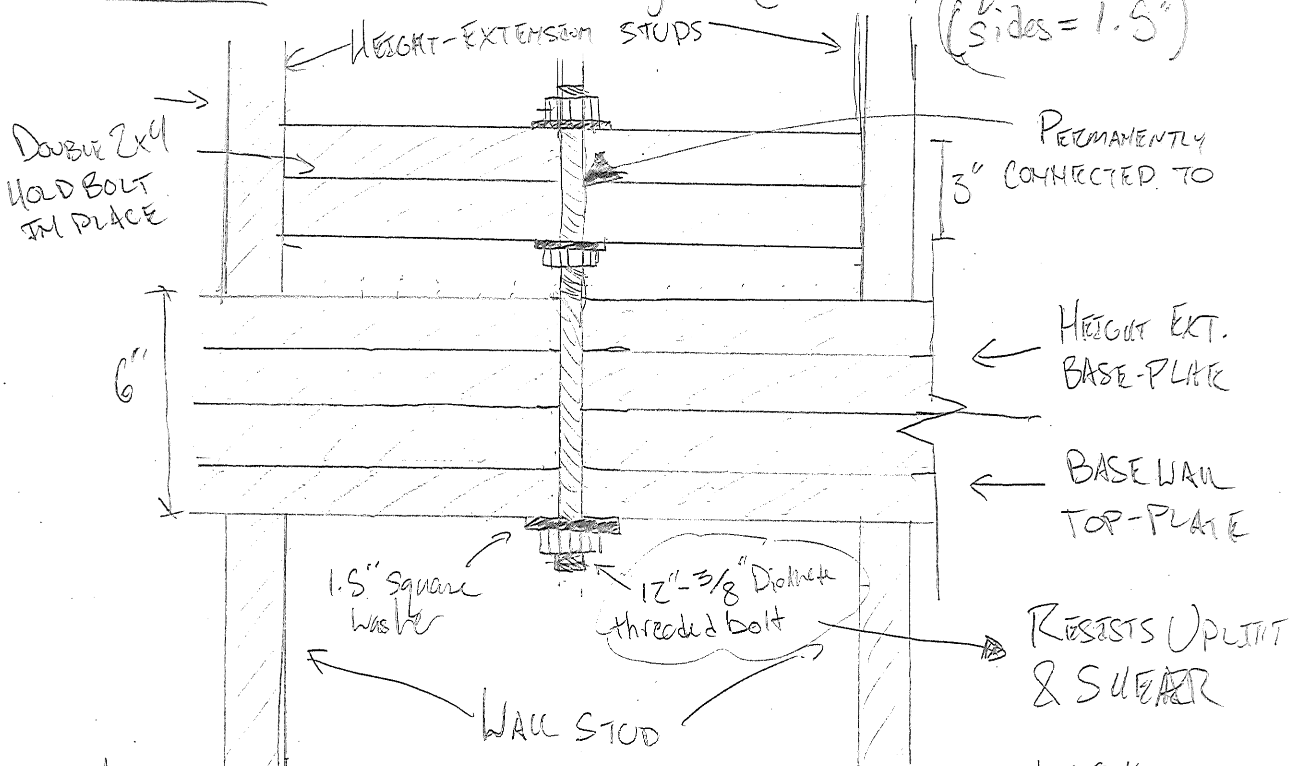
↳ UPLIFT & OVERTURNING MOMENT:

↳ SAME FORCES AS WALL-TO-FLOOR CONNECTION

↳ EACH WALL → $R = F_{overturn} + F_{uplift}$

$R = 200\,lb + 1210\,lb = 1410\,lb$ per wall

↳ DESIGN: → based on Doug Fir ($G_s = 0.5$), Square washer (sides = 1.5")



↳ CAPACITY FOR UPLIFT: → NDS (2005 → different, but O.K.) Commentary § C11.2.4

$\cdot W = 1200\, G_s^2 (D) \frac{lb}{in.\ of\ penetration}$

$W = 1200 (0.5)^2 (1.5") (9"\ \text{embeddment in wood}) = 4050\,lb$ per connection

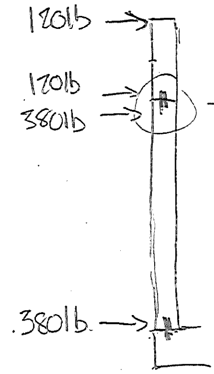
↳ USE TWO PER HEIGHT EXTENSION → F.S. ≥ 2.0

WALL-TO-HEIGHT EXTENSION:

↳ SHEAR:

↳ SIMILAR TO WALL-TO-FLOOR

↳ Forces per bolted connection (2 per wall)



→ NEED TO ACCOUNT FOR DIFFERENCES IN FORCES

A307 Grade A (similar to A36)
$F_y \approx 36$ KSi

CAPACITY: → 3/8"

$R_n = (F_y)(A_{bolt})$

$F_y = 36$ KSI

$A_{bolt} = \pi r^2 = \pi \left(\frac{3/8}{2}\right)^2 = 0.11 \text{ in}^2$

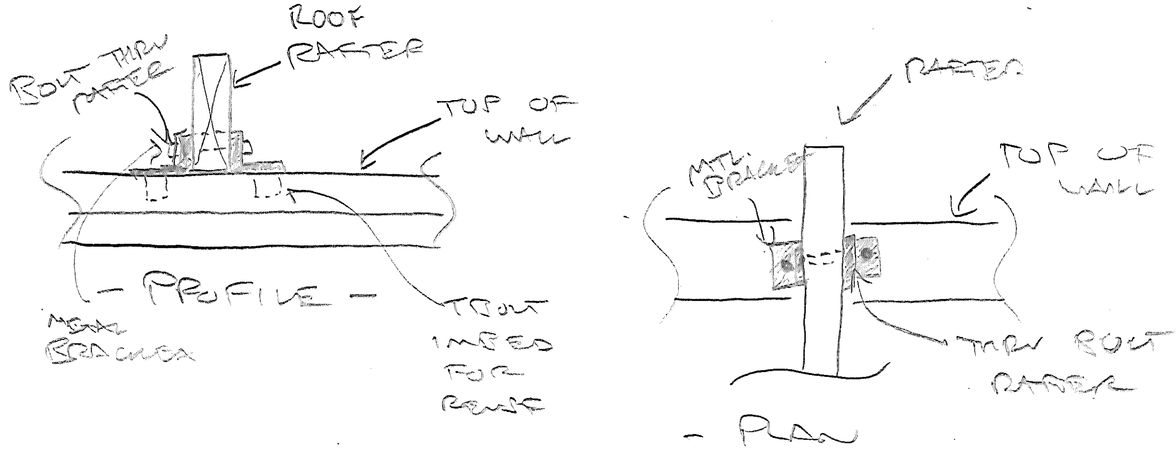
$R_n = (0.11 \text{in}^2)(36\text{ksi}) = 3.96 \text{ Kip} \approx 3960^{\#}$

$\frac{R_n}{\Omega = 2.0} = \frac{3960^{\#}}{2.0} = 1980^{\#}$ → ACCOUNTING FOR FACTOR OF SAFETY

MORE THAN ENOUGH TO ACCOUNT FOR DIFFERENCE IN FORCES

(3) WALL-TO-ROOF DETAIL

A) MID-WALL CONNECTION



B) ~~END OF WALL CONNECTION~~

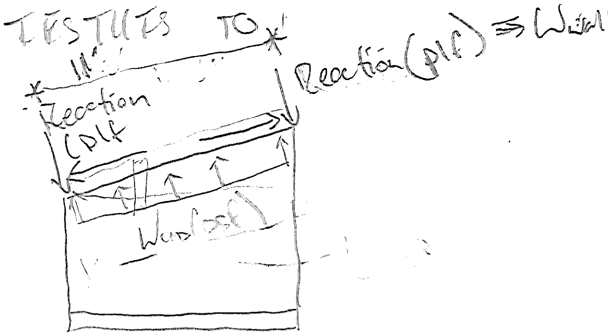
CONNECTION 4 → : ROOF-TO-to-HEIGHT-EXT. :

↳ ~~STRAPS WILL GO ALONG WIDTH~~

~~↳ SST MST 27~~

↳ BASED ON WIND LOAD PATH FOR UPLIFT, MAX UPLIFT DESIGN PRESSURE IS: $W_{up} = 22\,psf$

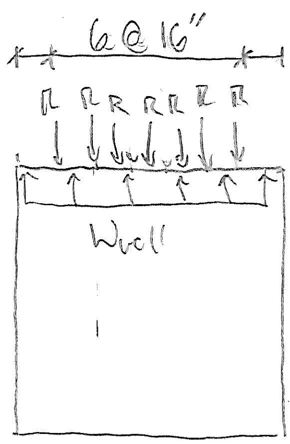
THE FRAMING CARRIES THIS TO RECTANGULAR WALLS:



$= W_{up}\left(\frac{L_{roof}}{2}\right) = 22\,psf\left(\frac{11'}{2}\right)$

★ $W_{upwall} = 121\,plf$

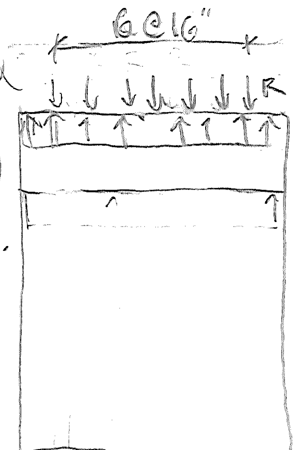
SO AT TOP OF RECTANGULAR WALL, LOAD IS TRANSFERRED VIA A24 ANGLE CLIPS TO TOPS OF WALLS. (7 total)



$R = W_{wall}(\text{tributary})$

$R = 121\,plf\left(\frac{4}{3}'\right)$

$R = 161.3\,lb.$



DO A PAIR OF A24 CLIPS HAVE UPLIFT CAPACITY OF 161.3 lb ? → CHECK CAPACITY ON NEXT PAGE

↳ CAN ONE USE LESS ?

ROOF-TO-WALL OR HEIGHT EXTENSION (cont.):

↳ UPLIFT CAPACITY OF A...

ONE PAIR OF A24 CLIPS:

↳ USE NDS 2005, COMMENTARY § C11.2.4

↳ $W = 1200\, G_s^2 (D) \frac{lb}{\text{in of penetration}}$

↳ $G_s = 0.5$ → Doug Fir-Larch

↳ $D = 1$ in → OF EMBEDDED T-NUT

↳ 1.5" of penetration from top of wall to t-nut

↳ $W = [1200(0.5^2)(1'')(1.5)] \times 2$ ↳ 2 t-nuts each connection

[W = 900 lb] → per pair of A24 clips

↳ IF ONE USES 3 PAIRS OF CONNECTIONS PER WALL EDGE

↳ 900 * 3 = 2700 lb CAPACITY PER WALL

DEMAND TOTAL PER WALL:

'W_u = 121 plf across ~ 10.5''

F_{dem} = 121 plf(10.5') = 1270 lb] → CAPACITY OF 3 CONNECTIONS

☆ MORE THAN TWICE THIS ☆

USE OF 3 PAIRS OF A24 CLIPS FOR ROOF HAS F.S. > 2.0

Appendix G
Construction Documents

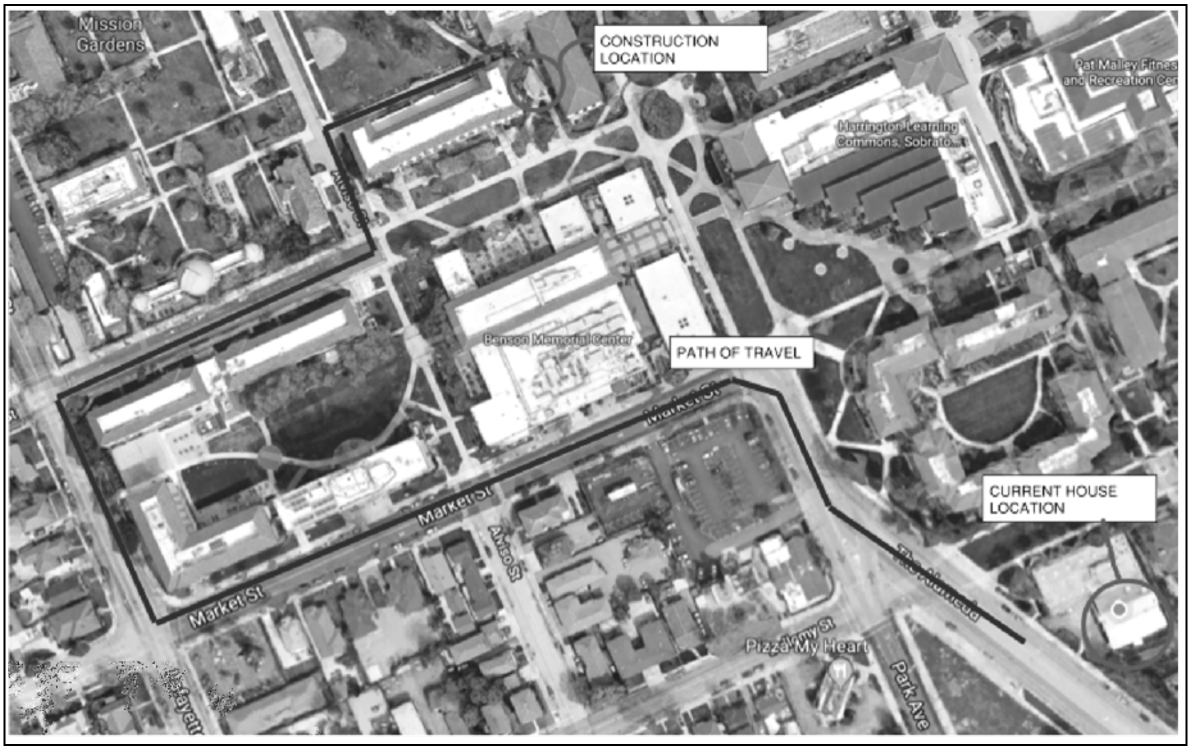


Figure G.1 - *Cabin transport plan (to conference site).*

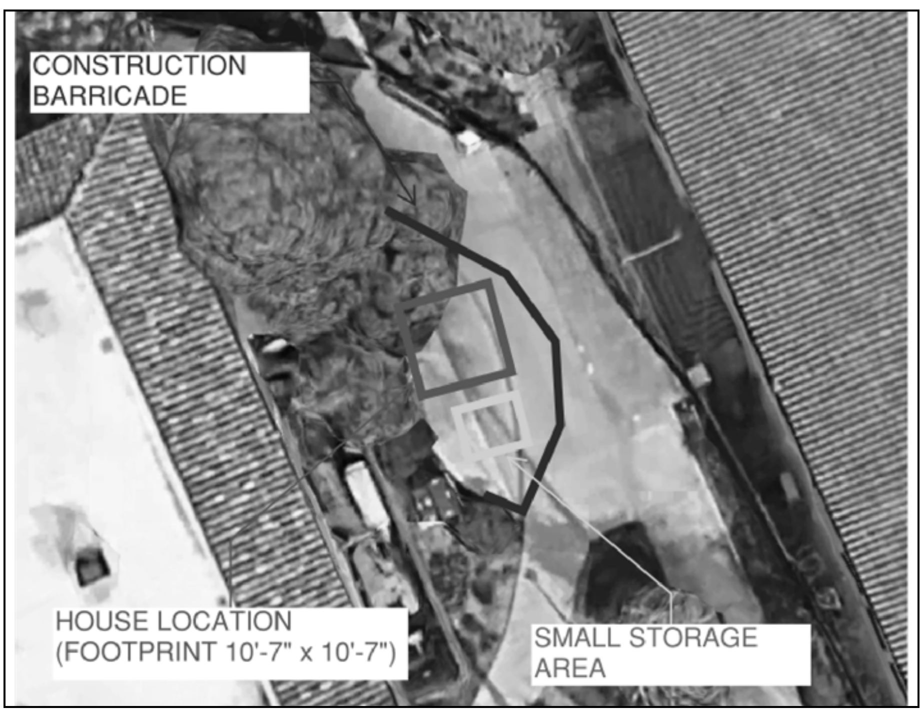
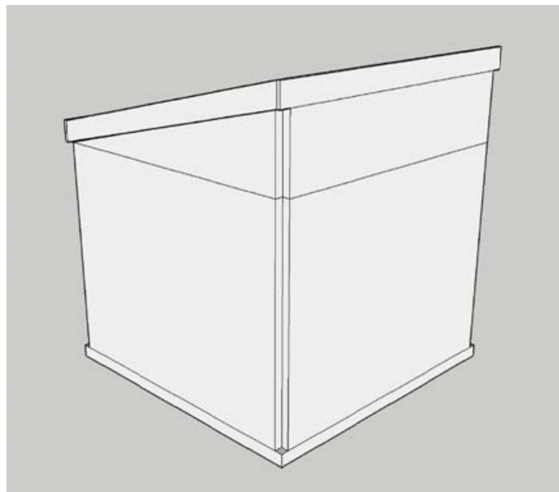


Figure G.2 - *Conference site plan.*

Table G.1 *- Prototype cabin cost estimate. Some values originate from actual costs during construction and others are estimates.*

Section	Item	Qty.	Unit	Unit Cost	UOM	Subtotal Cost	Lumber Tax (1.00%)	Tax (9%)	Total Cost
Lumber	2x4 DF stud x 10'	16	EA	$ 0.87	LF	$ 139.20	$ 1.39	$ 12.53	**$ 153.12**
	4x4 DF 10'	12	EA	$ 1.30	LF	$ 156.00	$ 1.56	$ 14.04	**$ 171.60**
	2x4 DF 8' stud	70	EA	$ 0.87	LF	$ 487.20	$ 4.87	$ 43.85	**$ 535.92**
	2x6 DF 12'	12	EA	$ 1.30	LF	$ 187.20	$ 1.87	$ 16.85	**$ 205.92**
	4x6 DF 12'	6	EA	$ 2.86	LF	$ 205.92	$ 2.06	$ 18.53	**$ 226.51**
	2x10 DF 12'	15	EA	$ 2.29	LF	$ 412.20	$ 4.12	$ 37.10	**$ 453.42**
	2x4 DF 12'	4	EA	$ 0.87	LF	$ 41.76	$ 0.42	$ 3.76	**$ 45.94**
	1/2" CDX Plywood	12	EA	$ 20.96	EA	$ 251.52	$ 2.52	$ 22.64	**$ 276.67**
	3/8" ACX Plywood	7	EA	$ 41.20	EA	$ 288.40	$ 2.88	$ 25.96	**$ 317.24**
	5/16" CDX Plywood	6	EA	$ 21.80	EA	$ 130.80	$ 1.31	$ 11.77	**$ 143.88**
	5/8" DF Plywood	14	EA	$ 60.21	EA	$ 842.94	$ 8.43	$ 75.86	**$ 927.23**
	Beadboard Plywood	10	EA	$ 46.09	EA	$ 460.90	$ 4.61	$ 41.48	**$ 506.99**
Connections	HL35-R	28	EA	$ 12.98	EA	$ 363.44	-	$ 32.71	**$ 396.15**
	HL37-R	12	EA	$ 15.27	EA	$ 183.24	-	$ 16.49	**$ 199.73**
	EPB44PHDG	24	EA	$ 10.98	EA	$ 263.52	-	$ 23.72	**$ 287.24**
	A24	40	EA	$ 3.47	EA	$ 138.80	-	$ 12.49	**$ 151.29**
Paint	KILZ 2 Primer	3	EA	$ 17.73	GAL	$ 53.19	-	$ 4.79	**$ 57.98**
	Interior Paint/Primer	1	EA	$ 35.00	GAL	$ 35.00	-	$ 3.15	**$ 38.15**
	Red Exterior Paint	2	EA	$ 24.48	GAL	$ 48.96	-	$ 4.41	**$ 53.37**
	White Exterior Paint	1	EA	$ 24.48	GAL	$ 24.48	-	$ 2.20	**$ 26.68**
Openings	Exterior Door	1	EA	$ 106.00	EA	$ 106.00	-	$ 9.54	**$ 115.54**
	3'x 3' Window	2	EA	$ 88.96	EA	$ 177.92	-	$ 16.01	**$ 193.93**
Insulation	R13 15" x 93" Batt	4	EA	$ 60.13	LF	$ 240.52	-	$ 21.65	**$ 262.17**
	R19 15" x 39.2' Roll	3	EA	$ 33.19	LF	$ 99.57	-	$ 8.96	**$ 108.53**
	R30 15" x 25' Roll	3	EA	$ 30.30	LF	$ 90.90	-	$ 8.18	**$ 99.08**
Exteriors/ Waterproofing	House Wrap, 3' x 165'	2	EA	$ 45.00	ROLL	$ 90.00	-	$ 8.10	**$ 98.10**
	Tyvek House Wrap Tape	2	EA	$ 12.95	ROLL	$ 25.90	-	$ 2.33	**$ 28.23**
	Roofing Paper, 3' x 72'	1	EA	$ 25.75	ROLL	$ 25.75	-	$ 2.32	**$ 28.07**
	Roof Shingles, 32.5 sq ft bundle	4	EA	$ 30.00	BUNDLE	$ 120.00	-	$ 10.80	**$ 130.80**
	Misc. Flashing	1	N/A	$ 75.00	N/A	$ 75.00	-	$ 6.75	**$ 81.75**
Electrical	Estimate: Wiring	1	N/A	$ 350.00	N/A	$ 350.00	-	$ 31.50	**$ 381.50**
	Estimate: Fixtures	1	N/A	$ 100.00	N/A	$ 100.00	-	$ 9.00	**$ 109.00**
	Estimate: Misc.	1	N/A	$ 150.00	N/A	$ 150.00	-	$ 13.50	**$ 163.50**
Fasteners	Nails, Assorted	1	N/A	$ 250.00	N/A	$ 250.00	-	$ 22.50	**$ 272.50**
	Screws, Assorted	1	N/A	$ 150.00	N/A	$ 150.00	-	$ 13.50	**$ 163.50**
	Nail Gun Nails, Assorted	1	N/A	$ 66.18	N/A	$ 66.18	-	$ 5.96	**$ 72.14**
								TOTAL	**$ 7,483.37**

SANTA CLARA UNIVERSITY MODULAR CABIN PROTOTYPE FOR THE BRIDGE HOUSING COMMUNITY



500 EL CAMINO REAL, SANTA CLARA, CA 95053

BUILD USING DOUGLAS FIR LARCH NO. 2 OR BETTER

SHEET INDEX

Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

COVER SHEET

SITE INFORMATION

SITE TYPE:
- SCHOOL CAMPUS (FIG. 1)
- OFFICE SPACE (IN ADJACENT CLASSROOM BUILDINGS)

LABOR ACCESS:
- ANY NORMAL FOOTPATH ACCESS POINT

TRUCK/FORKLIFT ACCESS:
- VIA SANTA CLARA STREET AND ADJACENT TO KENNA HALL (FIG. 2)

WORKING HOURS:
- WORK MUST BE DONE BEFORE

SAFETY CONCERNS:
- MAINTAIN A BARRIER SO STUDENTS DO NOT ENTER SITE
- FULL, PROPER P.P.E. MUST BE WORN BY ANYONE ON SITE
- ALL FORKLIFT LIFTS WILL BE PERFORMED BEFORE CLASS TIME WHEN STUDENTS PASS BY SITE
- WHOLE WALKWAY WILL BE CLOSED FOR FORKLIFT WORK

SITE CLEANING:
- SITE WILL BE KEPT CLEAN TO AVOID SAFETY CONCERNS
- DAILY CLEANINGS WILL BE PERFORMED
- VISQUEEN AND TARPS WILL BE PLACED DOWN TO AVOID DAMAGED OR STAINING OF CONCRETE WALKWAY

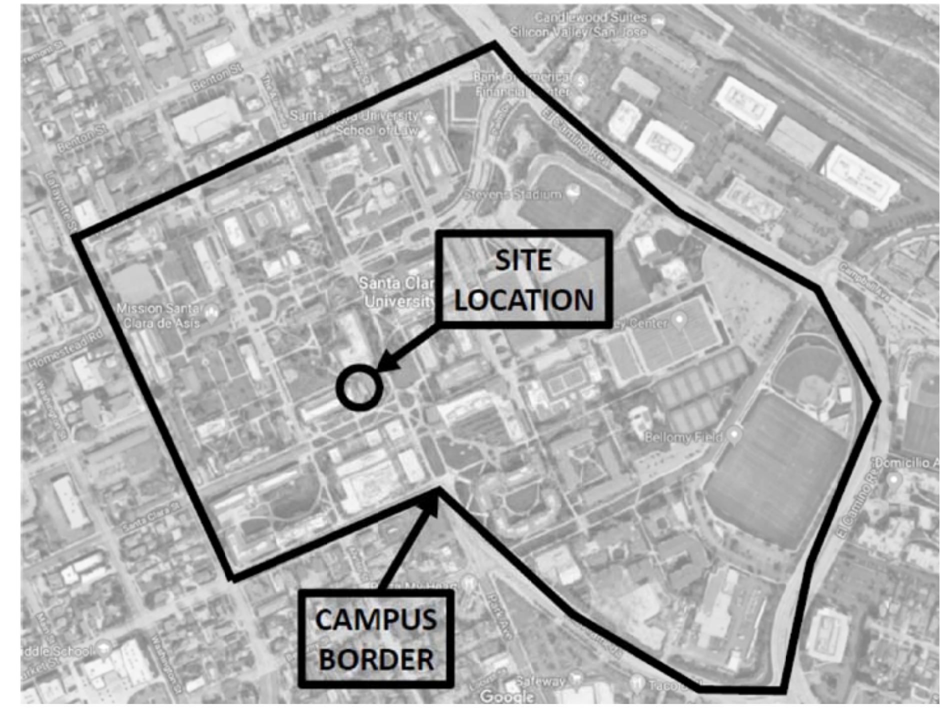


FIG. 1: SITE LOCATION ON CAMPUS OF SANTA CLARA UNIVERSITY.

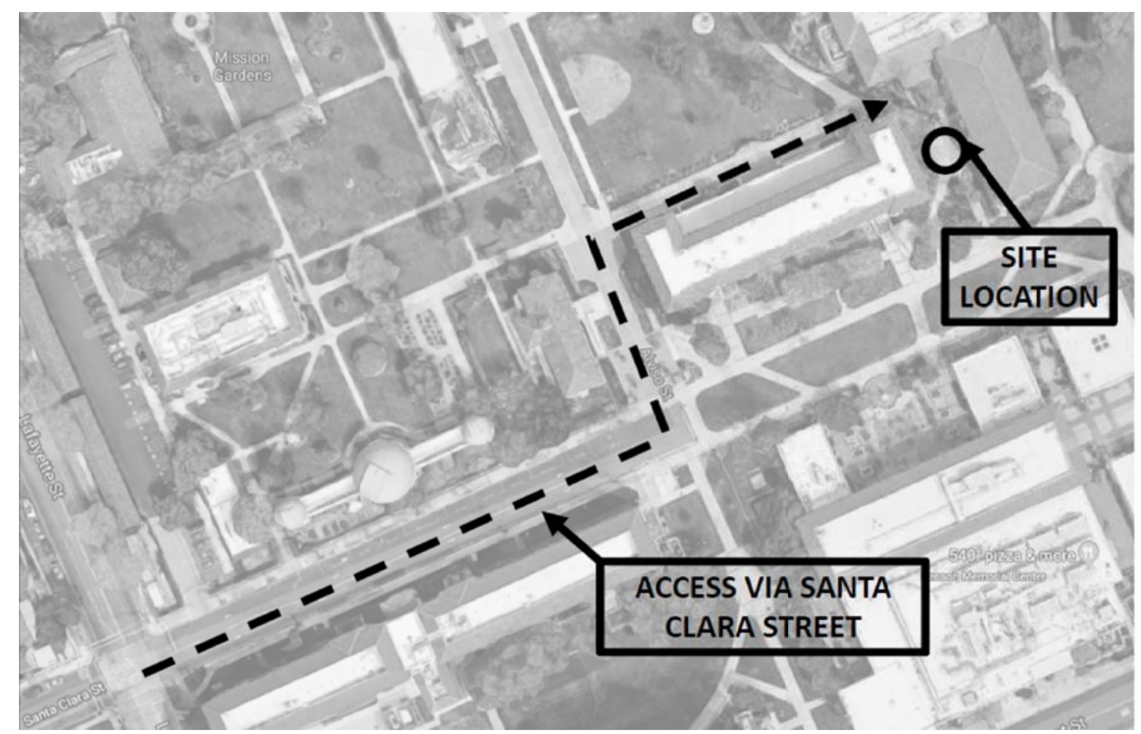


FIG. 2: TRUCK/FORKLIFT ACCESS ROUTE VIA SANTA CLARA STREET.

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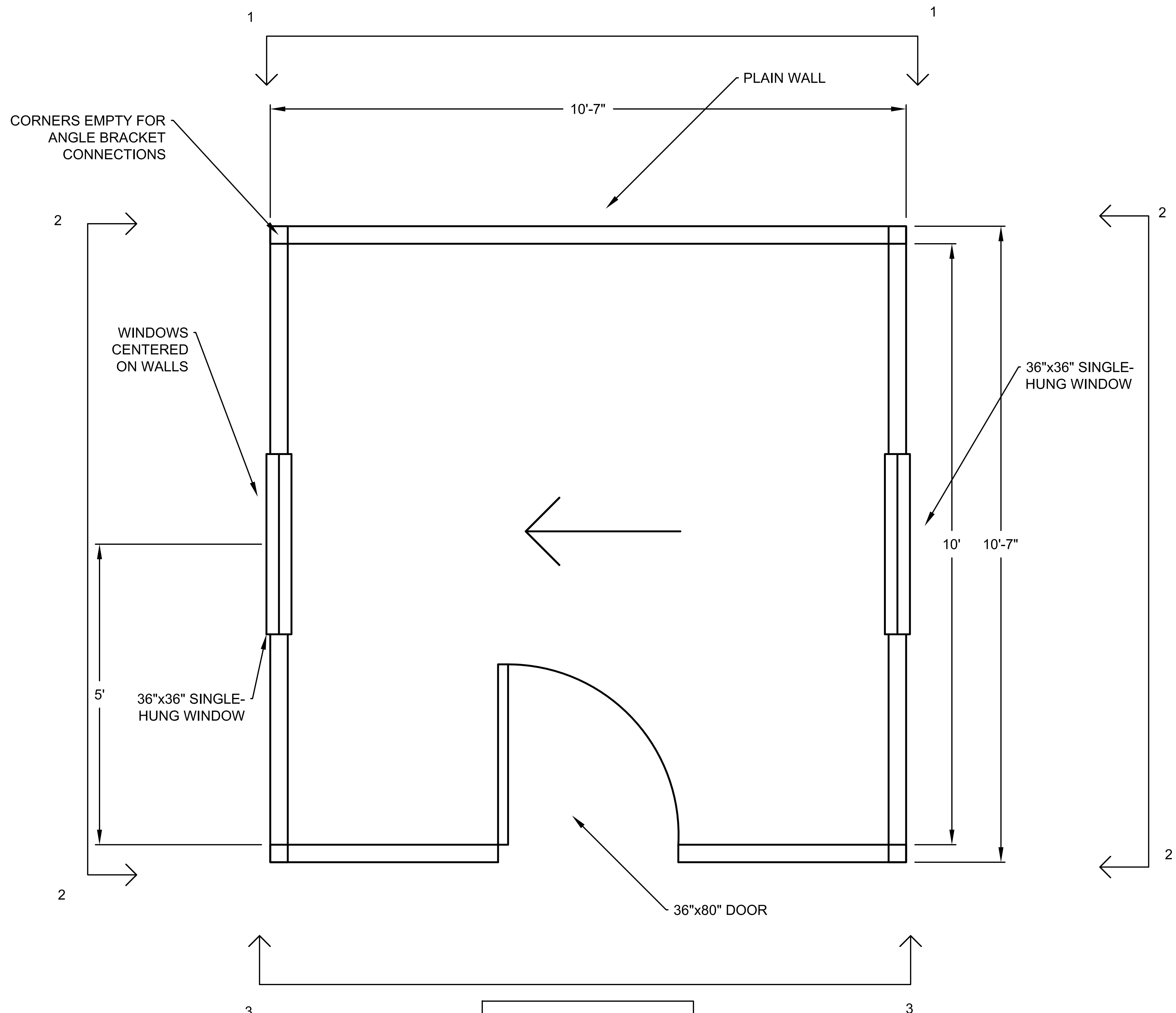
SITE INFORMATION

A001



PLAN - HOUSE WALL LAYOUT

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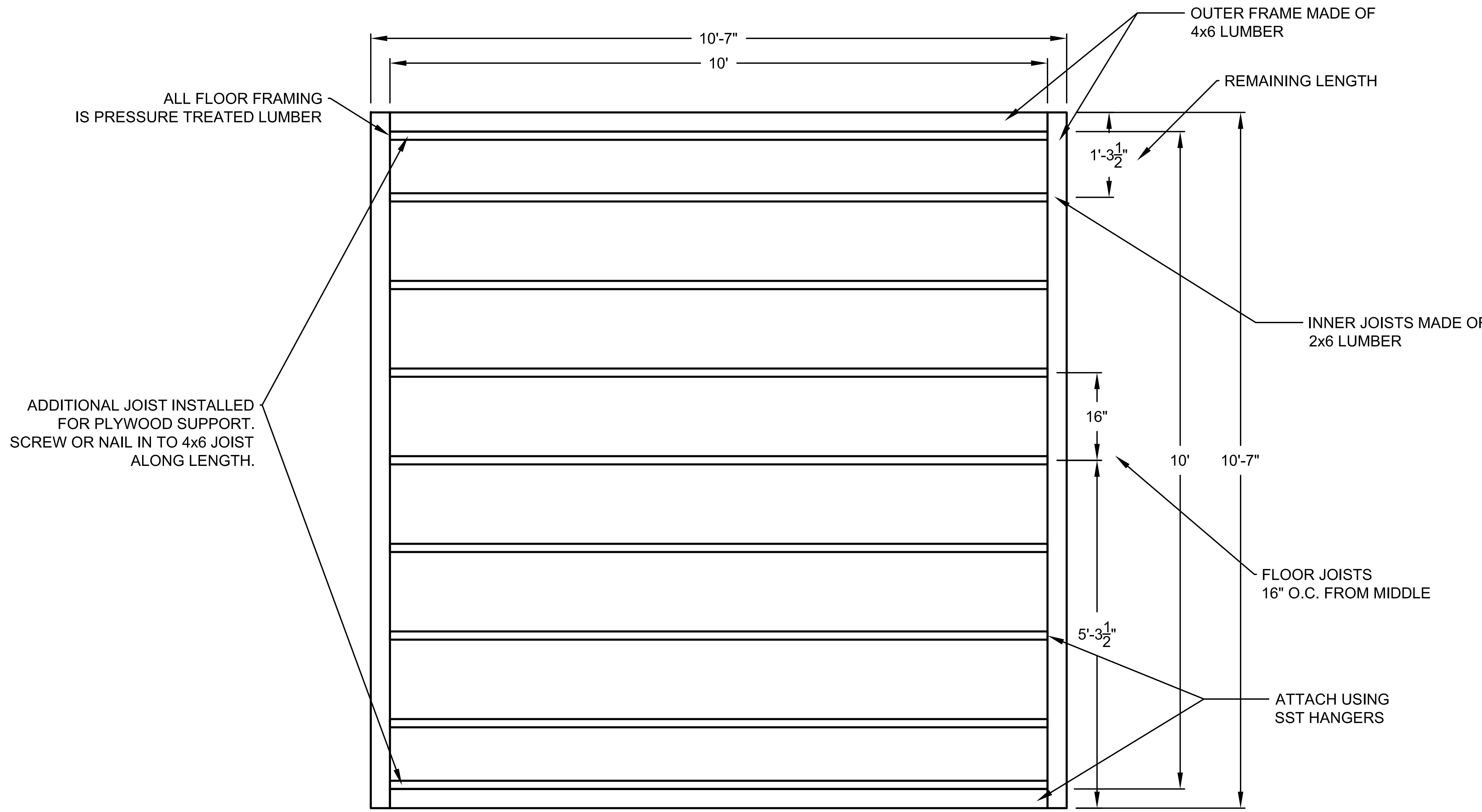
CABIN PLAN OVERVIEW

SCALE: 1/2" = 1'

A100



FLOOR
FRAMING PLAN

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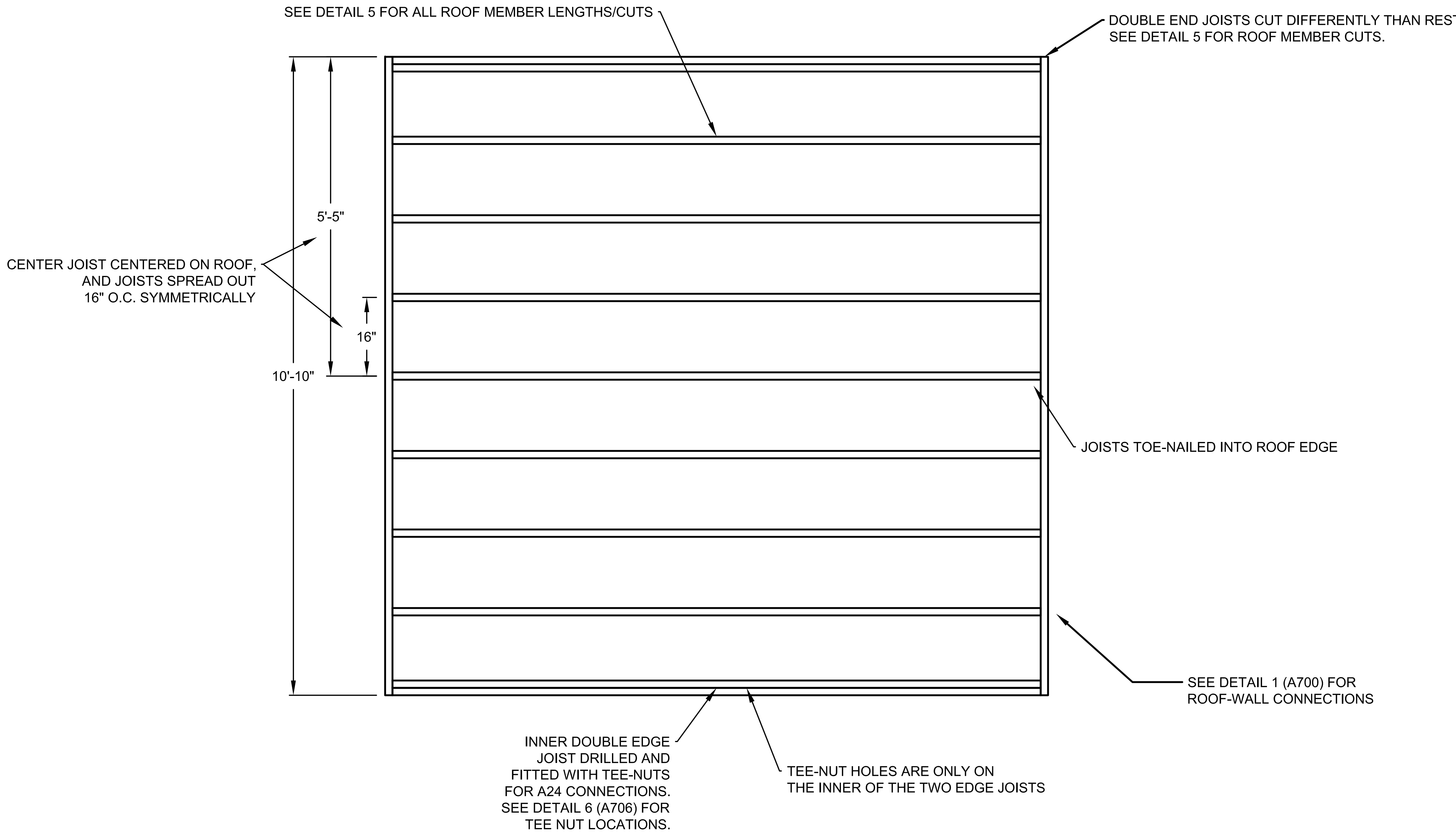
FLOOR FRAMING PLAN

SCALE: 1/2" = 1'

A101



ROOF FRAMING PLAN

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THE BHC MODULAR RE-DESIGN PROTOTYPE

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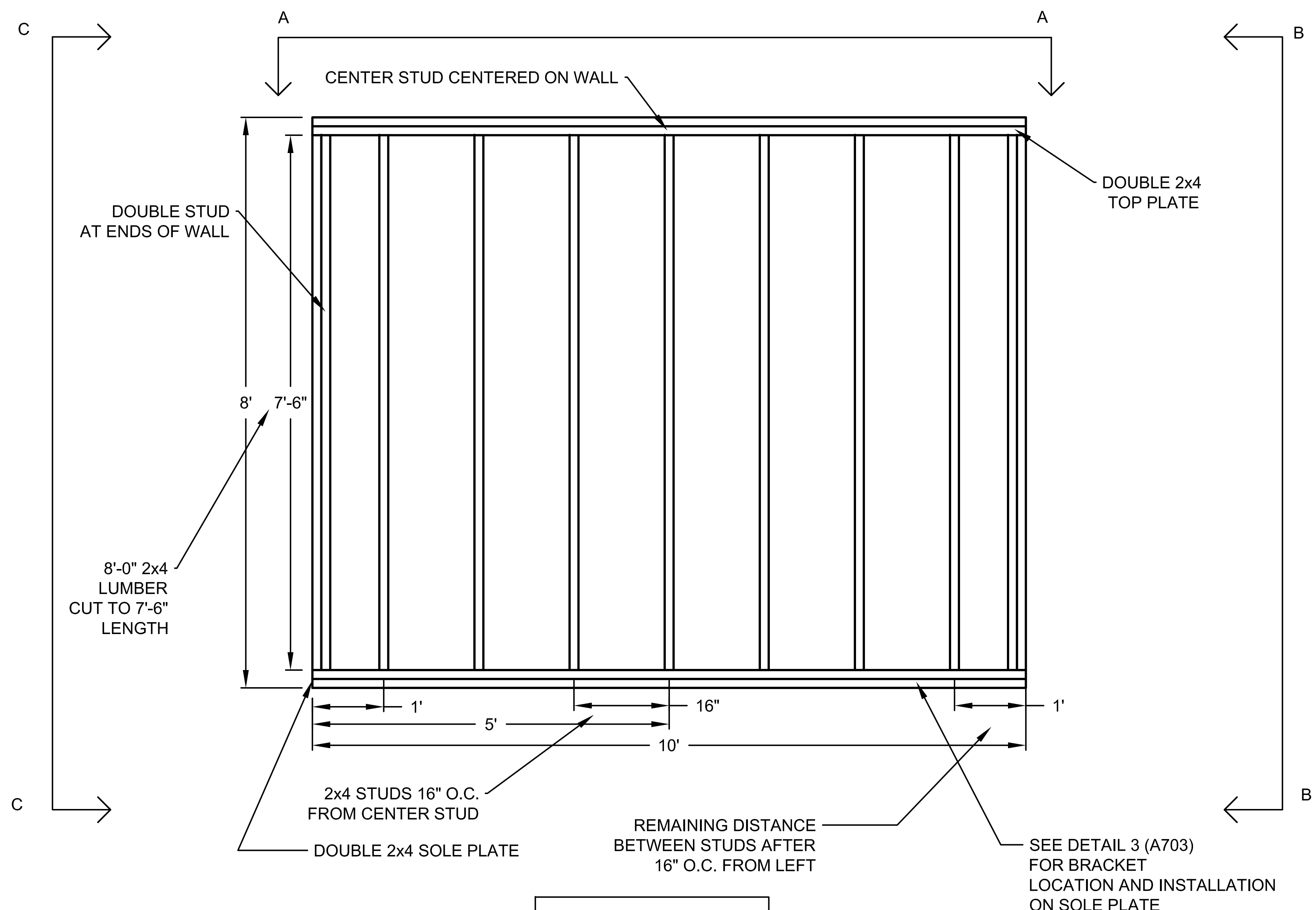
ROOF FRAMING PLAN

SCALE: 1/2" = 1'

A102



ELEVATION 1-1
[PLAIN WALL]

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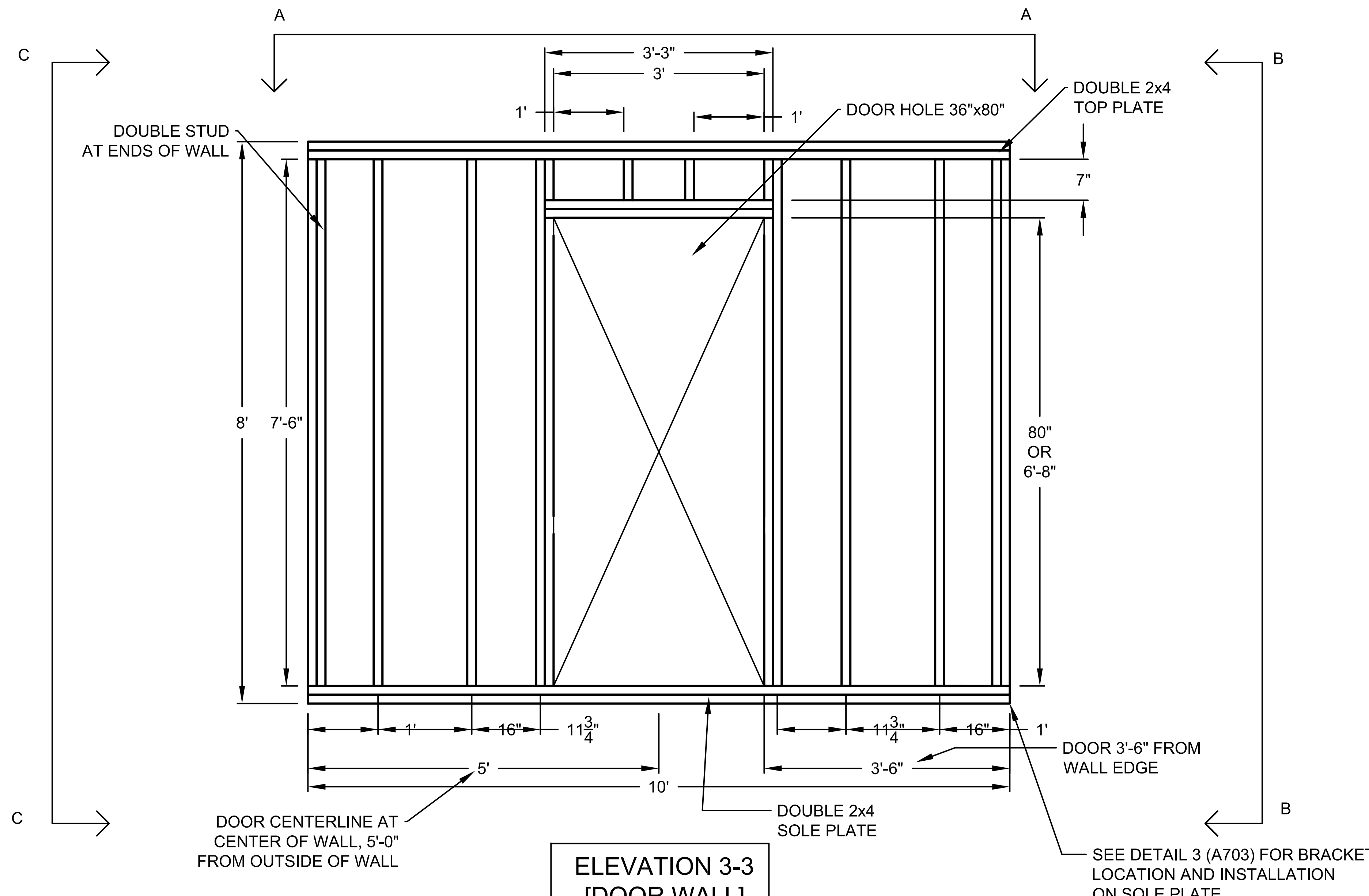
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

PLAIN WALL
FRAMING PLAN

SCALE: 1/2" = 1'

A200



ELEVATION 3-3
[DOOR WALL]

CONSTRUCTION NOTE: DOOR HOLE DIMENSIONS ARE APPROXIMATE. FOLLOW THE DIRECTIONS FOR THE ROUGH OPENING SIZE THAT COME WITH THE DESIRED DOOR. ENSURE THAT ADJUSTMENTS ARE MADE TO MAINTAIN THE SYMMETRICAL LAYOUT OF THE WALL DESIGN.

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CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

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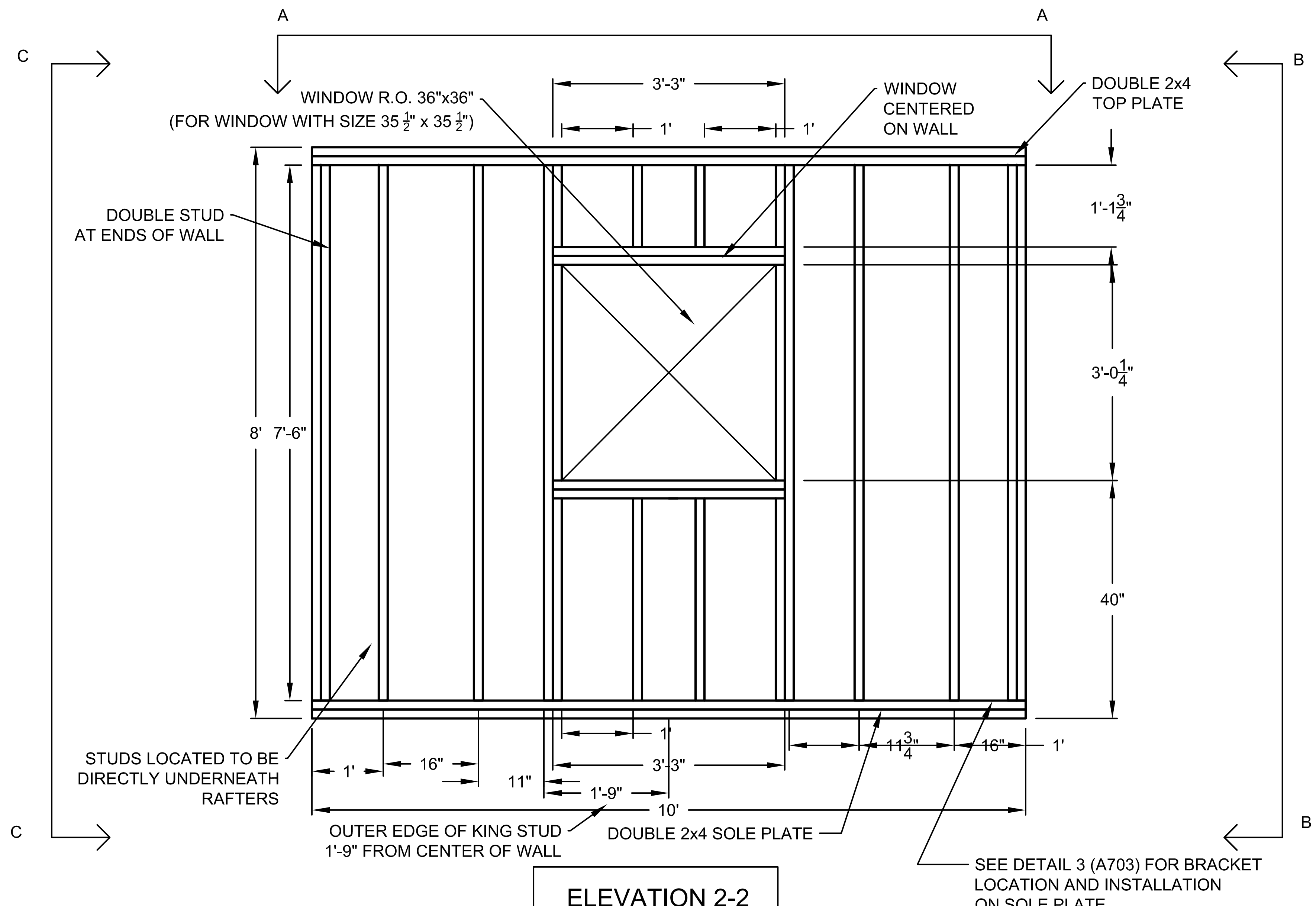
DOOR WALL FRAMING PLAN

SCALE: 1/2" = 1'



ELEVATION 2-2
[WINDOW WALL]

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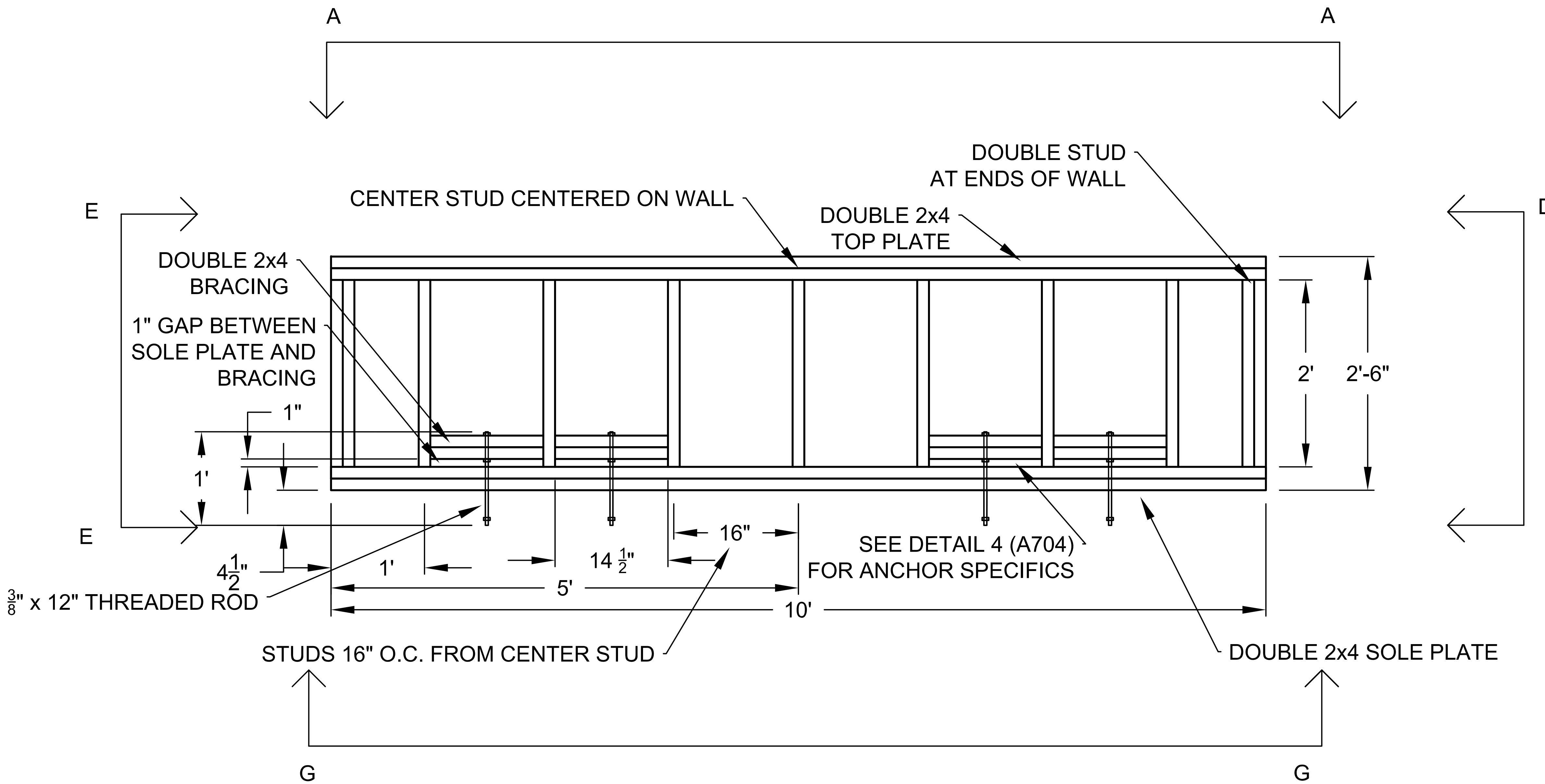
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

WINDOW WALL
FRAMING PLAN

SCALE: 1/2" = 1'



ELEVATION:
FULL WALL
EXTENSION

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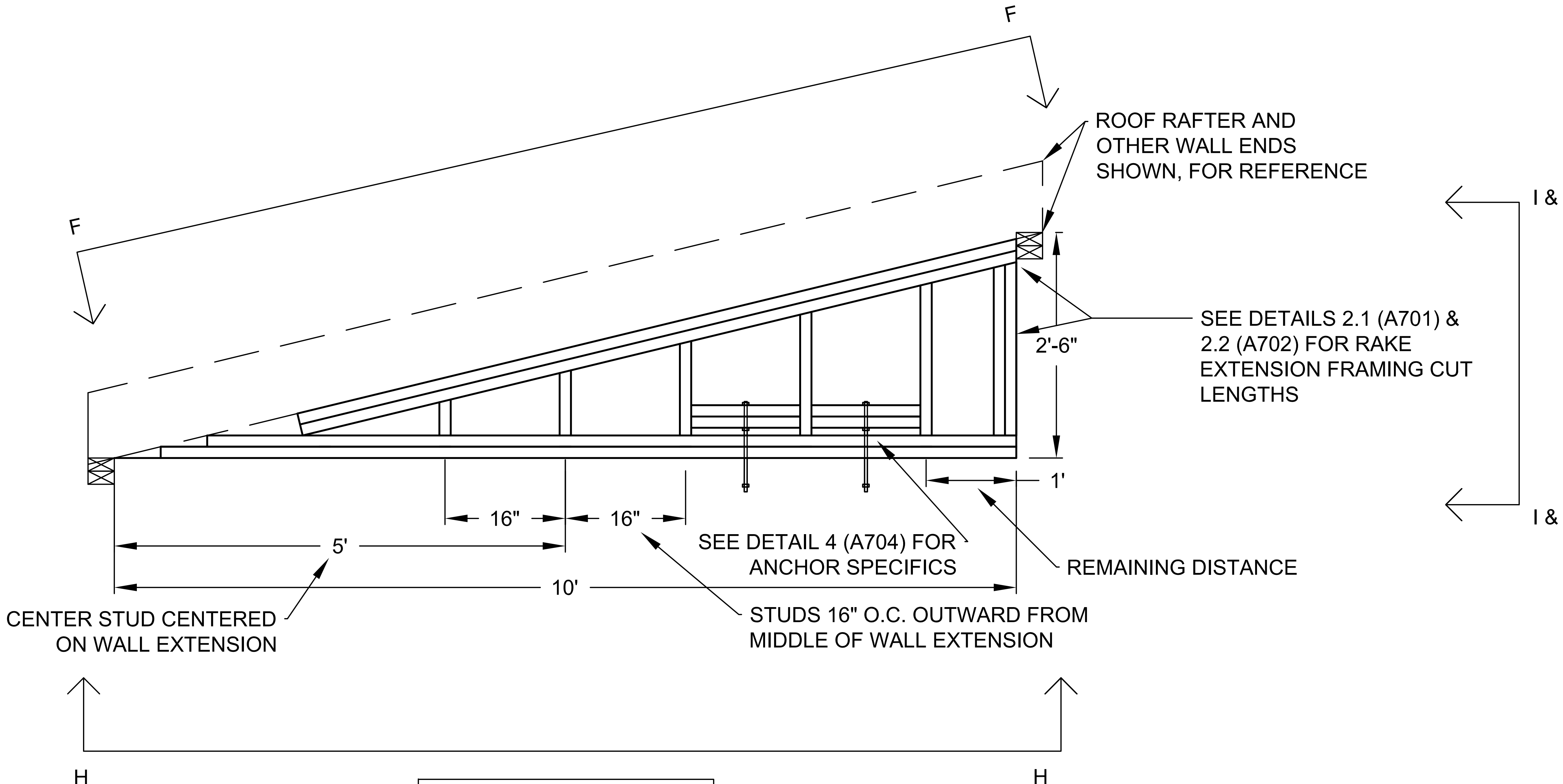
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

FULL EXTENSION
FRAMING PLAN

SCALE: 3/4" = 1'

A203



ELEVATION: RAKE WALL EXTENSION

CONSTRUCTION NOTE: FOR FULL HOME CONSTRUCTION, TWO RAKE EXTENSIONS MUST BE BUILT, MIRRORING EACH OTHER.THE FRAMING OF BOTH WILL BE THE SAME; HOWEVER, THE FINISH MATERIAL WILL BE ON OPPOSITE SIDES FOR THE TWO

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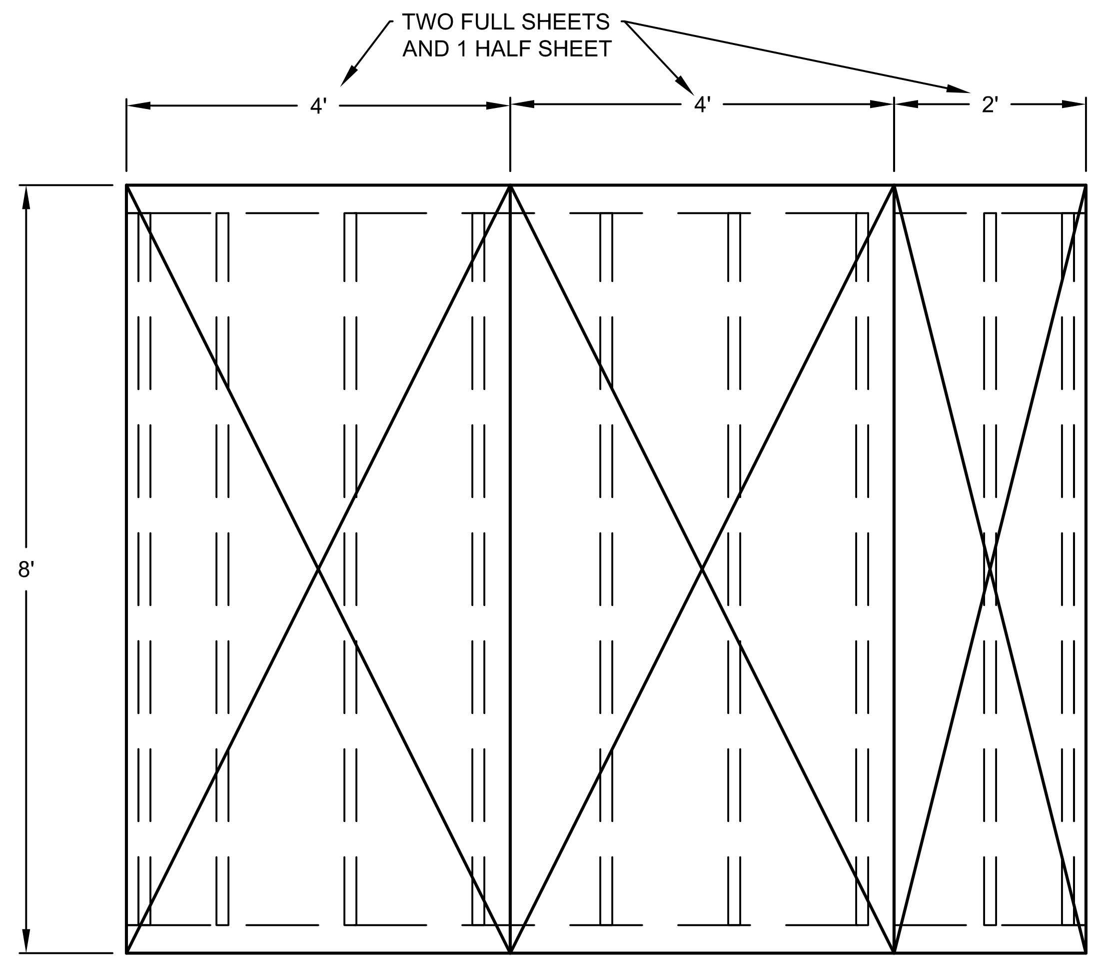
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

RAKE EXTENSION FRAMING PLAN

SCALE: 3/4" = 1'



EXTERIOR
PLYWOOD ORIENTATION:
PLAIN WALL

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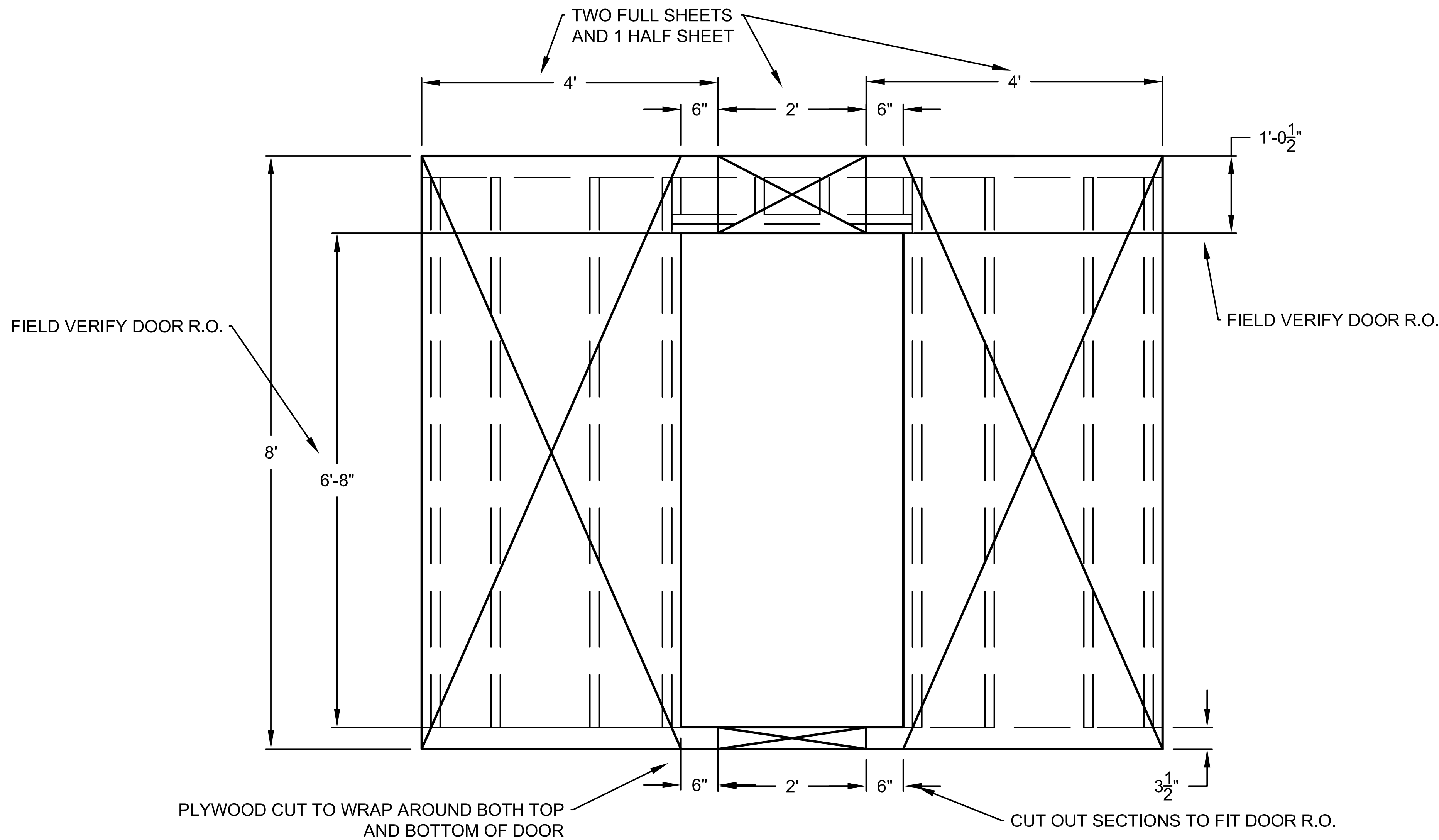
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

PLAIN WALL EXT.
PLYWOOD LAYOUT

SCALE: 1/2" = 1'

A210



EXTERIOR
PLYWOOD ORIENTATION:
DOOR WALL

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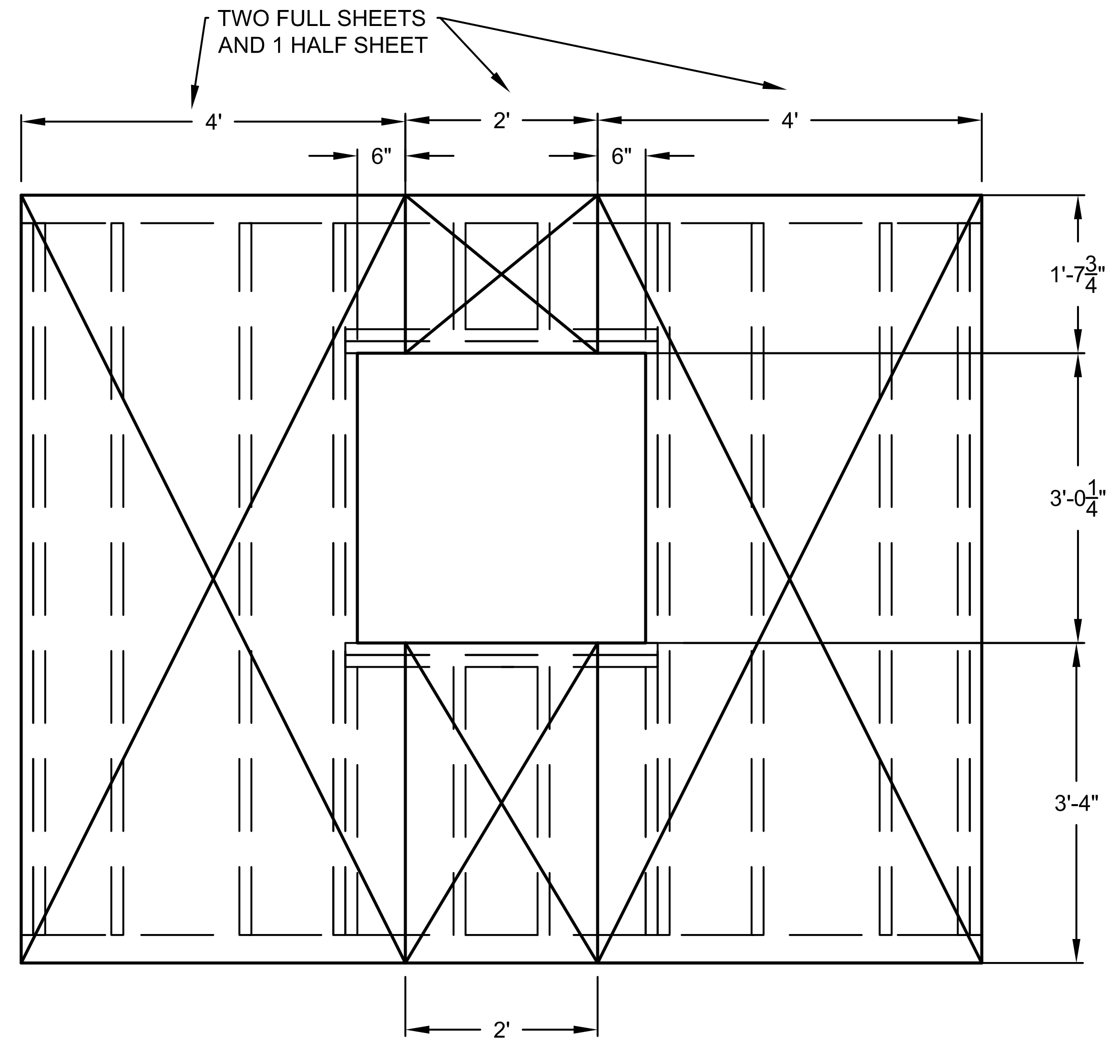
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

DOOR WALL EXT.
PLYWOOD LAYOUT

SCALE: 1/2" = 1'

A211



EXTERIOR
PLYWOOD ORIENTATION:
WINDOW WALL

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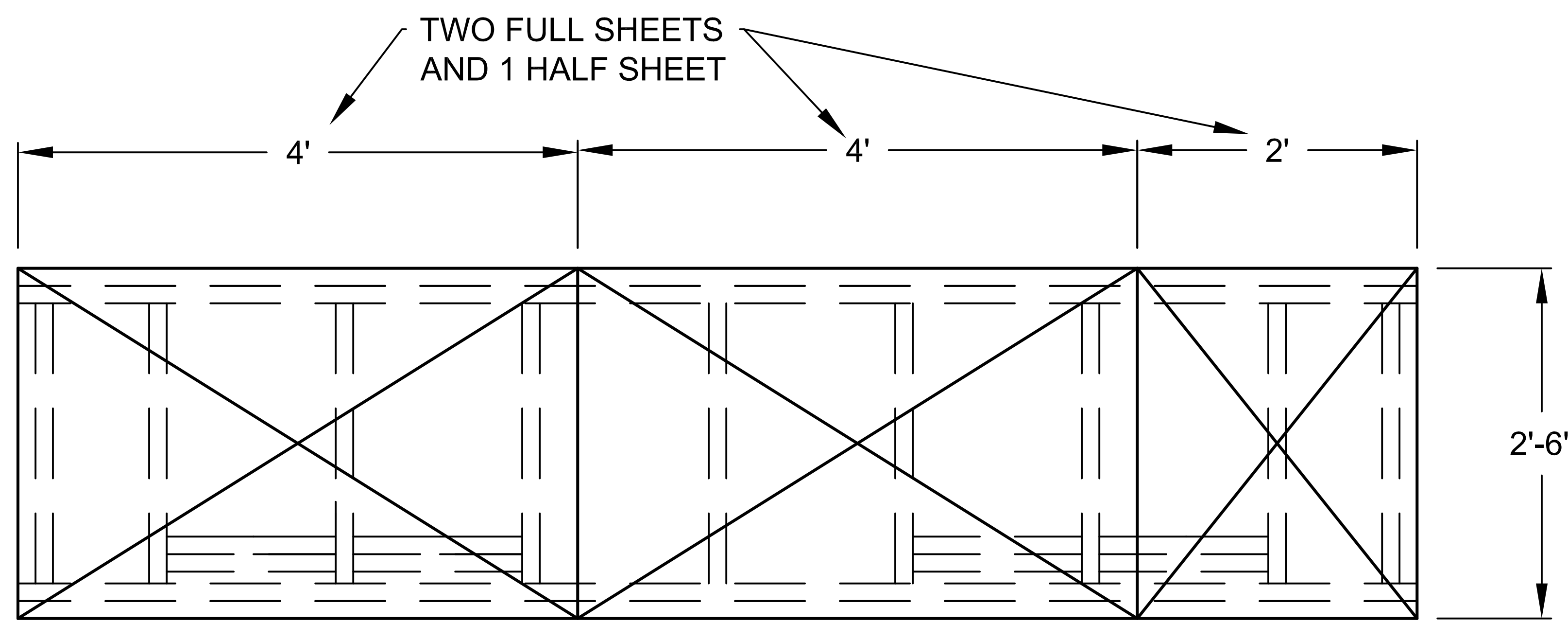
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

WINDOW WALL EXT.
PLYWOOD LAYOUT

SCALE: 1/2" = 1'

A212



EXTERIOR
PLYWOOD ORIENTATION:
FULL WALL EXTENSION

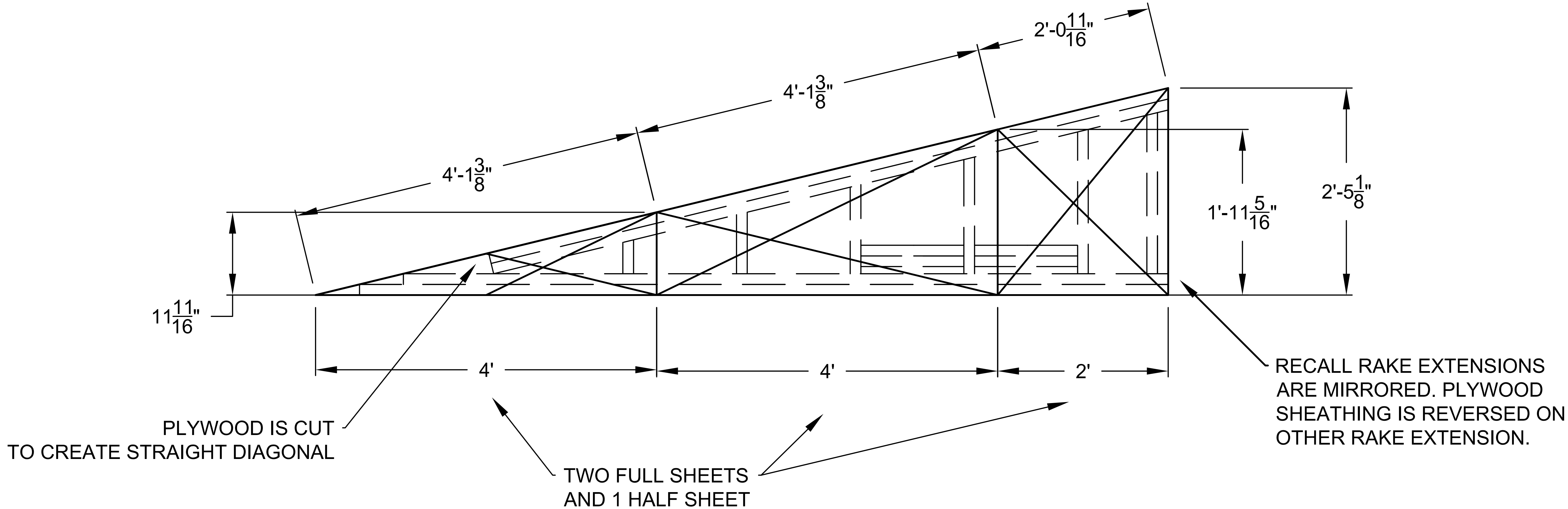
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

FULL EXTENSION
EXT. PLYWOOD
LAYOUT

SCALE: 3/4" = 1'

A213



EXTERIOR
PLYWOOD ORIENTATION:
RAKE WALL EXTENSION

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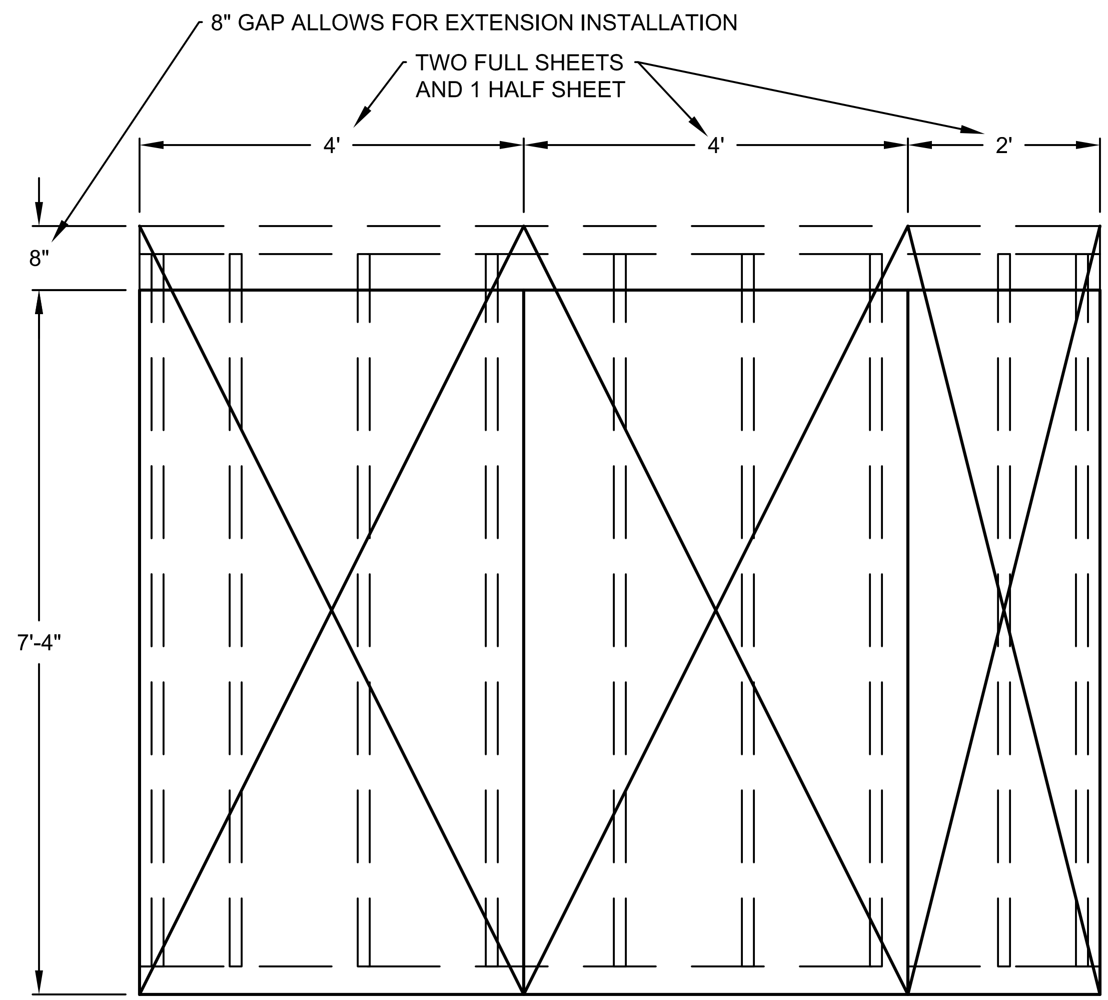
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

RAKE EXTENSION
EXT. PLYWOOD
LAYOUT

SCALE: 3/4" = 1'



INTERIOR
PLYWOOD ORIENTATION:
PLAIN WALL

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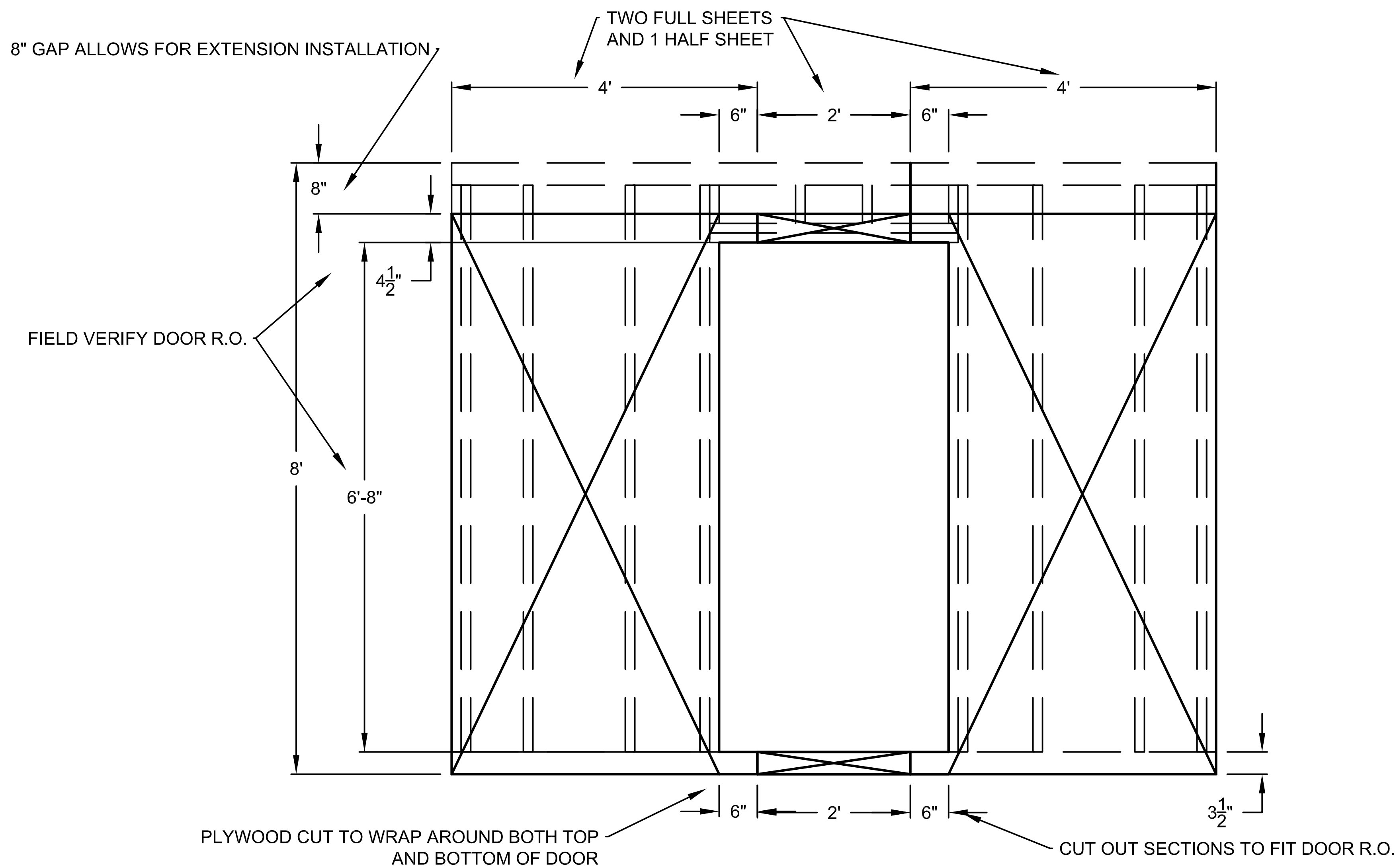
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

PLAIN WALL INT.
PLYWOOD LAYOUT

SCALE: 1/2" = 1'

A220



INTERIOR
PLYWOOD ORIENTATION:
DOOR WALL

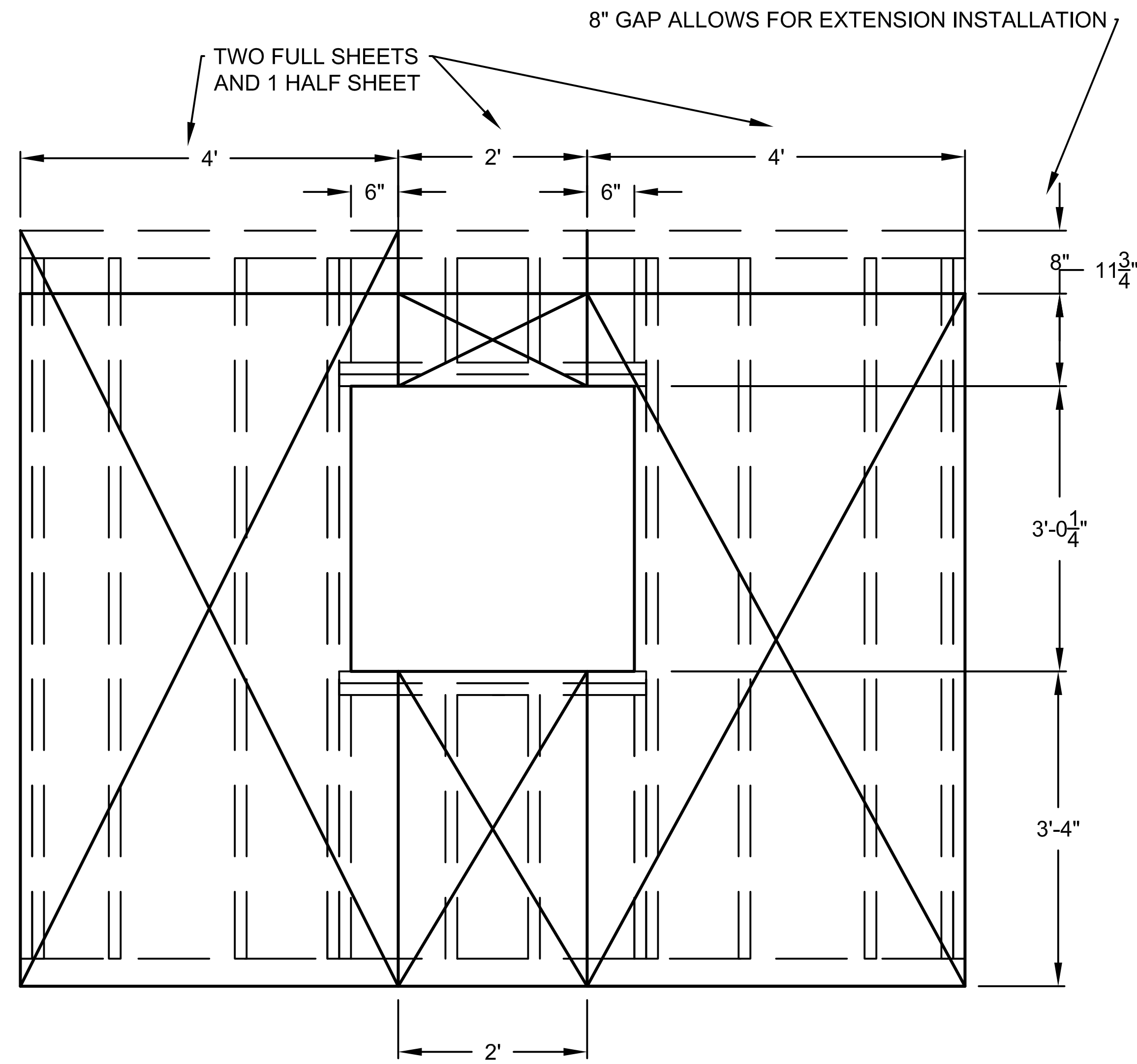
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

DOOR WALL INT.
PLYWOOD LAYOUT

SCALE: 1/2" = 1'

A221



INTERIOR
PLYWOOD ORIENTATION:
WINDOW WALL

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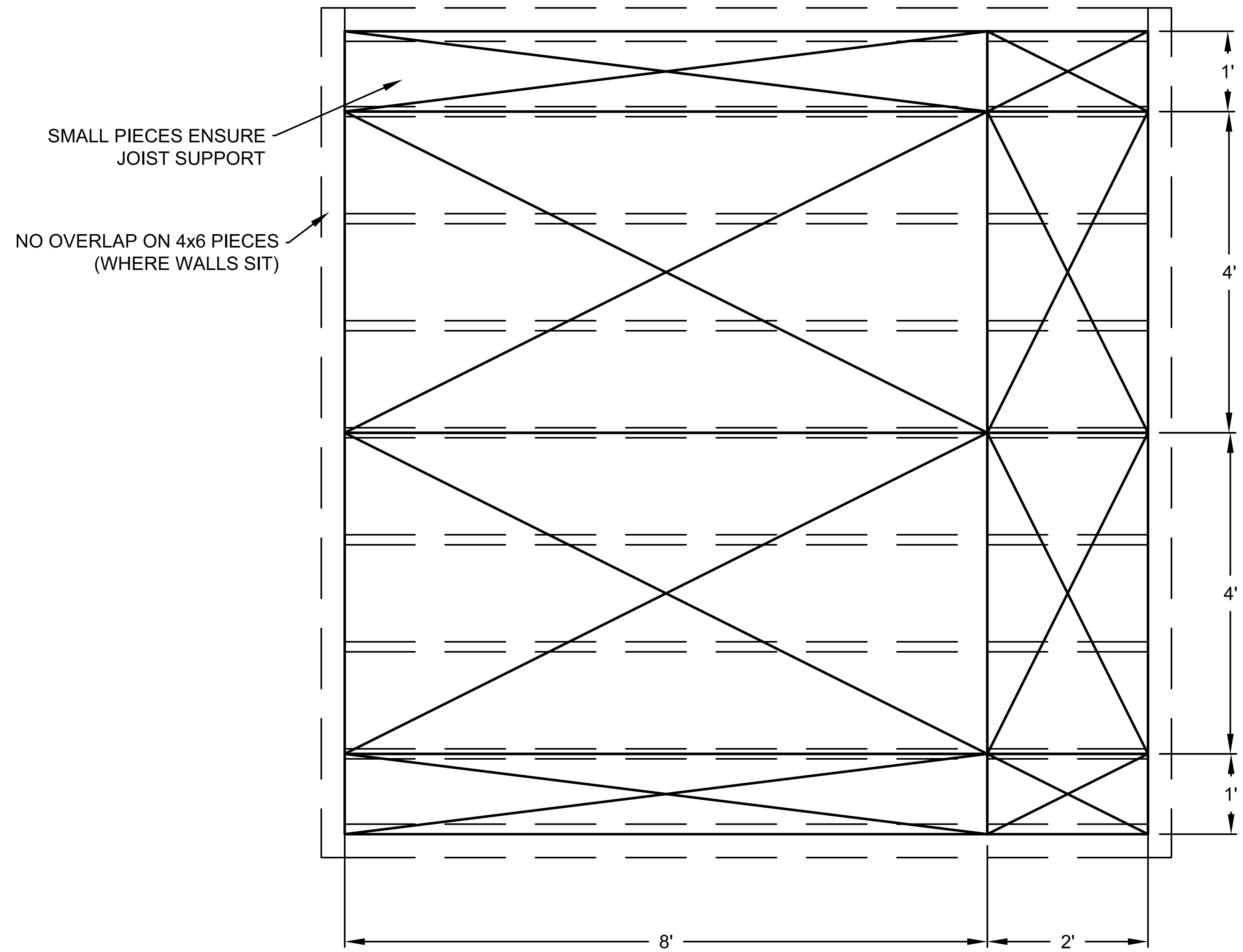
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

WINDOW WALL INT.
PLYWOOD LAYOUT

SCALE: 1/2" = 1'

A222



INTERIOR
PLYWOOD ORIENTATION:
FLOOR

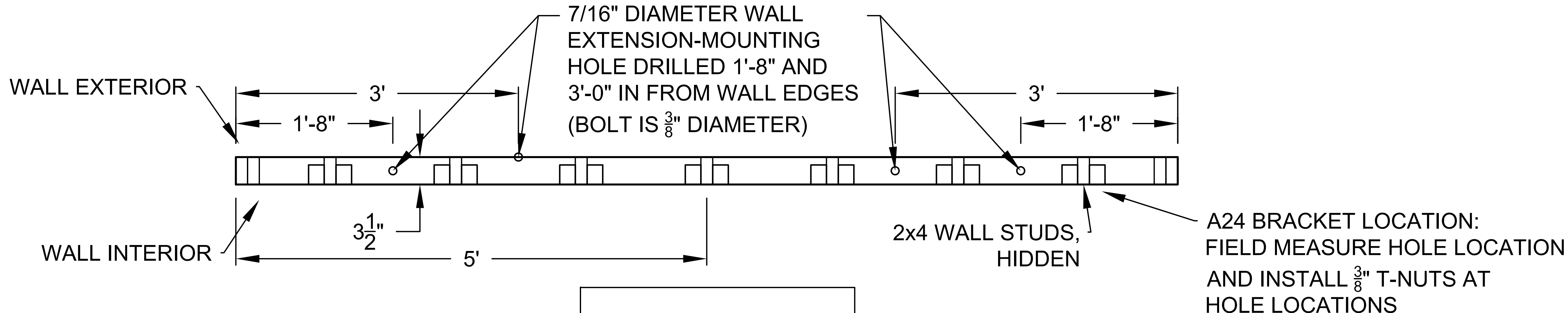
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

FLOOR SHEATHING LAYOUT

SCALE: 1/2" = 1'

A230



SECTION A-A

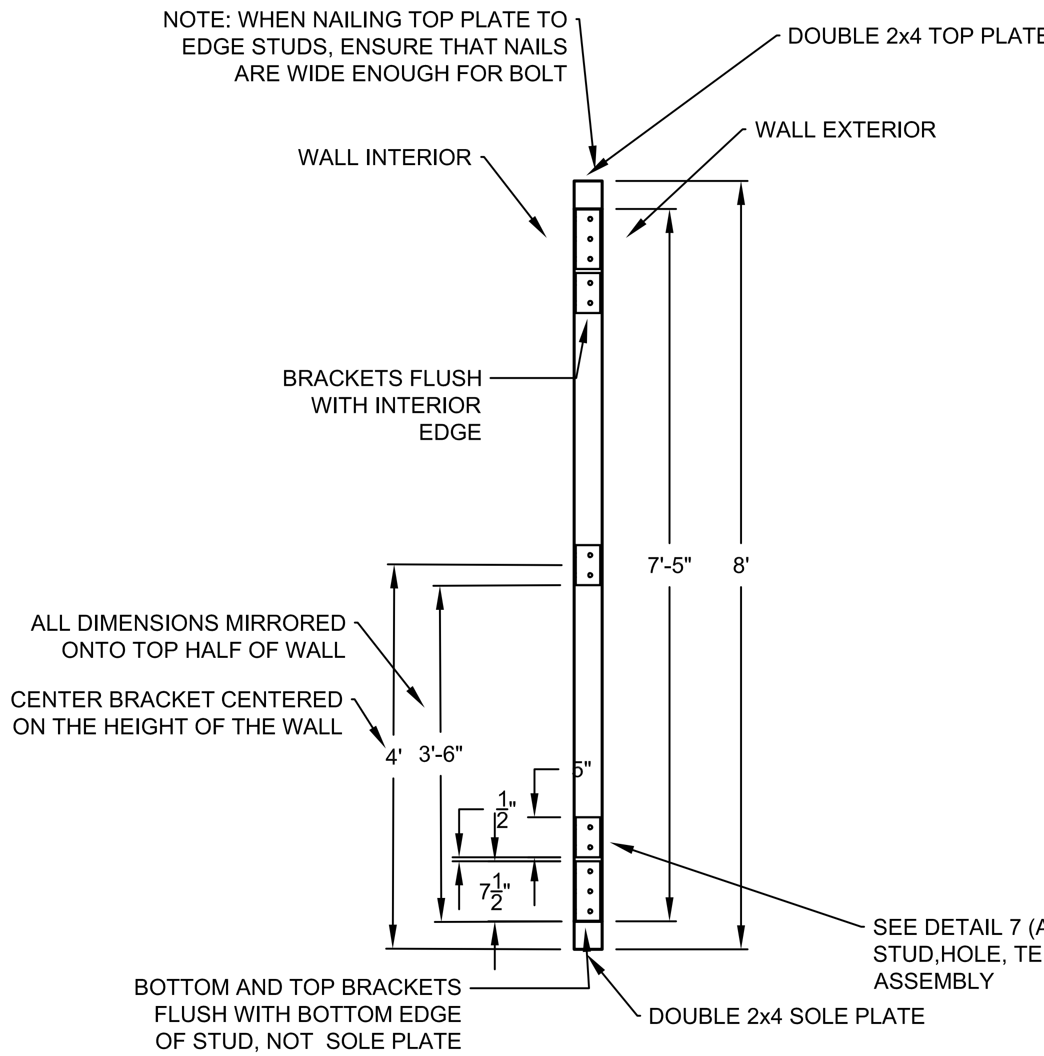
Santa Clara University

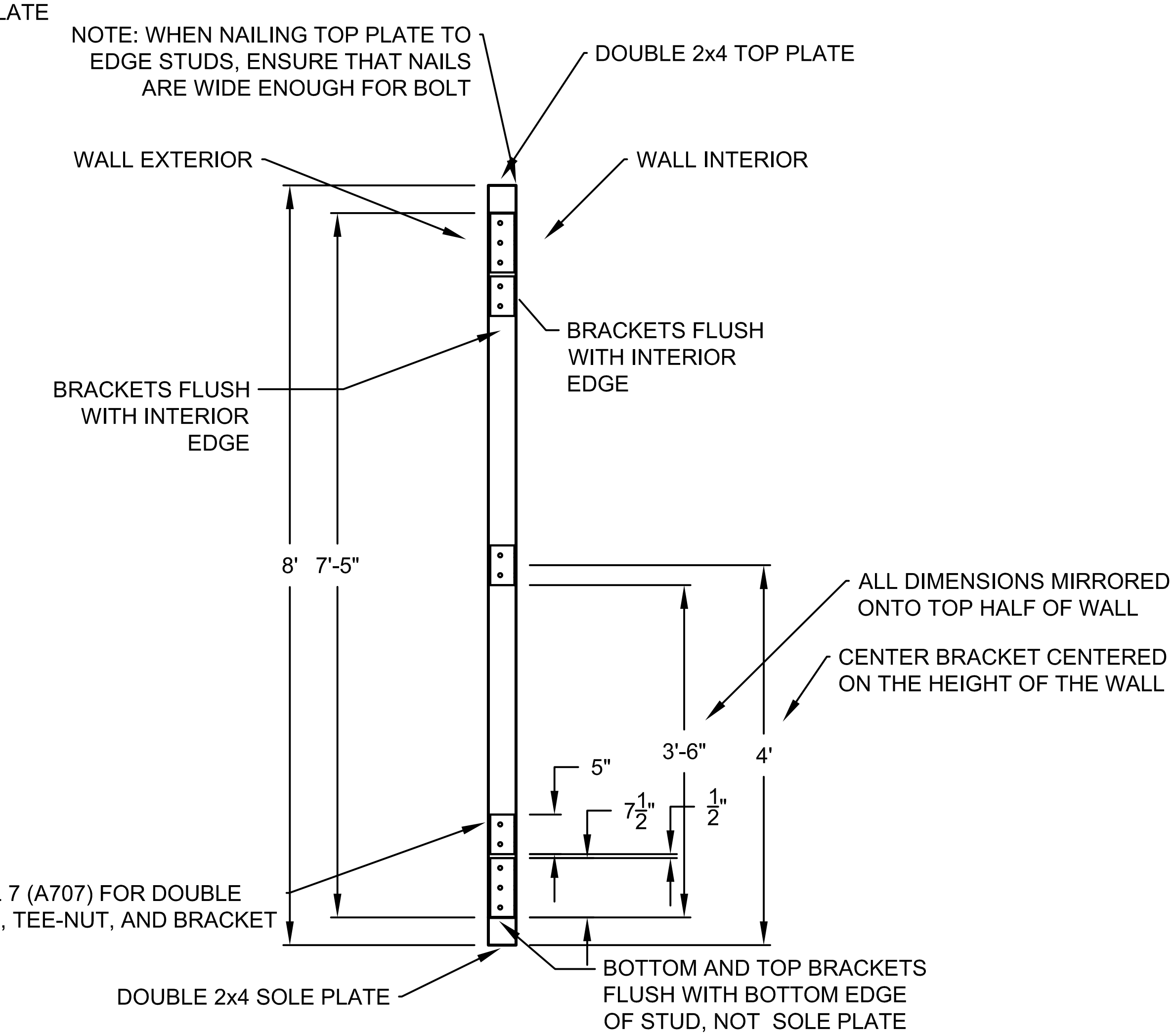
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

SECTION A-A:
WALL TOP PLATE

SCALE: 3/4" = 1'

A600





SECTION C-C
[WALL SECTION END - EXTERIOR ON THE RIGHT]

SECTION B-B
[WALL SECTION END - EXTERIOR ON THE LEFT]

CONSTRUCTION NOTE: BRACKET LOCATION WILL DETERMINE WHERE HOLES ARE DRILLED AND T-NUTS ARE INSTALLED. FIELD MEASURE HOLE LOCATION AND DRILL BASED ON SIZE OF $\frac{3}{8}$" T-NUT. T-NUTS ARE INSTALLED IN BETWEEN DOUBLE STUD, AND WILL BE HAMMERED IN ONCE APPROPRIATE HOLE IS DRILLED THROUGH BOTH EDGE STUDS. BOLTS NEED TO BE $\frac{3}{8}$" AND HAVE AT LEAST A 3.25" THREADED PORTION. BOTH SECTIONS CAN BE CONSTRUCTED IDENTICALLY; HOWEVER, WHEN FRAMING WALLS, USE CAUTION TO ENSURE THE CORRECT INTERIOR AND EXTERIOR ORIENTATION IS USED. (MARK INT./EXT. WHEN BUILDING DOUBLE STUDS TO MAKE THIS EASIER)

Santa Clara University

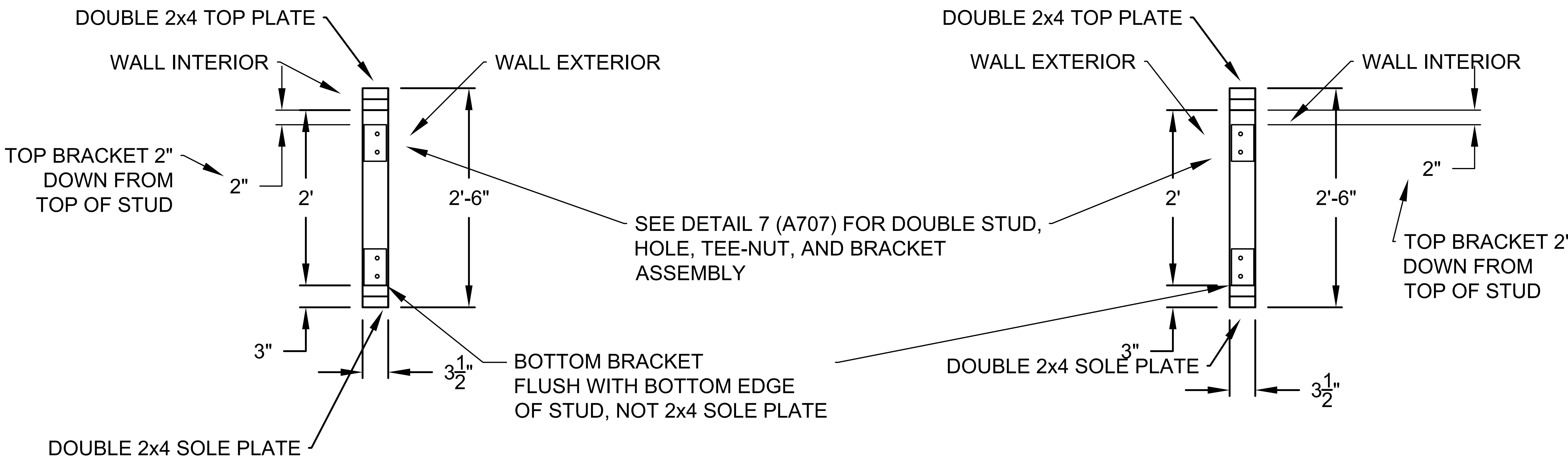
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

SECTION B-B & C-C:
WALL END STUDS

SCALE: 1/2" = 1'

A601



SECTION E-E
[FULL WALL EXTENSION END - EXTERIOR ON THE RIGHT]

SECTION D-D
[FULL WALL EXTENSION END - EXTERIOR ON THE LEFT]

CONSTRUCTION NOTE: BRACKET LOCATION WILL DETERMINE WHERE HOLES ARE DRILLED AND T-NUTS ARE INSTALLED. FIELD MEASURE HOLE LOCATION AND DRILL BASED ON SIZE OF $\frac{3}{8}$" T-NUT. T-NUTS ARE INSTALLED THROUGH BACK OF STUD, AND WILL BE HAMMERED IN ONCE APPROPRIATE HOLE IS DRILLED THROUGH BOTH EDGE STUDS. BOLTS NEED TO BE $\frac{3}{8}$" AND HAVE AT LEAST A 3.25" THREADED PORTION. BOTH SECTIONS CAN BE CONSTRUCTED IDENTICALLY; HOWEVER, WHEN FRAMING WALLS, USE CAUTION TO ENSURE THE CORRECT INTERIOR AND EXTERIOR ORIENTATION IS USED. (MARK INT./EXT. WHEN BUILDING DOUBLE STUDS TO MAKE THIS EASIER)

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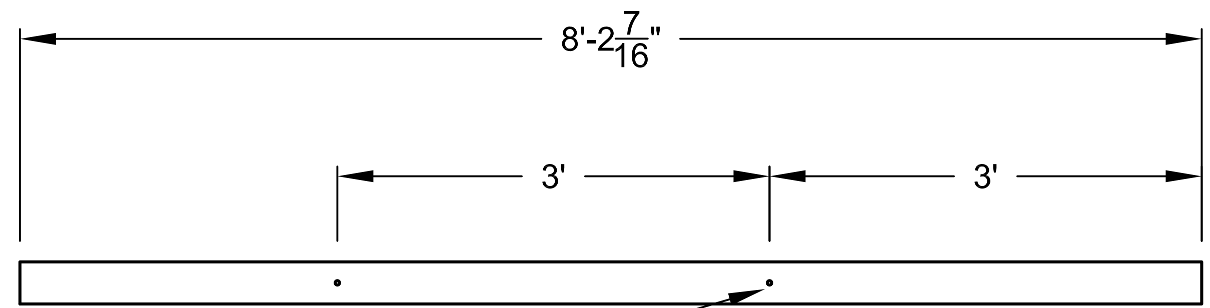
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

SECTION D-D & E-E:
FULL EXTENSION END
STUDS

SCALE: 3/4" = 1'

A602



7/16" DIAMETER HOLES DRILLED
THROUGH BOTH SOLE PLATES
IN THE CENTER OF THE PIECE
WIDTH FOR CONNECTION TO ROOF.

SECTION F-F
[RAKE EXTENSION
TOP PLATE PLAN]

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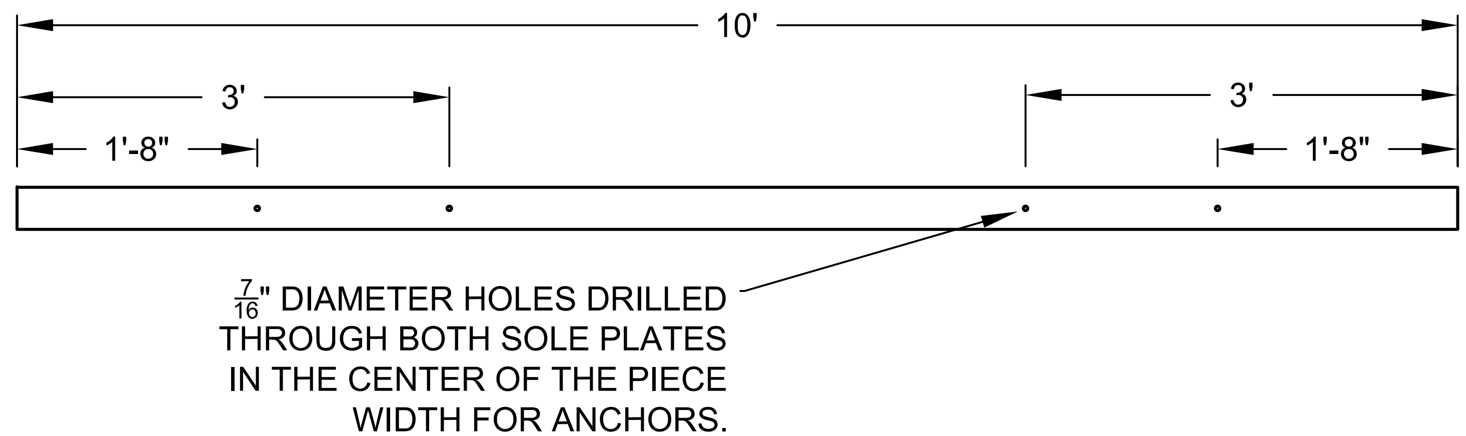
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

SECTION F-F:
RAKE EXTENSION
TOP PLATE

SCALE: 3/4" = 1'

A603



SECTION G-G
[FULL WALL EXTENSION
SOLE PLATE PLAN]

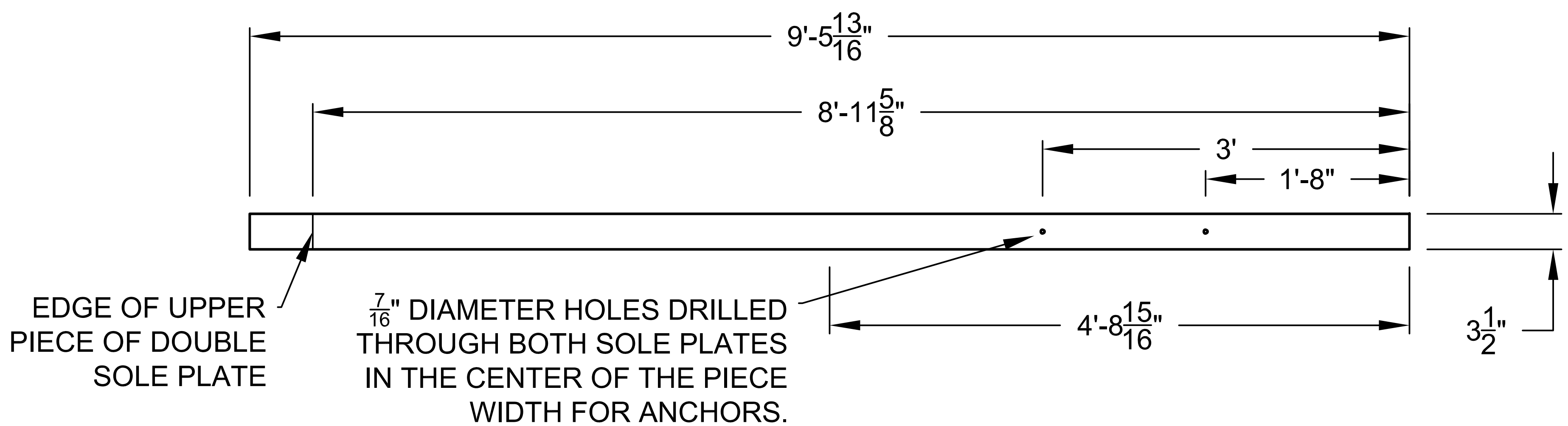
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

SECTION G-G:
FULL EXTENSION
SOLE PLATE

SCALE: 3/4" = 1'

A604



SECTION H-H
[RAKE WALL EXTENSION SOLE PLATE PLAN]

Santa Clara University

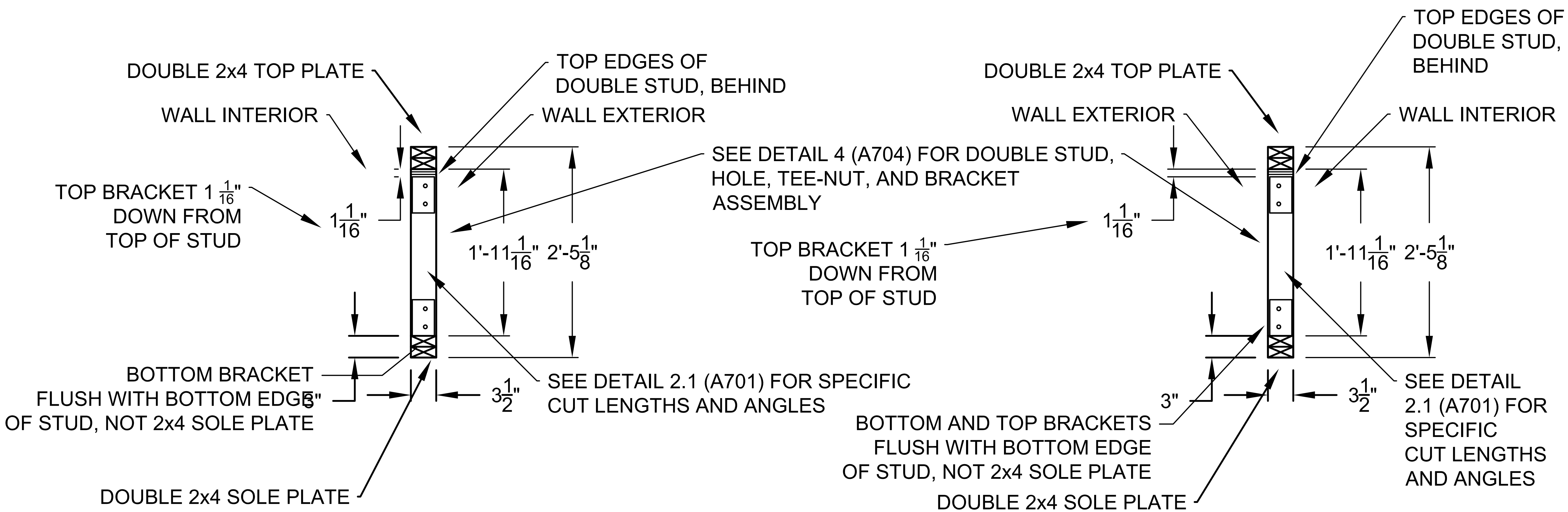
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

SECTION H-H:
RAKE EXTENSION
SOLE PLATE

SCALE: 3/4" = 1'

A605



SECTION I-I
[RAKE WALL EXTENSION END - EXTERIOR ON THE RIGHT]

SECTION J-J
[RAKE WALL EXTENSION END - EXTERIOR ON THE LEFT]

CONSTRUCTION NOTE: BRACKET LOCATION WILL DETERMINE WHERE HOLES ARE DRILLED AND T-NUTS ARE INSTALLED. FIELD MEASURE HOLE LOCATION AND DRILL BASED ON SIZE OF $\frac{3}{8}$" T-NUT. T-NUTS ARE INSTALLED THROUGH BACK OF STUD, AND WILL BE HAMMERED IN ONCE APPROPRIATE HOLE IS DRILLED THROUGH BOTH EDGE STUDS. BOLTS NEED TO BE $\frac{3}{8}$" AND HAVE AT LEAST A 3.25" THREADED PORTION. BOTH SECTIONS CAN BE CONSTRUCTED IDENTICALLY; HOWEVER, WHEN FRAMING WALLS, USE CAUTION TO ENSURE THE CORRECT INTERIOR AND EXTERIOR ORIENTATION IS USED. (MARK INT./EXT. WHEN BUILDING DOUBLE STUDS TO MAKE THIS EASIER)

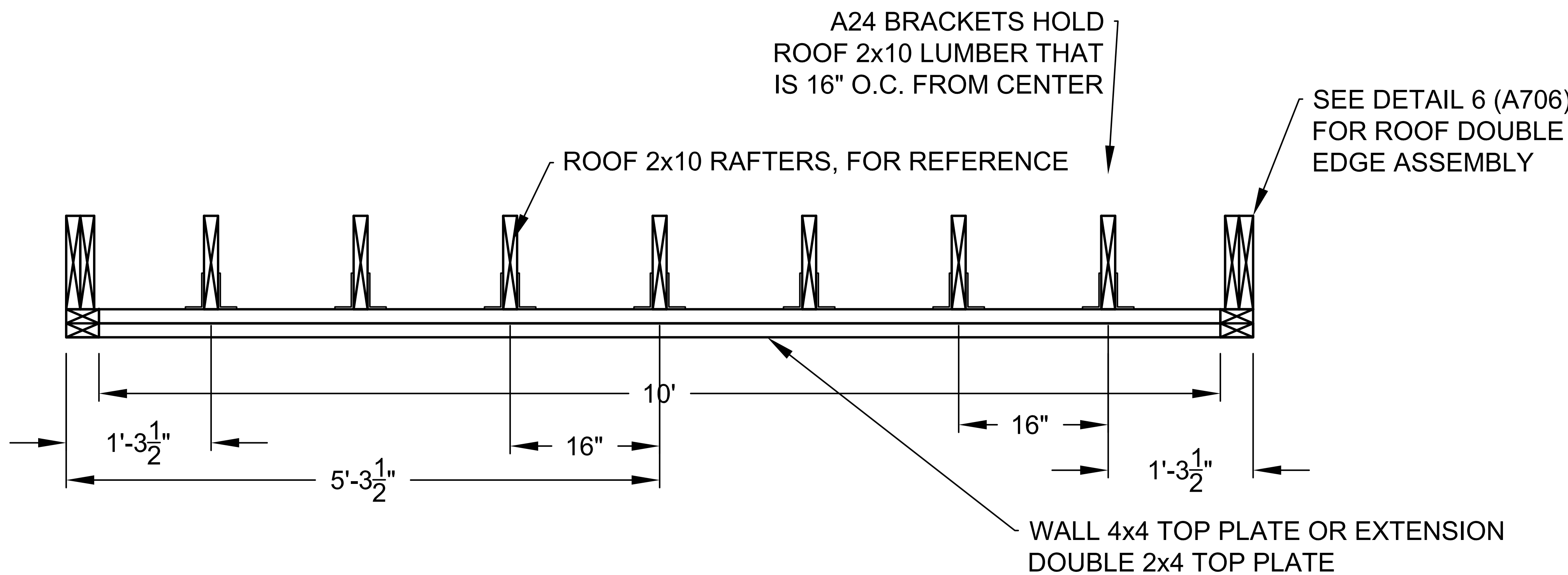
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

SECTION I-I & J-J:
RAKE EXTENSION END STUDS

SCALE: 3/4" = 1'

A606



DETAIL 1:
ROOF-WALL INTERSECTION

Santa Clara University

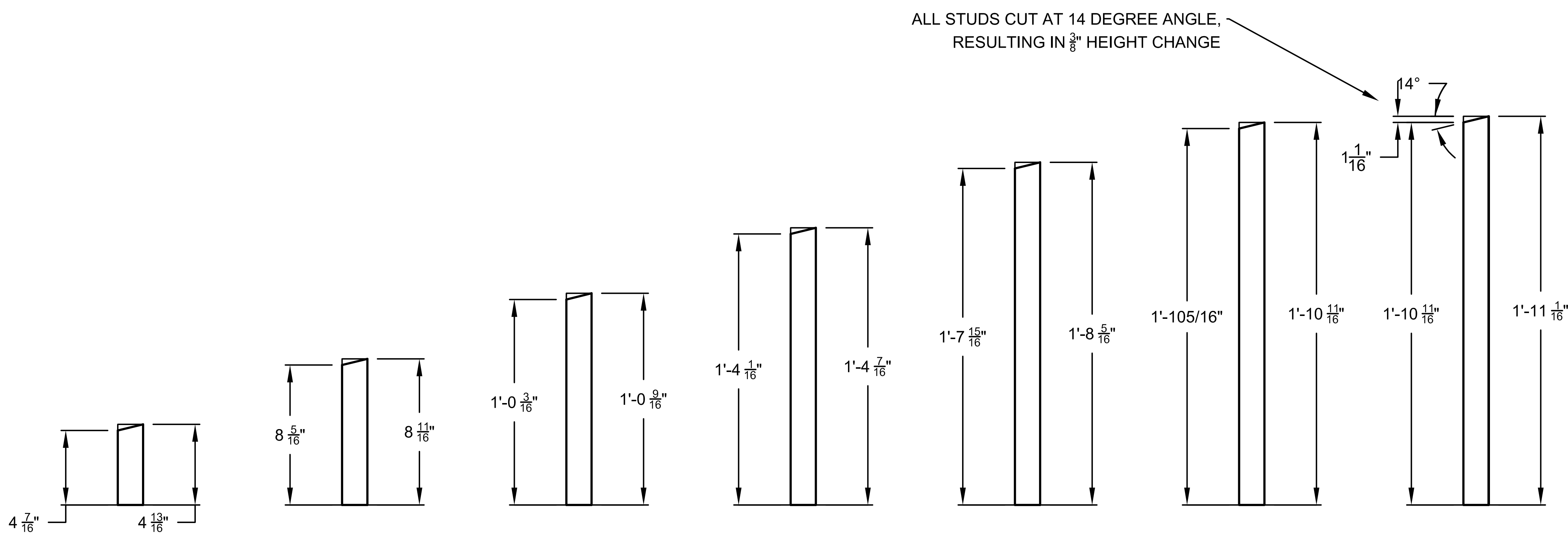
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

DETAIL 1:
ROOF-WALL
INTERSECTION

SCALE: 3/4" = 1'

A700



DETAIL 2.1:
RAKE EXTENSION
STUD CUT LENGTHS (N.T.S.)

Santa Clara University

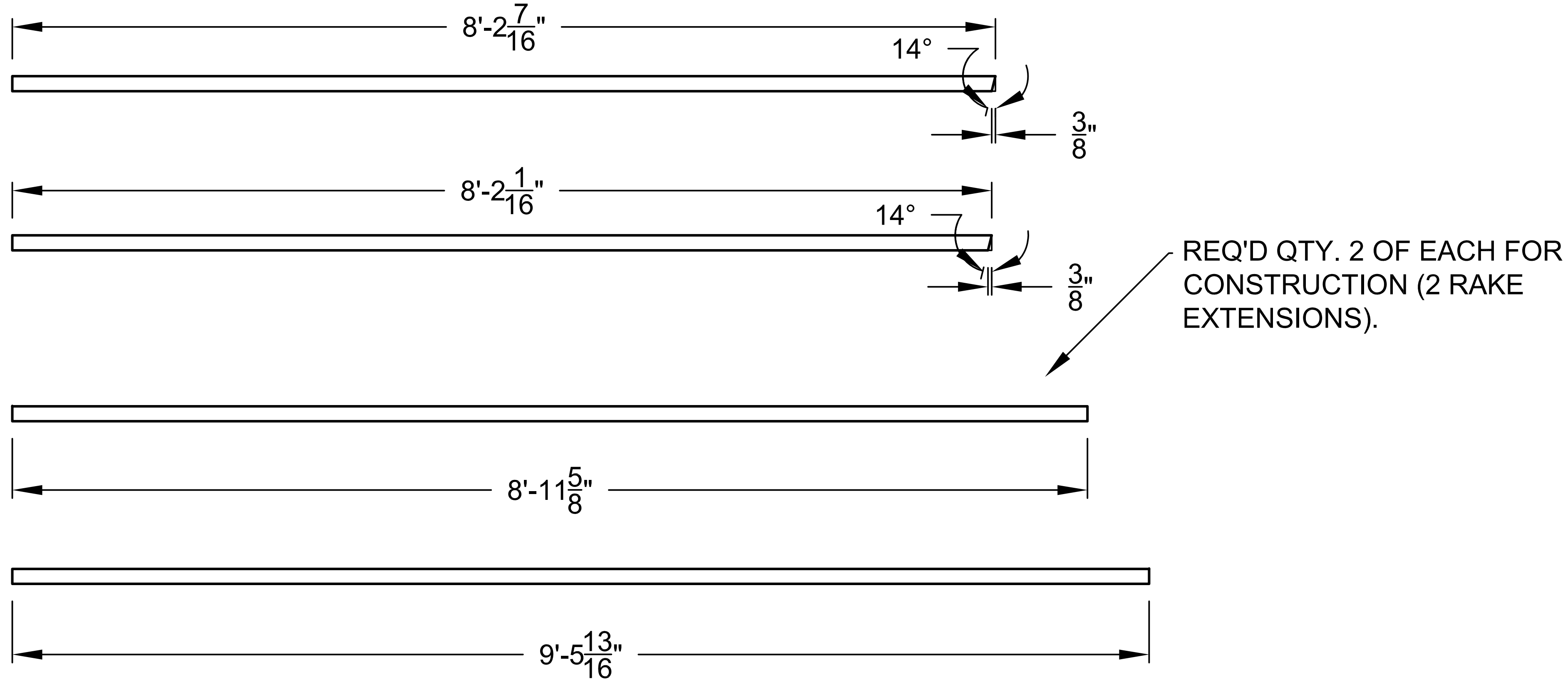
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

DETAIL 2.1:
RAKE EXTENSION
STUD CUTS

SCALE: N.T.S.

A701



DETAIL 2.2:
RAKE EXTENSION TOP/SOLE PLATE CUT LENGTHS

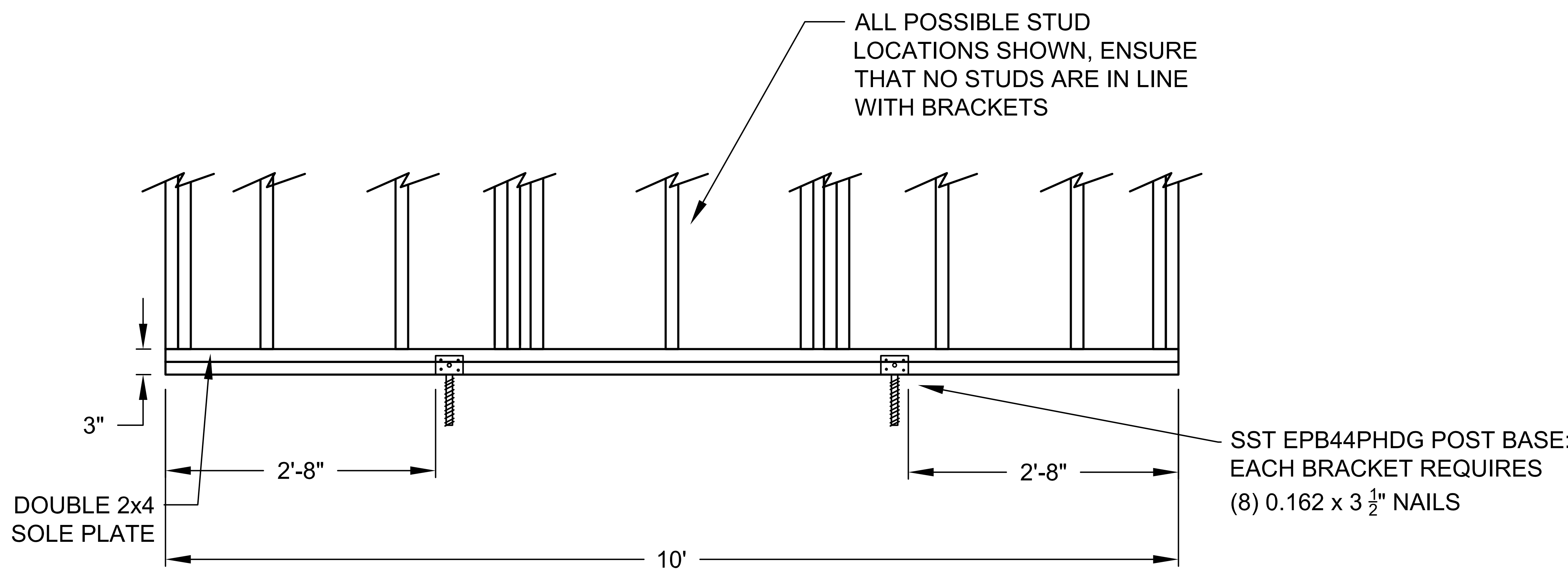
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

DETAIL 2.2:
RAKE EXTENSION
PLATE CUTS

SCALE: 3/4" = 1'

A702



DETAIL 3: WALL SECTION SOLE PLATE BRACKETS

Santa Clara University

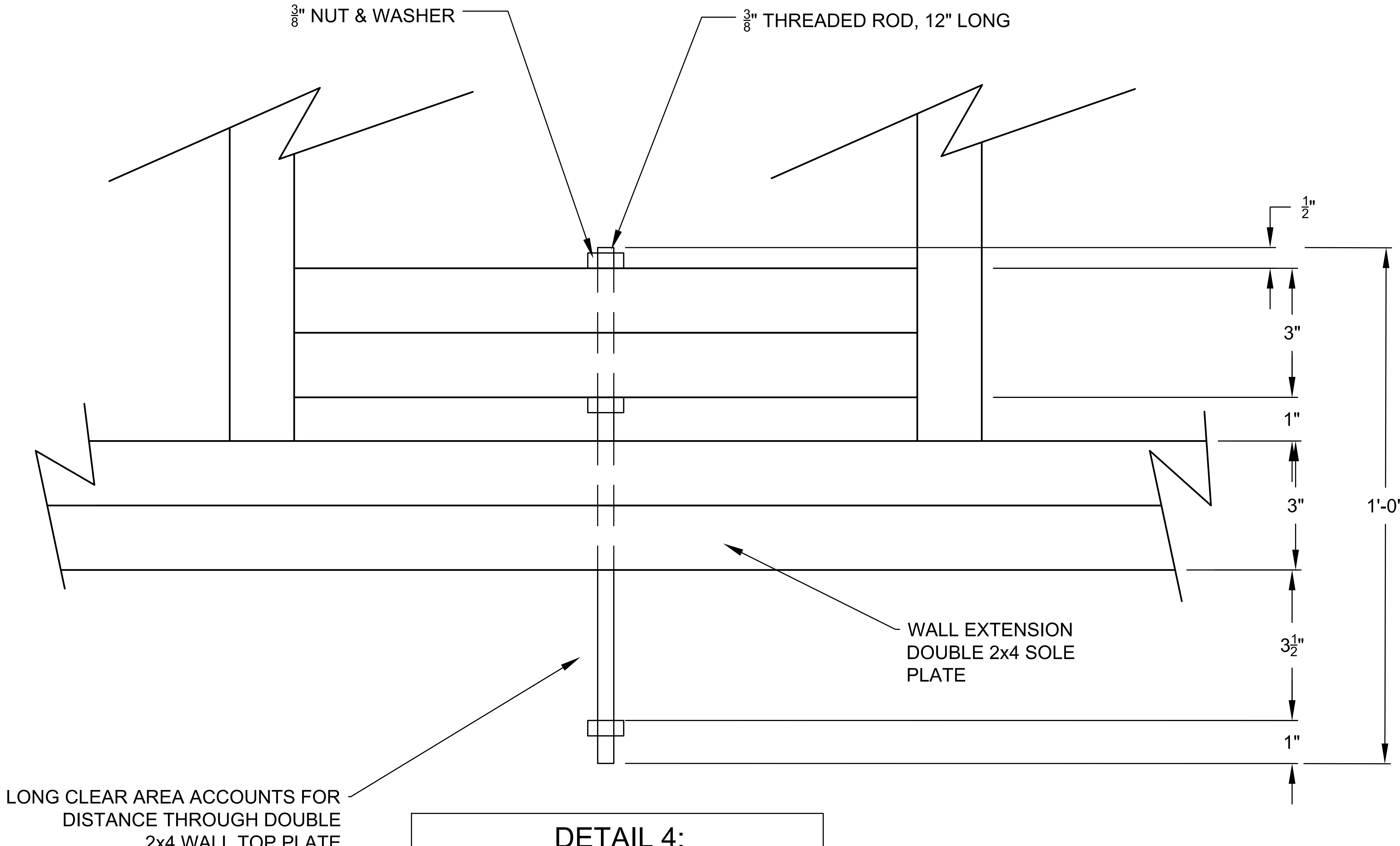
CONSTRUCTION DRAWINGS FOR THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

DETAIL 3: WALL-FLOOR BRACKET LOCATIONS

SCALE: 3/4" = 1'

A703



DETAIL 4:
WALL EXTENSION ANCHOR
CLOSE-UP (N.T.S.)

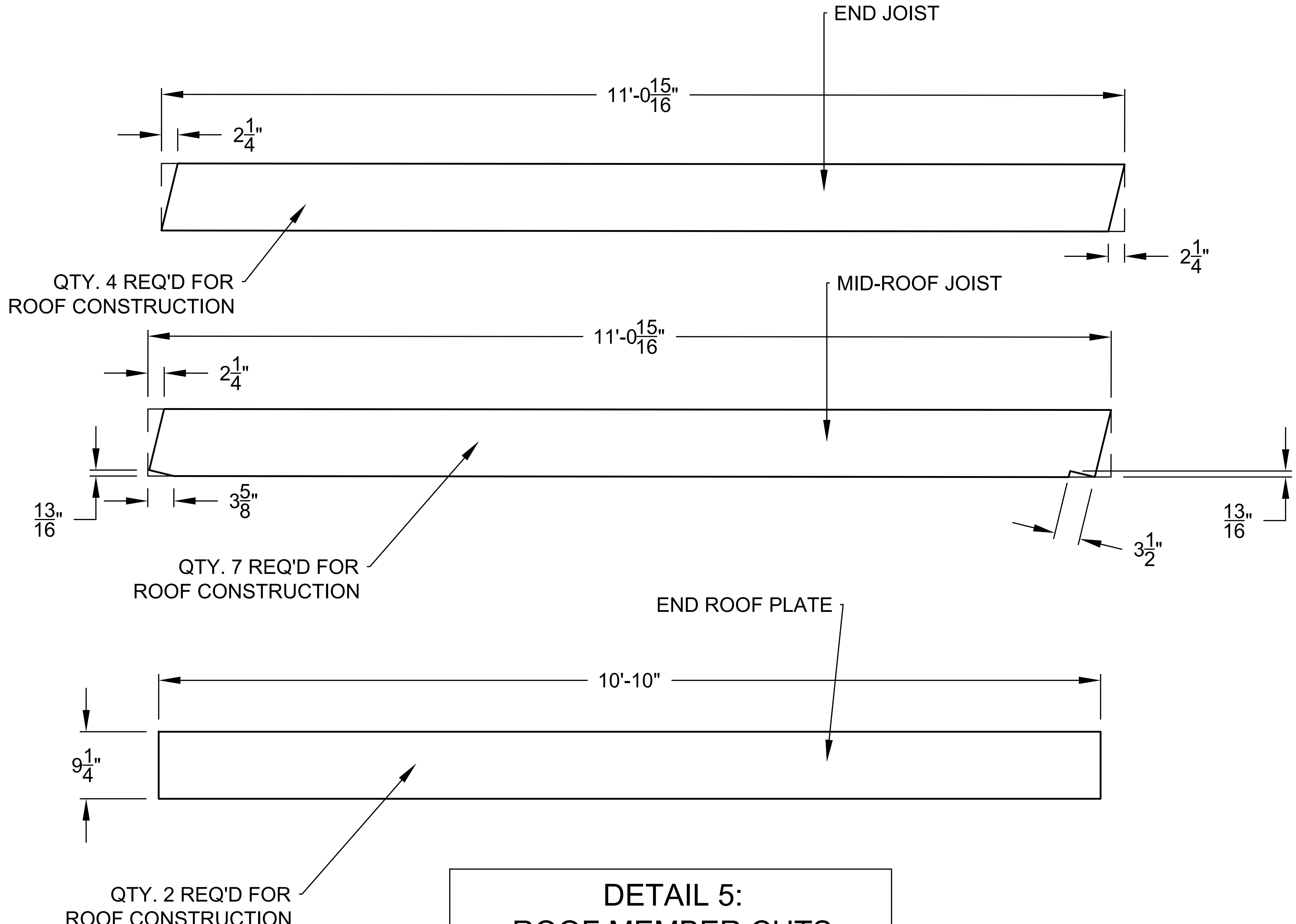
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

DETAIL 4:
WALL-HEIGHT
EXTENSION CONNECT.

SCALE: N.T.S.

A704



DETAIL 5:
ROOF MEMBER CUTS

Santa Clara University

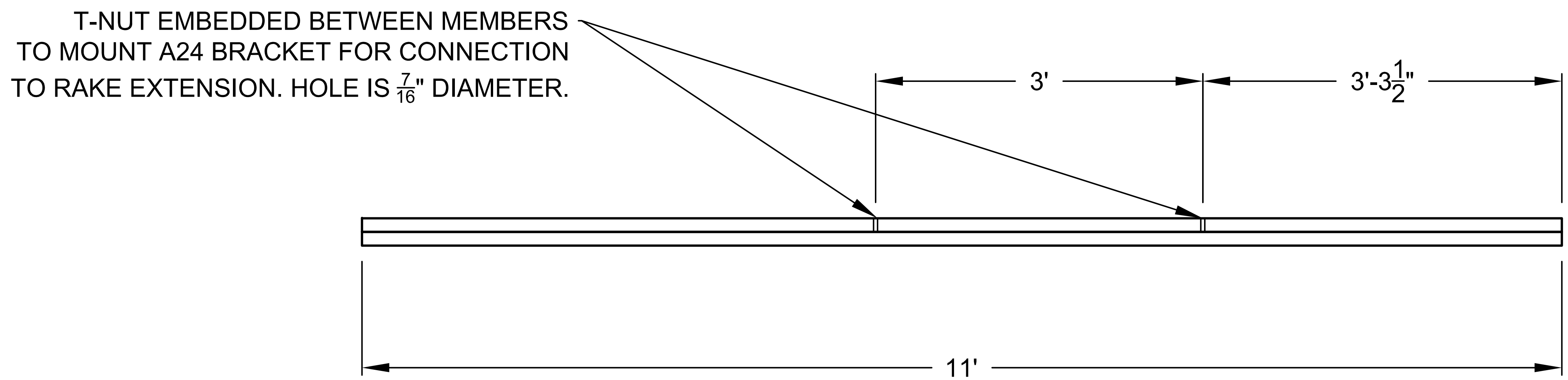
CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE

JACKSON BORDELON & JOHN O'HAGAN

DETAIL 5:
ROOF MEMBER CUTS

SCALE: 3/4" = 1'

A705



DETAIL 6:
ROOF DOUBLE EDGE JOIST
TEE-NUT LOCATIONS

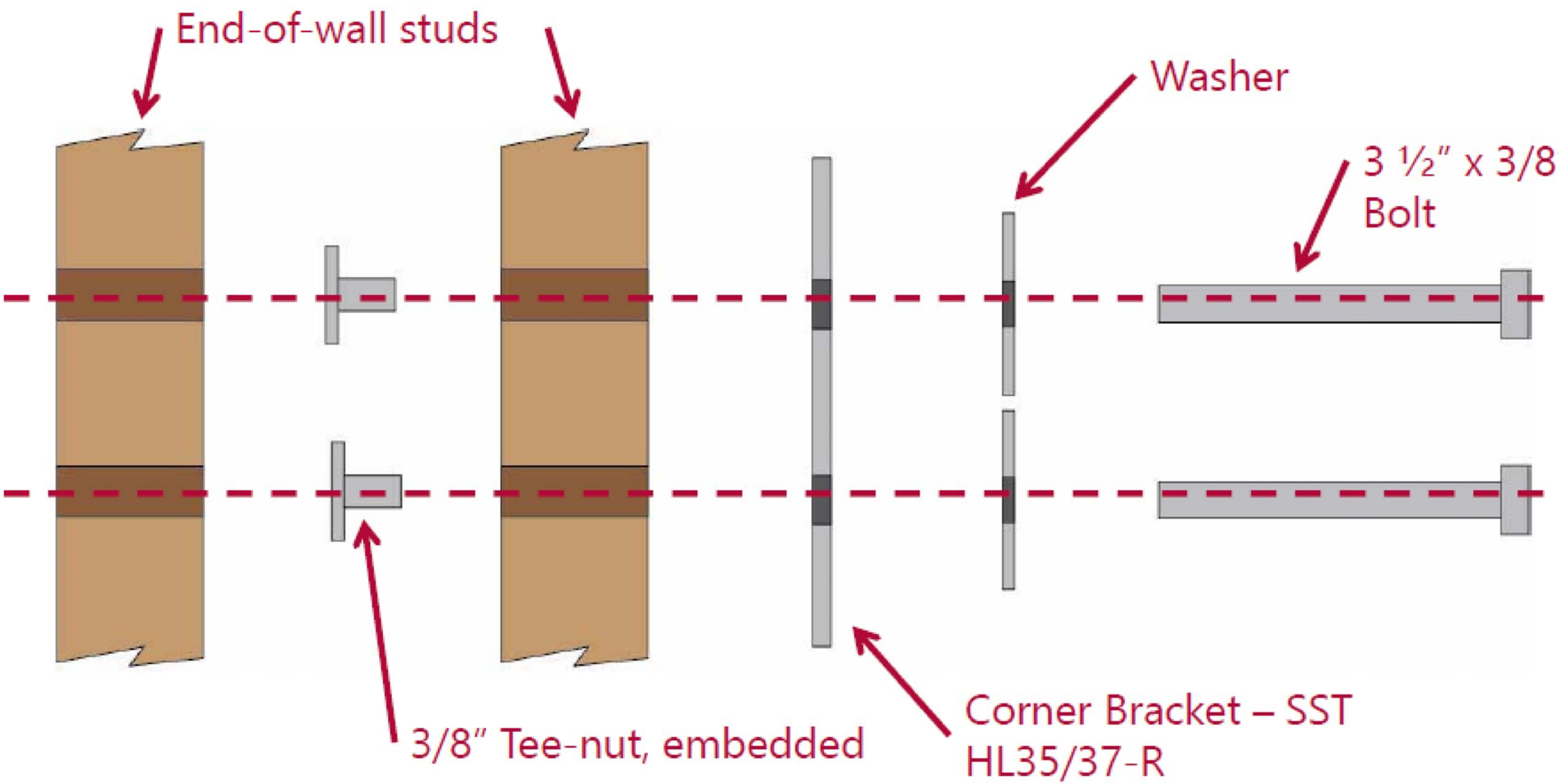
Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

DETAIL 6:
ROOF DOUBLE EDGE
JOIST T-NUTS

SCALE: 3/4" = 1'

A706



DETAIL 7:
DOUBLE STUD ASSEMBLY

Santa Clara University

CONSTRUCTION DRAWINGS FOR
THE BHC MODULAR RE-DESIGN PROTOTYPE
JACKSON BORDELON & JOHN O'HAGAN

DETAIL 7:
DOUBLE STUD
ASSEMBLY

SCALE: N.T.S.

A707

Appendix H
Construction Photos

Figure H.1 - *Materials (brackets, left and lumber, right) provided by generous partners Simpson Strong Tie and Pine Cone Lumber.*

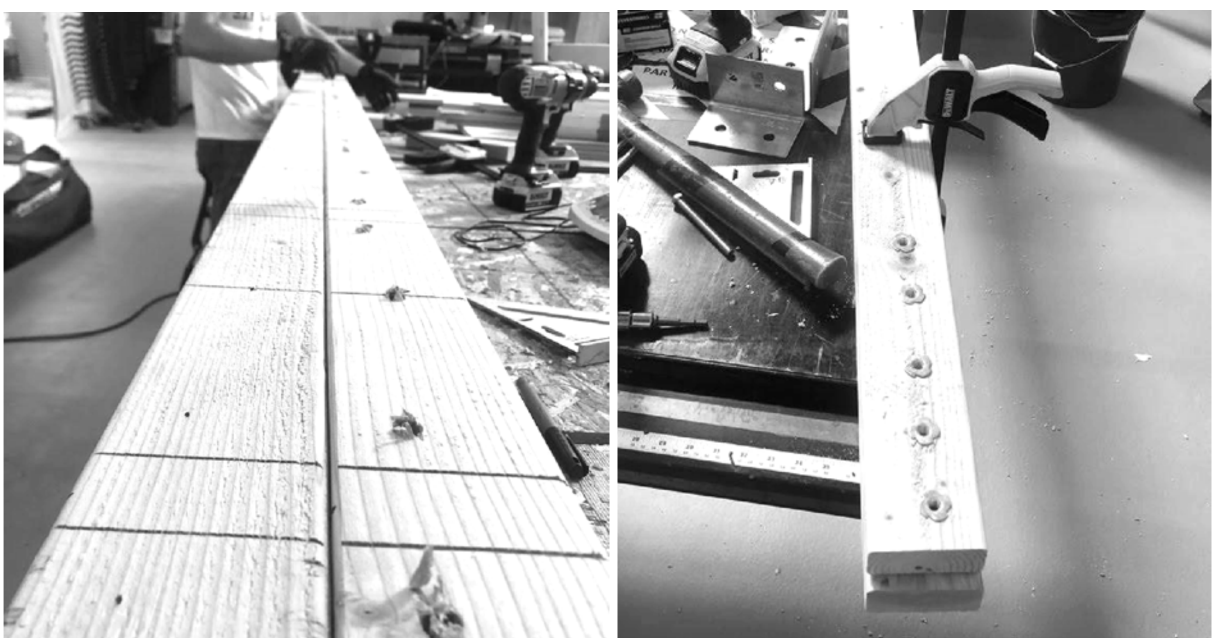


Figure H.2 -*.Wall end studs, top plates, and sole plates had to be prepared for connections (T-nut installation and hole drilling).*

Figure H.3 - *The floor beams were prepared for the wall-to-floor connections (left) and then the floor was framed (right).*

Figure H.4 - *The walls were framed (left) and then erected to test the wall-to-wall corner connections (right).*

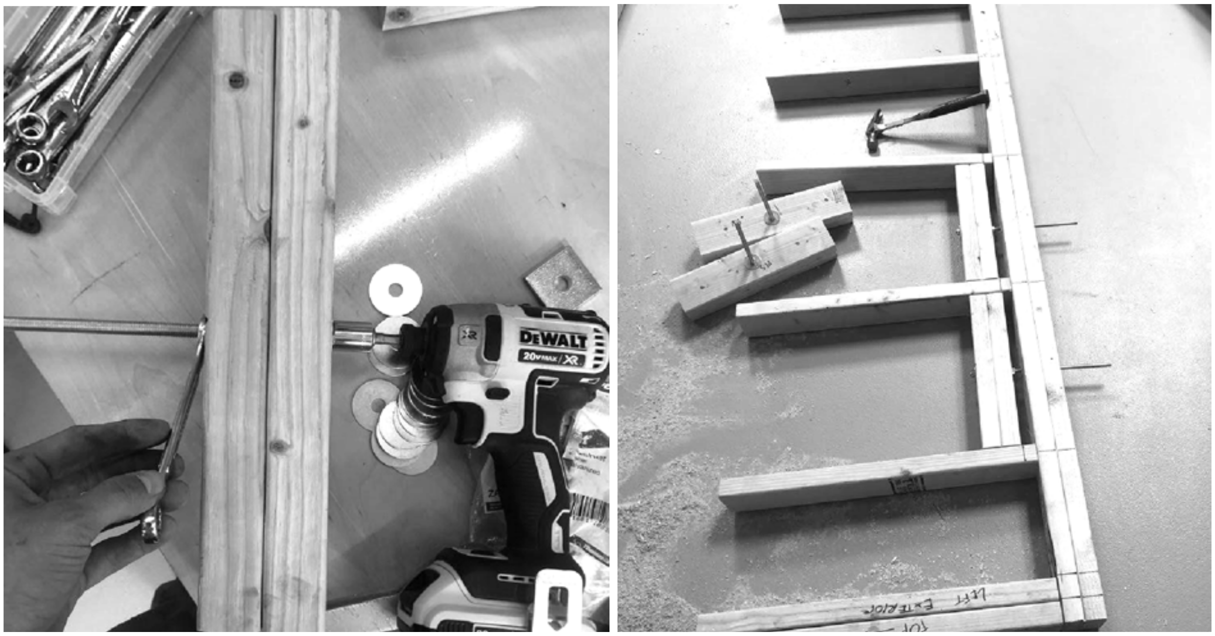


Figure H.5 - *The wall-to-height extension connections were built (left) and then installed in the height extensions (right).*

Figure H.6 - *The height extensions were installed to ensure that they worked and then moved to the ground for roof construction.*

Figure H.7 - *The roof joists were cut (left) and the roof was framed on the height extensions (right).*

Figure H.8 - *The roof was finished with roofing paper, flashing, and shingles on the ground.*

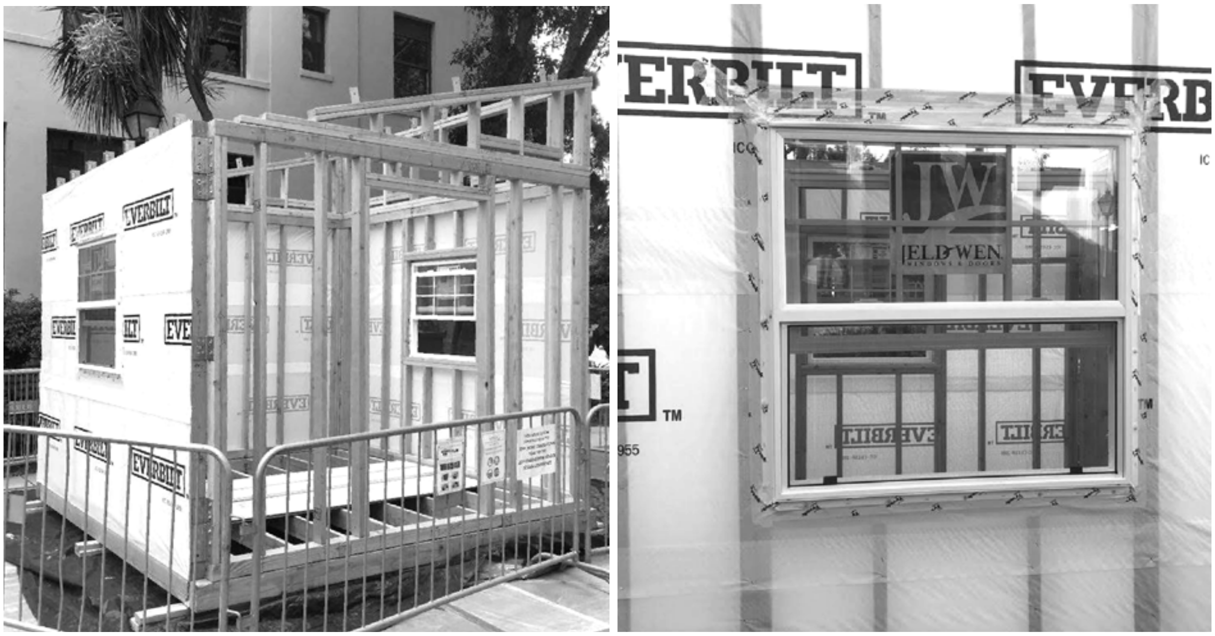


Figure H.9 - *The wall sections were transported to the conference site and erected (left) and house wrap and windows were installed (right).*

Figure H.10 - *The roof was transported to the site and placed on top of the cabin.*

Figure H.11 - *The exterior sheathing was installed (left) and primed for paint (right).*

Figure H.12 - *The exterior paint was completed (left) and the door hung (right).*

Figure H.13 - *The interior plywood was hung (left) and painted (right).*

Figure H.14 - *The vinyl flooring was installed on the plywood subfloor (left) and interior trim was installed (right).*

Figure H.15 - *The conference was very successful (left) , and the SCU Team was able to show off its connection designs (right).*

Figure H.16 - *After the conference, the house was dismantled, starting with the roof.*

Figure H.17 - *The height extensions were removed by connecting straps to the A24 brackets on top of the extensions.*

Figure H.18 - *The walls were removed and carried using straps wrapped around bolts connected into the T-nuts used for the wall-to-wall corner connections..*

Figure H.19 - *The floor was removed and stacked on the truck, concluding the dismantling procedure.*

Figure H.20 - *The conference site was cleared and cleaned.*

Figure H.21 - *The SCU Team with their beloved cabin prototype on conference day.*

Appendix I

Alternative Uses Full Table

Group/Idea Number	Idea Title	Idea Notes	Move Forward?	Falls in Larger Group?	Rank Category	Category	Feasability	Required Design	Design Notes
5	Unit that was only for bathrooms/shower		Yes	No	Second	Community Use (Non-Sleeping)	Medium	High	
8	Animal Shelter		Yes	Yes	Third	Community Use (Non-Sleeping)	Low	Medium	
4	Art Centers	Pop up art studio	Yes	Yes	First	Community Use (Non-Sleeping)	High	Low	
7	Kitchen/Food Distrution (for Food Deserts)		Yes	No	Second	Community Use (Non-Sleeping)	Medium	High	Intense re-design, but beneficial
4	Community Garden Office/Shed	Some gardens need a building	Yes	Yes	First	Community Use (Non-Sleeping)	High	Medium	
4	Miniature Libraries	Some areas do not have libraries, according to SJC	Yes	Yes	First	Community Use (Non-Sleeping)	High	Low	
3	Retreat Center/Camp Ground	A village of “cabins” at a campsite	Yes	Yes	First	Community Use (Sleeping)	High	Medium	
3	People in Residencies (Montalvo Art Center-esqu)		Yes	Yes	First	Community Use (Sleeping)	High	Low	
3	Place in Hospital Parking Lots	Overnight use for people staying with family/friends in hospital	Yes	Yes	First	Community Use (Sleeping)	High	Medium	
N/A	Used for chronically homeless?		No	Yes	Third	Community Use (Sleeping)	Medium	Low	Not moving forward becasue it wouldn't require any current redesign and doesn't rovide anything new)
N/A	Senior Isolation Remedy	From SJC - create community to reduce senior isolation	No	No	Third	Community Use (Sleeping)	High	Low	Have to find takers
N/A	Refugee Shelter	You would need a lot of them - could be for people staying near those who are detained/waiting for trial	No	Yes	Third	Community Use (Sleeping)	Low	Low	would need too many units
3	Short term shelter for someone who has land (building, remodeling, flood damage)		Yes	Yes	First	Community Use (Sleeping)	Medium	Low	Cheap single home unit - it just a tiny hosue
3	Church/Community Center	Like Guadalupanos?	Yes	Yes	First	Community Use (Sleeping)	High	Low	
2	Disaster Relief	Emergency Responder Housing	Yes	No	First	Disaster Relief	High	High	Diasters could be varying (earthquake in Bay, Forest Fire), likely for emergency responders not for those displaced
6	Medical Quarentine Area/Medical Treatment Center	In case someone has contagious disease/used to treat those affected by natural disaster	Yes	No	Second	Disaster Relief	Medium	High	
4	Space for Studying (After-School Program)	Make a full development	Yes	Yes	First	Education	High	Low	
3	University Housing - homeless students		Yes	Yes	First	Education	High	Medium	
4	Tutor space	Similar to others... maybe just education space	Yes	Yes	First	Education	High	Low	
1	Joining Units	Modularization	Yes	No	First	Full Re-Design	High	High	
1	Look into Complete Redesign	Could include using different materials,	No	No	Third	Full Re-Design	High	High	
2	Evaluate Mobility/Placement Issues	Possible if they want to move the units around much more, site to site --> one issue is foundation when ground is sloped (use jacks?)	Yes	Yes	First	Full Re-Design	High	Medium	Supplements other design initiatives
3/4	Sell After BHC	Improve the Units. Likely include adding plumbing, utilities	Yes	Yes	First	Sell to Consumer	Medium	Medium	
4	Use as offices (work "from home" perse)		Yes	Yes	First	Sell to Consumer	High	Low	
4	Use as Rental - like a trailer		Yes	Yes	First	Sell to Consumer	Low	Medium	
4	Storage Shed		Yes	Yes	First	Sell to Consumer	High	Low	
8	Recording Studio	Some acoustical changes required	Yes	Yes	Second	Sell to Consumer	Low	Low	Can simply be advertised as having this use.