The University of Iowa
IOWA INITIATIVE FOR SUSTAINABLE COMMUNITIES

FINAL DELIVERABLE

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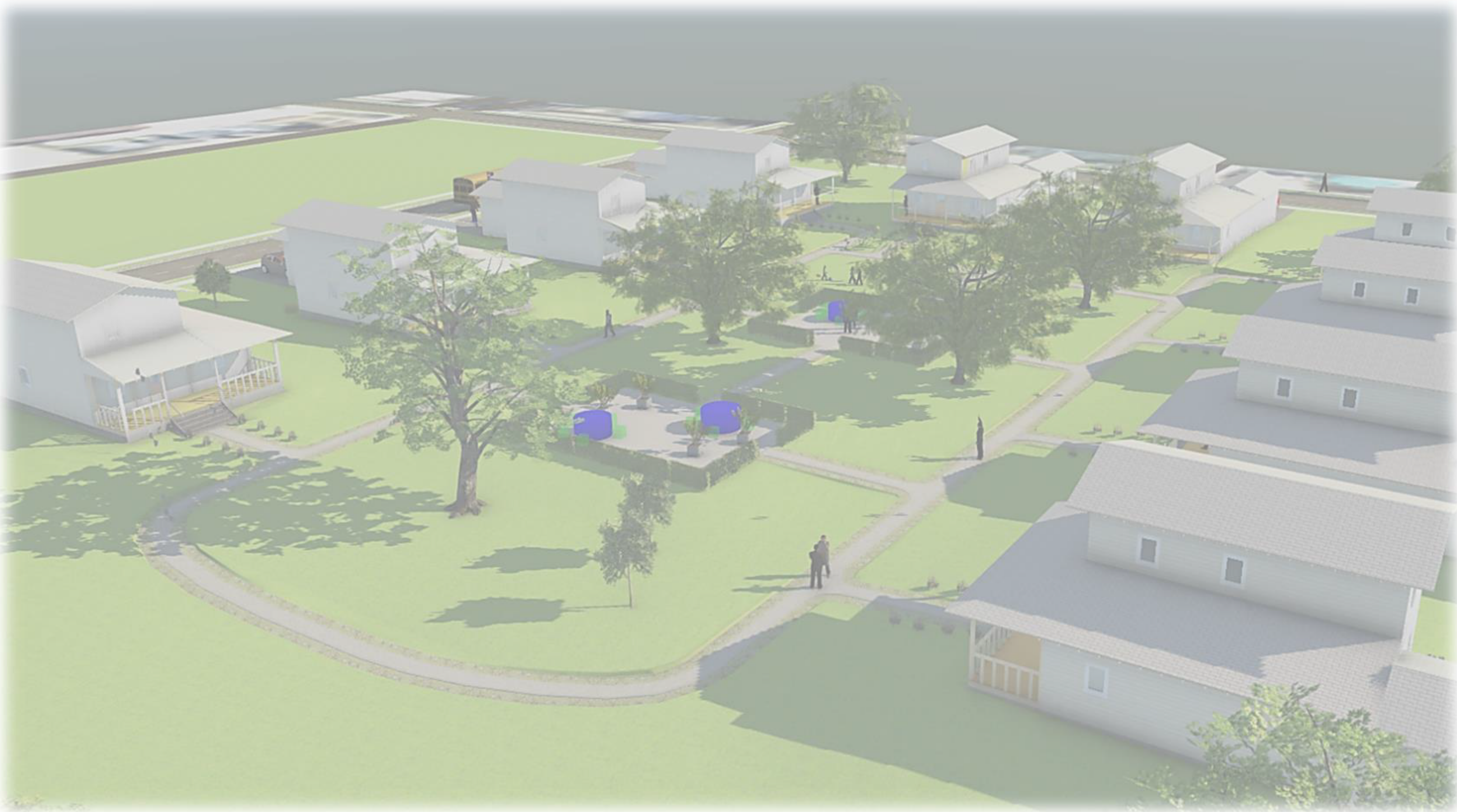
City of Clinton
INFILL DEVELOPMENT



Final Design Report

May 5, 2023

Iowa City, IA 52242

The University of Iowa | College of Engineering

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Section I – Executive Summary

The following document outlines the recommended infill development plans and alternatives for the city of Clinton, Iowa by a design team of University of Iowa seniors: Ryan Carlson (project manager), Sofie Stribos, Jacob Tobey, and Josemaria Espinoza. They provided their wide range of experience in structures, mechanics, and materials.

Infill development is defined as the development of underutilized or vacant land in existing urban areas. By making use of existing utility and transportation infrastructure, infill is an environmentally sustainable and valuable option for urban growth given Clinton's dire need for housing stock of all levels. Spurred by a stricter approach toward condemning derelict or abandoned properties in the last five years, Clinton currently has 233 vacant city owned lots and more than 1,000 vacant lots total.

The purpose of this infill development project was to evaluate, design, and provide plans for several spec buildings that could be built on vacant lots scattered around the city of Clinton. In addition to providing deliverables that included 3D renderings, design drawings, architectural sheets, site layouts, cost estimates, and phasing plans, there was an added emphasis on having the designs blend into the community both physically and financially. Given a 12-week project duration, the design team was provided with an open scope to pursue and produce the most suitable options. This included single-family, multi-family, commercial, and mixed-use possibilities. After research, field assessment, and communication with those involved, a preferred alternative was decided upon.

We recommend economy style, single-family housing infill for low- to moderate-income earners. Two site locations served as inspiration for this project: Longfellow Heights neighborhood on the southside of Clinton for standalone homes and Hawthorne Park on the northside of Clinton for an emerging pocket neighborhood style layout. Although these locations served as inspiration, it is beneficial to acknowledge these housing designs are to be placed on any vacant lot where city leaders see fit.

The previously mentioned pocket neighborhood can be defined as micro-neighborhoods with a scale of sociability. The arrangement of eight to twelve homes all facing a shared common space like a courtyard fosters neighborhood interaction while maintaining a level of personal privacy for the homeowner. Appealing to retirees seeking to downsize, young families, and single professionals, pocket neighborhoods apply to many demographics and are especially perfect for the growing segment of residents who want a stronger sense of community.

In terms of the alternatives considered, multi-family, commercial, and mixed-use designs never received much traction. It was evident early on and backed by research in conjunction with a team of graduate students in the University of Iowa's School of Planning and Public Affairs that Clinton's number one priority is adequate and affordable housing for low- to moderate-income earners. In terms of items that received traction, modifications to the single-family housing models were created to incorporate a pair of highly sought after features. Attached garages and basements are both key needs for buyers in today's climate, thus making it appropriate to include as options with the base models and design plans.

For the designs themselves, the first is a single story, 840 square foot living area with one bed and one bath. The second is a 1300 square foot living area with three beds and two baths. Both homes are framed with wood and use stucco as the exterior finish. A 225 square foot open front porch is included with each home model. As previously mentioned, models also come with the option for a 300 square foot, one car attached garage and the option for an unfinished basement. Expanding to a two-car garage received strong consideration but was not ultimately included in the design. While each design can act as a standalone infill, variability and creativity is most prominent in the pocket neighborhood layout design. Like the recent $2.5 pocket neighborhood project in Maquoketa, IA, allowing accepted applicable homebuyers to select their preferred lot and house layout further encourages the success of the project. Opposed to a mixed match of one- and two-stories with varying modifications, however, our design renderings incorporate 10 two-story houses with one car attached garages, front porches, and unfinished basements.

The lowest housing model is the single-story, 840-square foot living area without any major modifications like a basement or garage. With excavation, footings, underground piping, roofing, electrical, general contractor overhead, 10% contingency, and a 10% admin cost, the team estimates the price floor for the stand-alone home to cost $169,500. On the opposite end is the price ceiling of $263,000, which is set by a two-story, 1300-square foot living area with a basement and garage. Carrying over into the pocket neighborhood design, if 10 of the $169,500-houses are chosen as the makeup, financers are looking at a total price tag just above $1.7 million. If 10 of the two-story, $263,000 houses are chosen, the price ceiling for the pocket neighborhood project gets set at just under $2.7. Market prices do not exceed these numbers, so steps to close the gap are necessary.

Project financing is where the experienced one of its toughest challenges. The current price of construction materials is high while the housing market in Clinton is low. It was no surprise that a recent study found that for the average 1500-square foot single-family home in Clinton, the total cost of construction exceeds the estimated market price by roughly $80,000. Nothing is getting any cheaper so city leaders willing to sell city-owned lots to developers for as low as $1 is an unfortunate but necessary step to keep this project close to reality. The waiving of administration costs that include inspection and building fees is also up for consideration to minimize costs.

Another cost-effective measure that will need further consideration comes in the form of grants and financing programs. For both the city and the homebuyer, the Iowa Finance Authority, Iowa Economic Development Authority, Eastern Iowa Regional Housing Authority, and the Federal Home Loan Bank are just a few of the potential partners who can offer help in the form of down payment, closing cost, and construction assistance. Additionally, combining these forms of assistance with the potential various loans and community development block grant programs can ultimately reduce the total cost by tens of thousands of dollars.

Even with these financial challenges, the societal impact that infill development will bring to Clinton cannot be underestimated. Infill will revivify neighborhoods by improving appearance, promote community resources by increasing access to local destinations, restrengthen the city’s finances with increased tax revenue, improve connectivity between residents, and reduce environmental impact by reducing development pressure on outlying areas.

Section II – Organization Qualifications and Experience

Organization and Design Team Description

We are a team composed of four students at the University of Iowa, all of whom are enrolled in the senior capstone design class for the Department of Civil and Environmental Engineering. The team is led by project manager Ryan Carlson who specializes in management. Ryan oversaw the entire project through to its closure, communicated with the client, monitored project progress, and was responsible for preparing meetings and presentations. Sofie Stribos and Jacob Tobey specialize in structures, mechanics, and materials. They performed the structural design and analysis for this project. Josemaria Espinoza specializes in pre-architecture. His substantive work consisted of architectural and structural design through drafting software.

Section III – Design Services

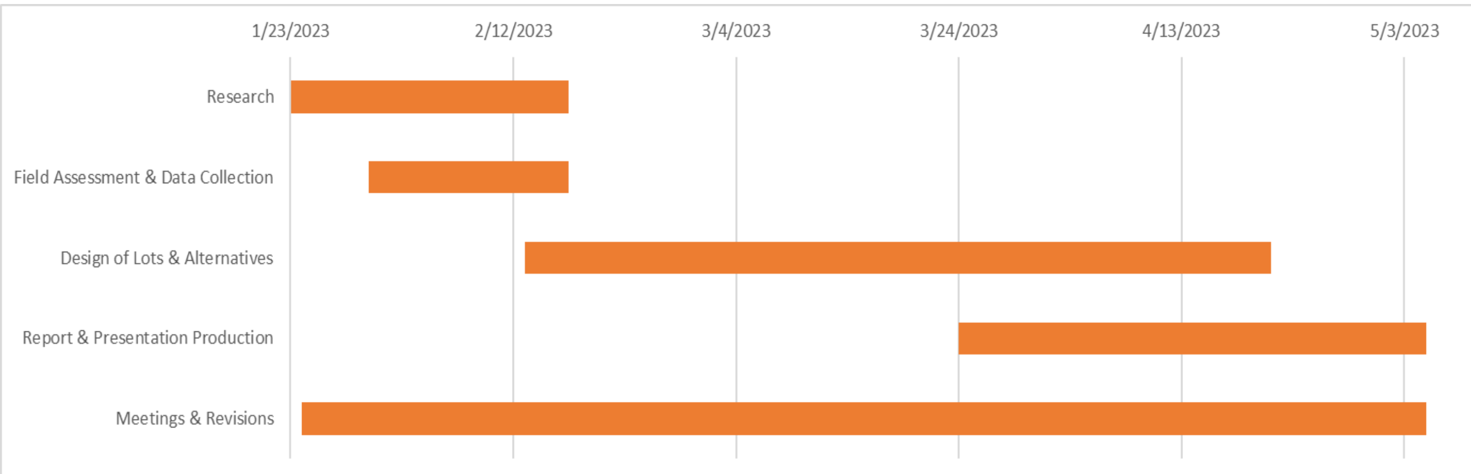
Project Scope

The City of Clinton, Iowa, wants to reimagine areas of their city that are currently underutilized. Looking to develop several empty lots scattered around their community, the design team was asked to repurpose the current dynamic and provide the city with a greater sense of community by providing the city with a handful of designs and building plans. The first task was to evaluate city owned lots and select one to three that can support several structural alternatives in terms of use and design. This included commercial options, mixed-use, multi-family, and single-family designs. After extensive research and discussion, we worked to provide the collection of design plans for single-family housing. This included one- and two-story building models, design drawings, architectural sheets, site layouts, cost estimates, and phasing plans.

Work Plan

To implement our design work, the plan for the duration of the 12-week project period was straightforward. For the first few weeks, research was conducted on the City of Clinton as well as on similar infill projects. While research was being finalized, the team conducted a site visit and data collection commenced for design possibilities. Three weeks into the duration, the modeling of building designs and site layout occupied the next two months. Toward the end of design, the final four weeks were spent focused on the professional report and presentation production. Throughout the project's duration, weekly meetings with advisors and milestone meetings with the client were conducted. This gave all members the opportunity to remain involved and provide their thoughts about the progress. This also allowed the team to make revisions along the way so the final deliverables could exceed client expectations. In terms of subtasks necessary to reach project completion, Ryan oversaw the reporting and cost estimates, Sofie was responsible for modeling through Revit and InfraWorks, Jacob was responsible for site layouts and drawings created using Civil3D, and Josemaria oversaw and completed the architectural design and drawings on Revit.

Graph 1: Gantt chart showing work plan for major tasks



Section IV – Constraints, Challenges, and Impacts

Constraints

The Clinton infill project was constrained in a few ways. First and foremost was the project duration. A 12-week timeline to provide final designs and plans for spec buildings was constrained even further with drafts for final work products due in eight weeks. The project was completed to the highest standard thanks to proper time management and planning, but the timeframe limited the team's ability to produce a larger number and complexity of designs.

Other factors that constrained the team were parcel and zoning requirements. Depending on the flexibility of the city with ordinances, parcel dimensions had the potential to play a significant role in constraining the design of our structure. With infill projects specifically, odd parcel configurations limit the sizing and design of the spec buildings. Using minimum square footing and building offsets as examples, single-family homes, apartment complexes, and commercial units all needed to comply with city codes.

Moreover, the zoning requirements and city ordinances represented a constraining aspect in the design. The city designates certain lots under a zone that prohibits certain buildings based on their intended use. Residential, commercial, or mixed-use buildings are all constrained in terms of placement around the city. The design team needed to consider what each lot allowed in terms of building type and adjust project plans accordingly.

Challenges

The overarching challenge to this project was to revitalize Clinton's sense of community. This was more important than filling an empty lot with a basic single-family home or commercial building. We took on the challenge of providing designs that will help strengthen relationships and improve community vibrancy. The successful design provides opportunities for residents to engage with their surroundings and generates an overarching feeling that Clinton is a place residents are happy to call home.

Figure 1: Resident engagement improves with pocket neighborhood layout

In most cases, the cost of land is a big challenge for those looking at infill. The construction costs alone make it hard to build any type of structure and turn a profit so adding on the purchase of a parcel that can cost tens of thousands of dollars to begin construction turns away many developers. For Clinton, however, community leaders are more than willing to resolve this challenge. The need for adequate and affordable housing is so large, the city is offering to sell vacant parcels to developers for prices as low as $1. Eliminating land acquisition costs certainly helps fight the fiscal challenge of developing infill, but it does not solve it completely.

As previously stated, the cost of construction materials and methods are at all-time highs. A recent study conducted by Alyssa Shaeffer and her team of fellow graduate students in the School of Planning and Public Affairs at the University of Iowa (Appendix C) found that for the average 1500-square foot single family home in Clinton, the total cost of construction exceeds the estimated market price by over $80,000. Cutting into this difference requires the implementation of low-cost construction materials and methods. Cost estimates required pinpoint accuracy as the margin for error regarding cost overruns is slim and the pursuance of applicable funding programs occupied numerous hours. This is a serious challenge but one that had to be addressed so that developers have a realistic opportunity to take on a design like this and make infill a reality for Clinton.

A unique challenge for the team was the aesthetic of each building design. Finding the right balance of blending into the community while still providing unique characteristics was a must. If the modern designs outshined the existing surrounding infrastructure, further issues would be created. Resistance and push-back from residents would be based on threats to property values. So, one approach that addressed this challenge was with the backside of single-family homes apart of individual infill. The front façade closely mimics neighboring homes, but the backside could display color schemes and/or murals that revitalize alleyways and provide that unique aspect that every community has.

In addition to the fiscal and physical challenges posed by infill, the planning challenge was just as prominent. With a total build cost that can push away many developers, we phased out the project, so it appears more reasonable. Also phasing this project in a way such that daily life for existing residents experienced little to no impact was tricky. Site work, actual construction, as well as interior and exterior finishes were all taken into consideration (Appendix A). In terms of financing, no matter the city partner or lender, the decision remains unsettled as to how many houses go up per year. With the pocket neighborhood, however, the design team recommends putting up the houses next to each other in sequential order and continuing down the line if the lots do not sell immediately.

Societal Impact within the Community and State of Iowa

Infill development within urban zones has shown many opportunities within the communities and the State of Iowa. By redeveloping vacant lots, urban infill projects create more environmentally and socially sustainable cities. It addresses sprawl and its associated problems while revitalizing and growing existing communities. Infill also promotes community resources, strengthens local economies, improves community connectivity, and reduces environmental impact. It can also revitalize the community by improving the community's appearance and increasing accessibility to jobs, entertainment, and daily activities. This kind of development positively supports the area surrounding it and its community. It improves community vibrancy, reputation and attracts people and businesses to the area. In addition, this kind of urban project offers opportunities to adapt to the current needs of the communities.

A key goal of this project is to enhance neighborhood connectivity. This project focuses on providing adequate, affordable housing options and a common space for citizens to interact and connect. Infill development increases access to local destinations that expand economic development opportunities and ensure the built environment addresses community needs and values. This infill project emphasizes connectivity throughout the community with minimal economic disadvantage for the existing population. Infill projects mean more people living in the heart of a community, which means less money needs to be spent on general urban infrastructure such as transportation and utility connections. In addition, building on these vacant urban lots with new and functional infrastructure is financially appealing for the city of Clinton. Rises in tax revenue for the city results in an increased ability to invest in infrastructure and in the community.

Investing in existing infrastructure promotes connectivity and trust between neighbors, enhances safety and discourages crime. Infill projects reduce the gaps in activity between existing destinations which in turn reduces safety risks. Further, infill projects have readily available local resources to protect the neighborhood. The empty lots already have close access to amenities such as hospitals, police stations, fire protection, and schools.

The development of infill projects is critical to accommodate growth and redesign our cities to be environmentally sustainable. Unused and vacant urban lands have an environmental benefit because they reduce development pressure on the outlying areas of a city and encourage the preservation of agricultural space and wildlife habitat. In addition, infill projects allow community members to decrease their daily commute, reduce regional vehicle emissions, and improve a city's overall air quality.

Section V – Alternative Solutions Used and Considered

Design Focused

Figure 2: Back view of pocket neighborhood rendering

The preferred alternative for infill development in Clinton is the single-family house in the economy class because low construction costs are more important than distinctive features. Factors leading to this decision were influenced by the need for adequate and affordable housing. Currently, roughly 7,500 people who work in Clinton choose to live outside the city; this does not promote future growth. This alternative will establish a stronger community, provide an opportunity for the aging population to find suitable housing, and give young and hopeful residents a place to establish roots. It also provides one solution to the current problem of higher income residents purchasing housing intended for lower-income demographics and squeezing them out of the market.

Although duplexes and townhomes would provide more units and cost less per unit than single-family, standalone housing, the latter was chosen due to its high demand. The major disadvantage to this is that commercial options that attract more business to the city are put on the backburner. This is countered, however, by a soon to be rejuvenated population that already supports the current businesses in town.

Figure 3: Front view of 1-story home & back view of 2-story home

After evaluation, two site alternatives were considered for two different approaches. The Longfellow Heights neighborhood on the south side of Clinton is for standalone infill (Figure 4). This neighborhood is characterized by smaller, single-story houses with wood as the main construction material. Bringing a greater sense of togetherness to a relatively newer area for low- to medium-income earners did not take much consideration. From the very beginning, city staff emphasized this location, and after visiting the site, it was easy to see the site is primed for infill.

Figure 4: Vacant, city-owned lots in Longfellow Heights neighborhood highlighted yellow

Figure 5: Back view of 2-story housing option (right) for lots in Longfellow Heights (left)

The other site alternative brings a unique and innovative idea to Clinton for the first time. Pocket neighborhoods offer a more accessible way of socializing in a neighborhood. The arrangement of houses around a shared common space fosters neighborhood interactions while preserving residents' personal privacy. Located in the northern part of downtown Clinton along Ninth Ave N lies Horseshoe and Hawthorne Park (Figure 6). Ten horseshoe courts sit on the southeast corner and a rundown basketball court and parking lot sit on the northeast corner. Level, empty space with a few large trees occupying the rest of 20 city-owned lots made this location intriguing. There are obstacles to relocating these park features, but the size, location, and surrounding infrastructure provided an opportunity for a unique design.

Figure 6: City owned Hawthorne and Horseshoe Park highlighted yellow

Figure 7: Hawthorne Park (left) with pocket neighborhood layout rendering (right)

Once economy single-family style housing was identified as the direction the design team wanted to take, a handful of useful alternative features were identified in conversation with the city. The first feature was a one-story versus a two-story home. With a $150,000 target cost, back calculation and online housing layouts serving as inspiration, the living areas for the homes were sized at 840- and 1300-square feet, respectively. Offering two different sizes with similar floor plans provides slight variability to the empty lots and to the demographic this project can impact.

Another alternative feature is a potential garage. Due to weather, including snow and potential damaging storms, the city expressed concerns that residents have car coverings. In terms of style, an attached garage was chosen as opposed to a detached garage merely because of the increase in price a detached garage would incur (Appendix B). With the Longfellow Heights location, this garage addition alternative fits into the community given that attached and detached garages are both present. In the case of a pocket neighborhood, the model includes garages. Many prospective buyers want a two-car garage, so it must be noted that the adjustment can be made for an additional $10,000. If cost becomes too much of a factor, this feature can be removed from the one- and two-story models. While not designed, the concerning lack of parking can be addressed by adding a large car port or lot with a constructed overhead covering on the south side of the neighborhood. Finding ways to designate the port just for pocket neighborhood residents or open it to surrounding residents lies with the city.

Figure 8: Rendering of 2-story house with one car attached garage alternative

The third alternative feature that was considered in the single-family house design was an unfinished basement below ground. The price increase is relevant but cheap considering it is only a matter of excavation and poured material. It makes a great location for mechanical utilities and if properly installed, can reduce problems with crawl space moisture, insulation, and infestation. More potential square footage to be finished is valuable for all involved. Many residents will feel safer if they have a place to go during weather events. The design team felt it was an especially important alternative to include given that a safe room on the first-floor layout was not created.

In terms of the aesthetic constraint, four alternatives for framing and façade offered different price points to consider. Three of the four are framed with wood. These three wood frames display wood siding, brick veneer, or stucco. The fourth alternative was painted concrete block and carries the second lowest price point behind the stucco on a wood frame alternative. This stucco finish with wood frame was ultimately the exterior finish chosen and remains as the strong recommendation given that price plays such an important factor.

Cost Effective Focused

Early in the process, cost effective solutions to single family housing included the idea of tiny homes and 3D printed housing. However, further research revealed that tiny homes, which were defined as no more than 500-square feet, fall into a market that is more niche than originally anticipated. Trying to provide housing at all levels, tiny homes do not currently fit into Clinton's plan. We believe tiny homes are a cost-effective housing strategy for a later time. With 3D housing, the appeal of speed is quickly offset by issues with finishing, plus the added cost and scarce availability of the relatively new technology. These potential alternatives lost traction as the team felt neither met the current needs of Clinton.

With increasing sustainability efforts and advances in manufacturing, prefabricated homes were an alternative to lower costs that did receive further consideration. Also called modular homes, prefabricated homes are manufactured off-site, shipped in sections, and assembled on-site. Noted benefits include optimized material usage, quicker construction time, and reduced labor costs; a general rule is that this method is 10% to 25% cheaper than traditional construction. The major drawback is current public perception, which may be unwarranted, but is a reality; these houses do not sell as well. Another drawback to consider is that financers always run the risk of incurring a hefty price tag with incorrect assembly if inexperienced contractors are selected. Still, the current economy and already known high construction costs make us believe this alternative is worthy of serious consideration. Using the Homes for Iowa program makes it even more enticing. This program, run through the state, uses prisoners at the Iowa State Penitentiary in Newton to build prefabricated house designs, which in turn offers them useful construction skills and prepares them for life after incarceration.

Various materials also received consideration to save costs, the first being the use of recycled building materials. This is a growing trend across the United States given concern about the climate and request for more sustainability measures. Using these materials to offset costs can be furthered by tax incentives and grants provided by many levels of government. The second material we considered were composites that include natural fibers like jute, sisal, and ramie. In addition to helping reduce corrosion, these lightweight composites and materials have proved useful in low stress applications like cladding and internal furnishings. Further research uncovered plenty of other less usual materials worthy of consideration when seeking to minimize costs.

Section VI – Final Design Details

1 and 2-Story Housing Option Renderings and Layouts

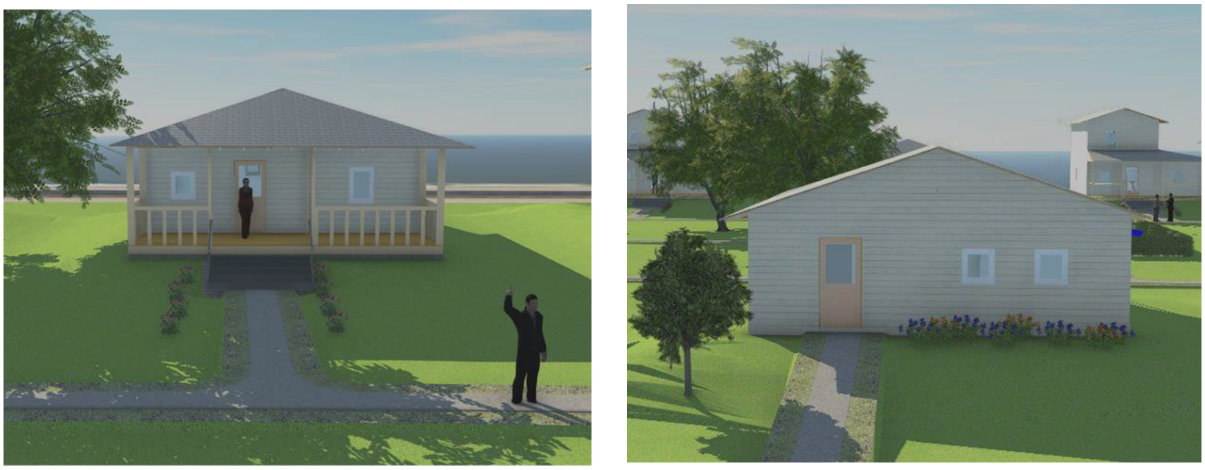


Figure 9: Front (left) and back (right) rendering of 1-story house without garage

Figure 10: Front (left) and back (right) rendering of 2-story house with garage

A 3D visual rendering of the one- and two-story housing options can be seen in Figure 9 and Figure 10. These spacious and modern one- and two-story homes with an outdoor porch, optional basement and garage will consist of a total living area of approximately 840- square feet and 1300-square feet, respectively. The floor-to-ceiling height is approximately eight feet for the basement and nine feet for the first and second floor. For the building dimensions and elevations, see Structural Sheets S- 201, S301-S302 (2-story with garage), S202, S303-S304 (2-story without garage), S203, S305 (1- story with garage), and S204, S306 (1-story without garage) in the separate drawing set.

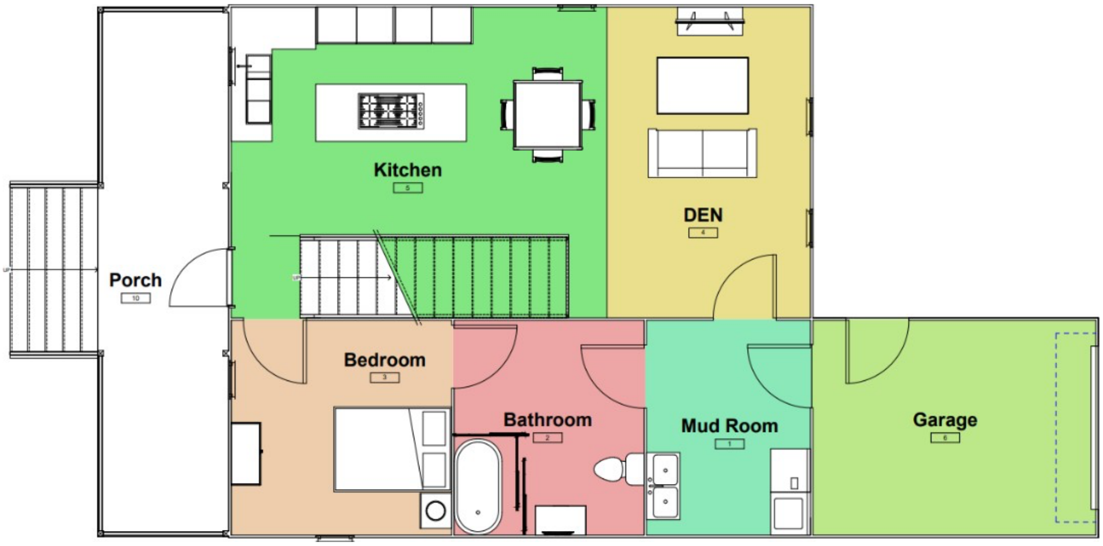


Figure 11: First Floor Layout

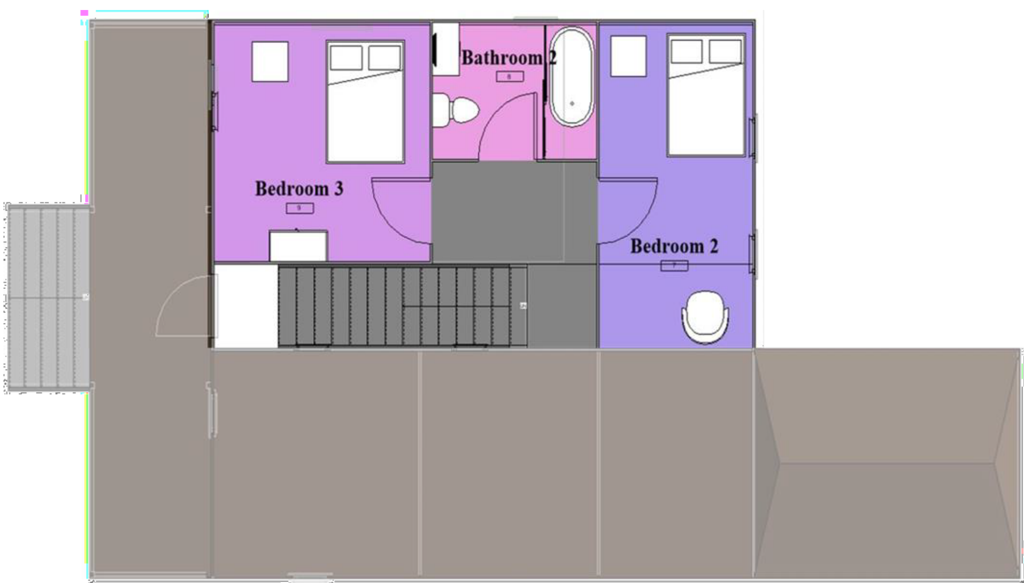


Figure 12: Second Floor Layout

The proposed layout for our first floor and second floor design is shown in Figure 11 and 12, respectively. The one- and two-story housing options have identical first floor layouts consisting of a modern kitchen, living room, a bedroom with attached bath, mud room, and optional basement and garage. The mud room is intended for mechanical and storage space. The front porch allows access to the common garden, which fosters interaction with neighbors and provides outside seating. The optional attached garage consists of 300-square foot area and is designed for the capacity of one parking space. The optional unfinished basement can be accessed via the stairs and serves as extra storage and utility space. The two-story option is designed with an additional staircase, giving access to the bathroom and two bedrooms. For more detailed architectural layouts see Architectural Sheets AR-101 for the first floor and AR-201 for the second-floor layout

Structural Design Elements

The structural system of the one- and two-story house consists of a wood framing structure. To design each element of this house, the applied wind, snow, dead load, and live loads were determined using ASCE (American Society of Civil Engineers) 7-22. For detailed calculation refer to *Design Calculation Report Clinton Infill: 2 Story House – SJJR*.

Roof Framing System:

The main roof system for the two-story housing option is a typical Fink Truss spanning 16'-4', spaced 24 inches on center, a 4/12 roof pitch, two-feet overhang, and a ¾ inch plywood sheathing on top. A Fink Truss is typical for a small span residential truss. The top chord and the interior web members are made of 2x4 Southern Pine No.2 while the bottom chord is a 2x6 Southern Pine No.2.

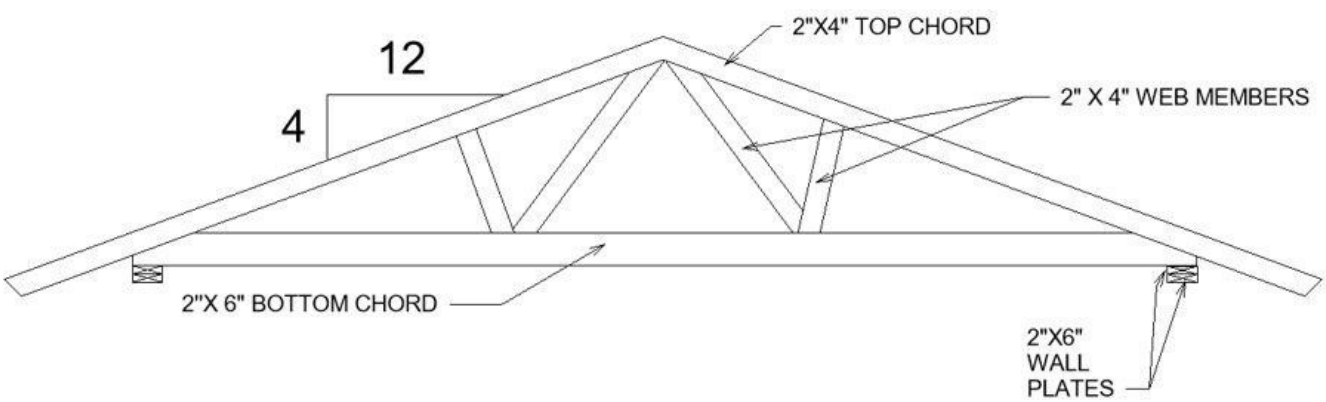


Figure 13: Fink Truss

The roof system on the first floor of the two-story house was designed as a residential mono Fink Truss spaced 24-inches on center, a 2/12 roof pitch, a two feet overhang, and a ¾ inch plywood sheathing on top. This truss system is made of 2x4 Southern Pine web and top chord members and a 2x6 Southern Pine bottom chord. All members were checked for tension, compression, combined bending, and deflection, following the National Design Specification for Wood Construction manual (NDS 2018). A Robot Structural analysis software model allowed a complete analysis of the system. See *Design Calculation Report Clinton Infill: 2 Story House.*

Floor Framing System:

The framing system for the first and second floors is composed of floor joist assumed to be 2x8 Southern Pine No.2 spaced 16-inches on center. The joists were checked for bending, shear and deflection following the National Design Specification for Wood Construction manual and using simple structural analysis. The joist system is covered with a ¾ inch OSB sheathing, these two elements are designed to sustain the gravity and lateral load applied on the structure and transfer them to supporting shear walls through diaphragm action. These elements are designed to sustain bending, shear, bearing stress and deflection. See *Design Calculation Report Clinton Infill: 2 Story House – SJJR.*

Wall Framing System:

The wall framing system for this residential structure is composed of the following elements: 2x8 Southern Pine No.2 bottom plate, 2x6 Southern Pine No.2 wall studs spaced 16-inches on center, double 2x8 Southern Pine top plate and 2x8 Southern Pine rim joist. These elements need to be designed to support gravity loads from roofs and floors and transfer the loads to the foundation. These elements are designed to sustain bending, shear, bearing stress and deflection. See *Design Calculation Report Clinton Infill: 2 Story House – SJJR.*

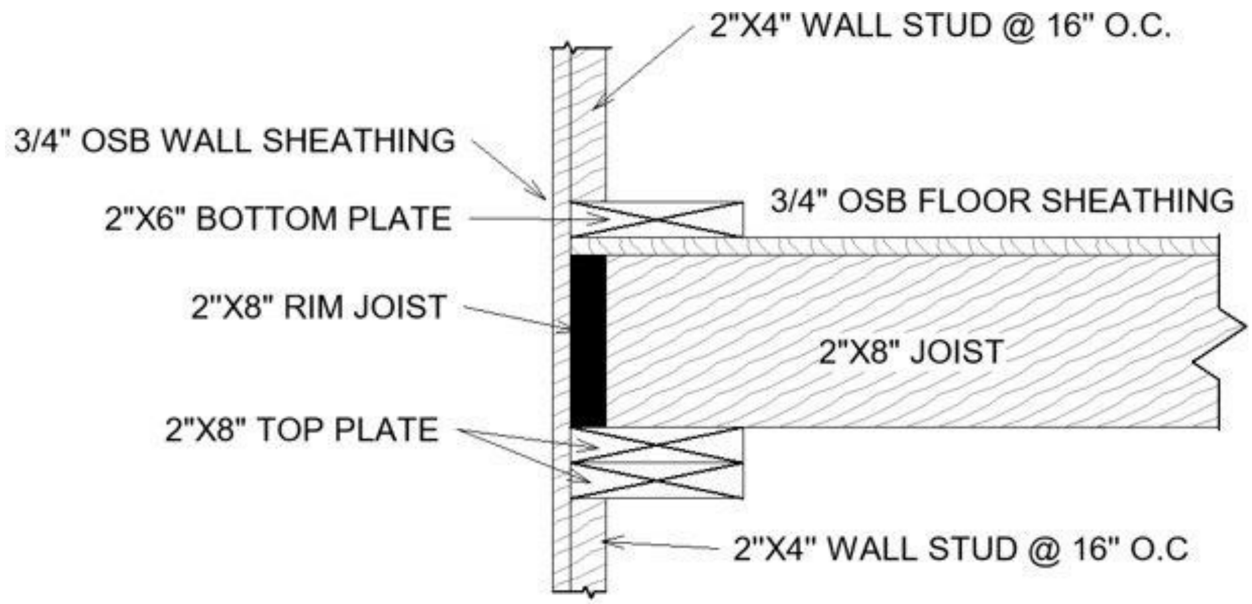


Figure 14: Wall Framing System

Foundation:

The foundation plan revolves around the decision of whether the home would include an unfinished basement. Not having a basement reduces some of the cost as there will be less materials used in foundation construction. Underneath the four-inch-thick floor slab will be a nine-inch-thick, cast-in-place concrete foundation wall. This wall will wrap around the house's perimeter and a wall down the center directly beneath the bearing wall. The foundation walls will provide stability for the house and some weather protection. The foundation will extend 4 1/2 feet into the ground to reach the frost line depth of 50-inches. A continuous footing resting under the center of the foundation wall is to be six-inchesthick and 18-inches-wide of cast-in-place of concrete. Given that specific soil information varies between each potential site, the load bearing value for the soil was assumed for the location average. This allowed us to create a preliminary design and then used Terzaghi's equation to check if the design was adequate.

The foundation for the houses with an unfinished basement is similar to the no-basement design with a few changes. A nine-inch-thick foundation wall extends eight feet into the ground with a six-inch concrete slab placed on top of the footing of the foundation. The dimensions for the foundation footings were analyzed using Terzaghi's equation to find the allowable bearing soil pressure. This value was compared to the assumed value to determine the adequacy of our design. After the calculations were completed, the adequate width for the foundation was determined to be three feet with a height of three feet. The International Building Code (IBC) was followed to check that results were under compliance, and the Council of American Building Officials (CABO) One- and Two-Family Dwelling Code was used as a reference for the results. The details for the basement foundation design are located on the second page of the structural sheets found separate to this report.

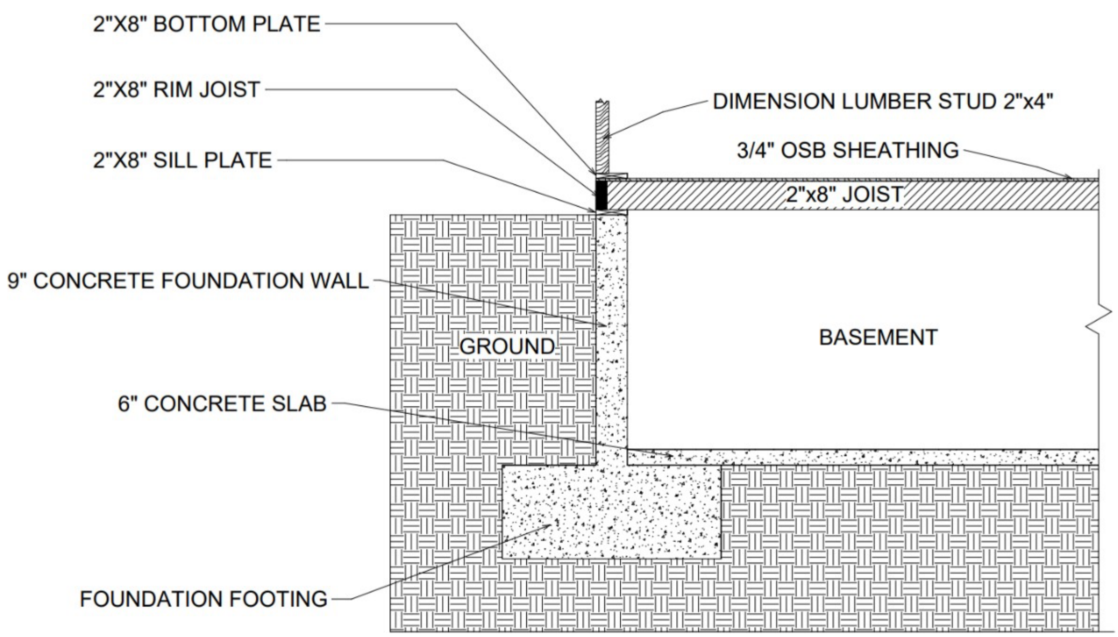


Figure 15: Foundation Section View

Section VII – Engineer's Cost Estimate

Summary Breakdown

Cost estimates for each home were based on square foot costs for RSMeans data from 2018. An inflation factor of 1.19 was used based on research. The lowest housing model is the single story, 840-square foot living area without any major modifications like a basement or garage. With excavation, footings, underground piping, roofing, electrical, general contractor overhead, 10% contingency, and a 10% admin cost, we estimate the price floor for an individual model at $169,500. On the opposite end is the price ceiling of $263,000 for the two-story, 1300-square foot living area with unfinished basement and one car attached garage. Summary tables outline these two estimates in Figure 16. Note that the unfinished basement modification is estimated to cost $13,000, while the one car attached garage is estimated at roughly $14,000. If an increase in garage size is desired, financers can expect the two-car attached garage to cost roughly $24,000 while the three-car option comes in at roughly $33,500.

Low Cost 1-Story Housing Option (840 SF)	Cost (USD)
Base	$122,117
Modifications: Open Porch	$9,320
Site Work	$9,633
Contingency + Admin Cost	20%
Total Estimated Cost	**$169,500**

High Cost 2-Story Housing Option (1300 SF)	Cost (USD)
Base	$170,664
Modifications: Open Porch + Basement + Garage	$36,833
Site Work	$11,568
Contingency + Admin Cost	20%
Total Estimated Cost	**$263,000**

Figure 16: Summary tables outlining price floor and ceiling for individual housing options.

For the pocket neighborhood design, if 10 of the $169,500 base model houses are chosen as the makeup, financers are looking at a total price tag just north of $1.7 million. If 10 of the $263,000 houses are chosen, the price ceiling is set at just under $2.7 million. As shown in Figure 17, these summary tables for pocket neighborhood estimates include the inner path, two central patios, and landscaping necessary to tie the project together. See Appendix B for more detailed cost spreadsheets and tables.

Low Cost Pocket Neighborhood Project	Cost (USD)
Housing (10 One-Story Houses Without Garage or Basement)	$1,695,000
Path (5440 SF)	$23,555
Patio (2 x 975 SF)	$8,444
Landscaping	$25,000
Total Estimated Cost	**$1,752,000**

High Cost Pocket Neighborhood Project	Cost (USD)
Housing (10 Two-Story Houses with Garage & Basement)	$2,630,000
Path (5440 SF)	$23,555
Patio (2 x 975 SF)	$8,444
Landscaping	$25,000
Total Estimated Cost	**$2,687,000**

Figure 17: Summary tables outlining price floor and ceiling for pocket neighborhood options.

Following the recent construction of a pocket neighborhood in Maquoketa, IA, a hypothetical target cost of $150,000 was set to determine the necessary square footage based on our appraisals. Changing the base cost per square foot in the cost spreadsheet (Appendix B) and not including the unfinished basement while maintaining key modifications such as the attached garage, a 600-square foot home would cost $133,000. After the 20% contingences and admin costs are added, the home pushes upwards of $160,000. Location plays a key role in price of the 600-square feet single-family home. The team decided this was unreasonable and instead decided the 840- and 1300-square footage living area options were preferable.

Each final design estimate was broken down into a couple key components. Once residence type, square footage, and exterior wall system was known, costs per square foot of living area can be determined from RSMeans data (Appendix B). This includes a base along with any alternatives such as an unfinished basement addition. After the base cost is determined, modifications that come in as unit costs are added, e.g., extra baths, attached one car garages, and porch additions. With a modified base cost, final costs are applied to get a total estimate. These include site improvements, inflation, relocation, contingencies, and final administration costs.

Any costs associated with property acquisition and easements are neglected because the chosen lots are already owned by the city. Cost of material is worked into the square footage costs based on the selected type of exterior wall system. The previously mentioned contingency was selected to be 10% based on industry average. Engineering and administration costs were also set at 10% given that general contractor overhead and profit are included in RSMeans data cost estimate.

Funding Sources

With such a high price tag for each home, financing will need multiple approaches. In an unfortunate but necessary step to keep this project close to reality, we have been made aware that the city is willing to sell the lots to developers for as low as $1. The waiving of administration costs that include inspection and building fees is also up for consideration to minimize costs. Like the approach that Maquoketa used to sell its 1064-square foot pocket neighborhood houses for $150,000, grant funds and financing programs for the city and home buyer will also be crucial to subsidize purchase costs. There are many fine details and requirements that will need to be met, but the following programs were found to be most applicable based on past pocket neighborhood and housing projects in eastern Iowa.

- The Iowa Finance Authority's (IFA) mission is to create opportunities for Iowans, communities, and businesses to thrive by making affordable financing possible for both home and community. For first time homeowners, programs like *FirstHome* can either provide a $2500 down payment and closing cost assistance grant or a 0% loan of up to 5% of the home's sale price. Similarly, *Homes for Iowans* also offers a 0% loan of up to 5% of the home's sale price, repayable upon refinance or sale of home. First time and repeat homebuyers are permitted to apply under this program. Their *Military Homeownership Assistance Program*, which can be used in conjunction with the previously mentioned programs, provides a grant up to $5,000 to eligible service members and veterans for down payments and closing costs assistance.

- Eastern Iowa Regional Housing Corporation Housing Trust Fund (EIRHC HTF) offers funding to cities for housing rehabilitation projects and up to $10,000 in down payment assistance for homebuyers. Like the IFA, their mission is to assist in providing decent, safe, and affordable housing with an emphasis on benefiting the moderate, very low, and extremely low-income residents of Clinton and neighboring counties.

- Another potential funding partner is the Federal Home Loan Bank (FHLB) of Des Moines. In addition to their *Competitive Affordable Housing Program,* which secures funds for the purchase and construction of affordable homeownership, they also administer down payment products that are also offered thanks to their member financial institutions.

From our brief research, it is evident that multiple partners and participating lenders exist in the county. It will require additional steps, detailed applications, lobbying, and knowledge on how to leverage these funds, but acknowledging the willing number of programs that can help bring infill development to life for the city of Clinton provides some much-needed guidance and reassurance.

Appendices

Appendix A - Phasing Plans

Phase 1: Site Work
- Clearing
- Surveying
- Grading
- Excavation
- Utility Access

Phase 2: Construction
- Foundation
- Rough Framing
- MEP
- Insulation & drywall

Phase 4: Interior & Exterior Finishes
- Landscaping
- Paving
- Flooring/Cabinets

Appendix B – Cost Spreadsheets and Tables

Detailed High-Cost Option for Single Story House

Owners Name:	City of Clinton	Appraiser:	Ryan Carlson
Residence Address:	N/A	Project:	Senior Design
City, State, ZIP code:	Clinton, IA, 52732	Date:	May-23

Class of Construction:	Economy	Occupancy:	One Family
Configuration:	Detached	Residence Type:	1 Story
Exterior Wall System:	Stucco on wood frame	Living Area (SF):	840

Base Cost + Alternatives	**Costs per SF Living Area**
Cost per SF of Living Area	123.4
Unfinished Basement, Add	13.03
Sum of Cost per SF of Living Area	136.43
Base Cost	$114,601.20

Base Cost + Modifications	**Unit Cost**	**Total Cost**
		$114,601.20
One Car Attached Garage	$13,994.00	
Open Economy Porch (225 SF)	$7,911.00	
Modified Base Cost	$136,506.20	

Additional Costs	
Modified Base Cost	$136,506.20
Site Work	
Excavation, Strip & Spread Footings, Underground Piping	5%
4" Paving (600 SF)	$2,598.00
	$145,929.51
Inflation Factor	1.19
Location Factor	0.99
Current Location Cost	$171,919.56
Contingency	10%
Engineering & Admin Cost	10%
Total Estimated Cost	**$206,500**

Detailed High-Cost Option for Two-Story House

Owners Name:	City of Clinton	Appraiser:	Ryan Carlson
Residence Address:	N/A	Project:	Senior Design
City, State, ZIP code:	Clinton, IA, 52732	Date:	May-23

Class of Construction:	Economy	Occupancy:	One Family
Configuration:	Detached	Residence Type:	2 Story
Exterior Wall System:	Stucco on wood frame	Living Area (SF):	1300

Base Cost + Alternatives	**Costs per SF Living Area**
Cost per SF of Living Area	108.5
Unfinished Basement, Add	7.2
Sum of Cost per SF of Living Area	115.7
Base Cost	$150,410.00

Base Cost + Modifications	**Unit Cost**	**Total Cost**
		$150,410.00
Bath (including plumbing, wall, and floor finishes)	$3,814.00	
One Car Attached Garage	$13,994.00	
Open Economy Porch (225 SF)	$7,911.00	
Modified Base Cost	$176,129.00	

Additional Costs	
Modified Base Cost	$176,129.00
Site Work	
Excavation, Strip & Spread Footings, Underground Piping	4.1%
4" Paving (600 SF)	$2,598.00
	$185,948.29
Inflation Factor	1.19
Location Factor	0.99
Current Location Cost	$219,065.68
Contingency	10%
Engineering & Admin Cost	10%
Total Estimated Cost	**$263,000**

Base cost per square foot of living area (RSMeans data 2018)

RESIDENTAL Economy 1 Story	Includes: 1 full bath, 1 kitchen, no basement, asphalt shingles, hot air heat & gypsum wallboard interior finishes									
	Living Area									
Exterior Wall	**600**	**800**	**1000**	**1200**	**1400**	**1600**	**1800**	**2000**	**2400**	**2800**
Wood Siding - Wood Frame	147.60	133.20	122.20	113.55	105.85	100.95	98.60	95.25	88.80	84.10
Brick Veneer - Wood Frame	153.35	138.30	126.90	117.70	109.70	104.60	102.05	98.50	91.70	86.80
Stucco on Wood Frame	138.95	125.45	115.20	107.20	100.10	95.60	93.40	90.35	84.30	79.90
Painted Concrete Block	143.95	129.85	119.25	110.90	103.45	98.70	96.40	93.25	86.85	82.30
Finished Basement, Add	33.15	31.2	29.8	28.5	27.5	26.8	26.45	25.9	25.15	24.55
Unfinished Basement, Add	14.85	13.25	12.15	11.1	10.35	9.8	9.55	9.1	8.45	8.00

Modifications

Add to the total cost

Upgrade Kitchen Cabinets	+1216
Solid Surface Countertops	+870
Full Bath - including pulmbing, wall and floor finishes	+6440
Half Bath - including pulmbing, wall and floor finishes	+3814
One Car Attached Garage	+13994
One Car Detached Garage	+18103
Fireplace & Chimney	+6624

Alternatives

Add to or deduct from the cost per square foot of living area

Composition Roof Rolling	-1.05
Cedar Shake Roof	+4.20
Upgrade Walls and Ceilings to Skim Coat Plaster	+0.80
Upgrade Ceilings to Textured Finish	+0.60
Air Conditioning, in Heating Ductwork	+4.79
In Seperate Ductwork	+7.05
Heating Systems, Hot Water	+1.60
Heat Pump	+1.32
Electric Heat	-1.44

RESIDENTAL Economy 2 Story	Includes: 1 full bath, 1 kitchen, no basement, asphalt shingles, hot air heat & gypsum wallboard interior finishes									
	Living Area									
Exterior Wall	**1000**	**1200**	**1400**	**1600**	**1800**	**2000**	**2200**	**2600**	**3000**	**3400**
Wood Siding - Wood Frame	132.05	119.65	113.60	109.45	105.30	100.70	97.65	91.75	86.10	83.55
Brick Veneer - Wood Frame	138.00	125.15	118.70	114.35	109.90	105.15	101.85	95.60	89.70	86.90
Stucco on Wood Frame	123.05	111.35	105.80	102.00	98.35	93.95	91.20	86.00	80.80	78.45
Painted Concrete Block	128.55	116.40	110.55	106.55	102.60	98.05	95.10	89.50	84.05	81.55
Finished Basement, Add	17.4	16.6	16	15.65	15.2	14.95	14.6	14.05	13.65	13.40
Unfinished Basement, Add	8.05	7.45	6.95	6.65	6.3	6.1	5.85	5.35	5.10	4.85

Modifications

Add to the total cost

Upgrade Kitchen Cabinets	+1216
Solid Surface Countertops	+870
Full Bath - including pulmbing, wall and floor finishes	+6440
Half Bath - including pulmbing, wall and floor finishes	+3814
One Car Attached Garage	+13994
One Car Detached Garage	+18103
Fireplace & Chimney	+7318

Alternatives

Add to or deduct from the cost per square foot of living area

Composition Roof Rolling	-0.55
Cedar Shake Roof	+2.10
Upgrade Walls and Ceilings to Skim Coat Plaster	+0.82
Upgrade Ceilings to Textured Finish	+0.60
Air Conditioning, in Heating Ductwork	+2.91
In Seperate Ductwork	+5.68
Heating Systems, Hot Water	+1.48
Heat Pump	+1.53
Electric Heat	-1.00

Low, Middle, and High-Cost Options for Individual Housing & Pocket Neighborhood Options

Low Cost Pocket Neighborhood Project	Cost (USD)
Housing (10 One-Story Houses Without Garage or Basement)	$1,695,000
Path (5440 SF)	$23,555
Patio (2 x 975 SF)	$8,444
Landscaping	$25,000
Total Estimated Cost	**$1,752,000**

Middle Cost Pocket Neighborhood Project	Cost (USD)
Housing (5 One-Story & 5 Two-Story with Basements)	$2,140,000
Path (5440 SF)	$23,555
Patio (2 x 975 SF)	$8,444
Landscaping	$25,000
Total Estimated Cost	**$2,197,000**

Low Cost 1-Story Housing Option (840 SF)	Cost (USD)
Base	$122,117
Modifications: Open Porch	$9,320
Site Work	$9,633
Contingency + Admin Cost	20%
Total Estimated Cost	**$169,500**

Middle Cost 1-Story Housing Option (840 SF)	Cost (USD)
Base	$122,117
Modifications: Open Porch + Basement	$22,214
Site Work	$10,277
Contingency + Admin Cost	20%
Total Estimated Cost	**$185,500**

Low Cost 2-Story Housing Option (1300 SF)	Cost (USD)
Base	$170,664
Modifications: Open Porch	$9,320
Site Work	$10,440
Contingency + Admin Cost	20%
Total Estimated Cost	**$228,500**

Middle Cost 2-Story Housing Option (1300 SF)	Cost (USD)
Base	$170,664
Modifications: Open Porch + Basement	$20,347
Site Work	$10,892
Contingency + Admin Cost	20%
Total Estimated Cost	**$242,500**

High Cost Pocket Neighborhood Project	Cost (USD)
Housing (10 Two-Story Houses with Garage & Basement)	$2,630,000
Path (5440 SF)	$23,555
Patio (2 x 975 SF)	$8,444
Landscaping	$25,000
Total Estimated Cost	**$2,687,000**

High Cost 1-Story Housing Option (840 SF)	Cost (USD)
Base	$122,117
Modifications: Open Porch + Basement + Garage	$38,701
Site Work	$11,102
Contingency + Admin Cost	20%
Total Estimated Cost	**$206,500**

High Cost 2-Story Housing Option (1300 SF)	Cost (USD)
Base	$170,664
Modifications: Open Porch + Basement + Garage	$36,833
Site Work	$11,568
Contingency + Admin Cost	20%
Total Estimated Cost	**$263,000**

Appendix C: Bibliography (Design Specifications, Standards, & Guidelines)

American Legal Publishing (2023). *City of Clinton, Iowa: Code of Ordinances*

American Society of Civil Engineers (2021). *ASCE/SEI 7-22: Minimum Design Loads and Associated Criteria for Buildings and Other Structures*

American Wood Council's Wood Design Standards Committee (2018). *National Design Specification (NDS) for Wood Construction*

International Code Council (2021). *International Building Code*

University of Iowa School of Planning and Public Affairs: Alyssa Schaeffer, Mae McDonough, Maeve Biscupski, Matt Hodges, Olivia Galyon, & S M Samiul Islam (2023). *Clinton Housing Needs & Strategies*

Design Renderings & Models

Figure A: InfraWorks model of single-story home

Figure B: InfraWorks model of two-story home

Figure C: InfraWorks model showing garage attached to two-story home

Figure D: InfraWorks model showing overview of pocket neighborhood layout

Figure E: InfraWorks model showing overview of pocket neighborhood layout

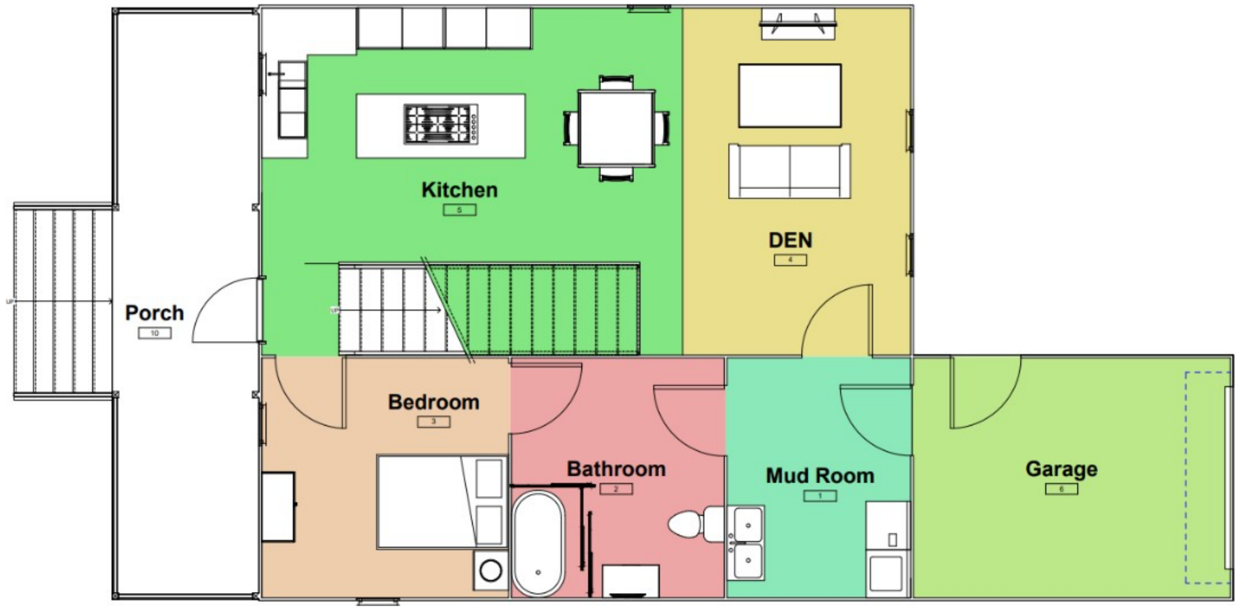


Figure F: Architectural layout of first floor for one- and two-story home

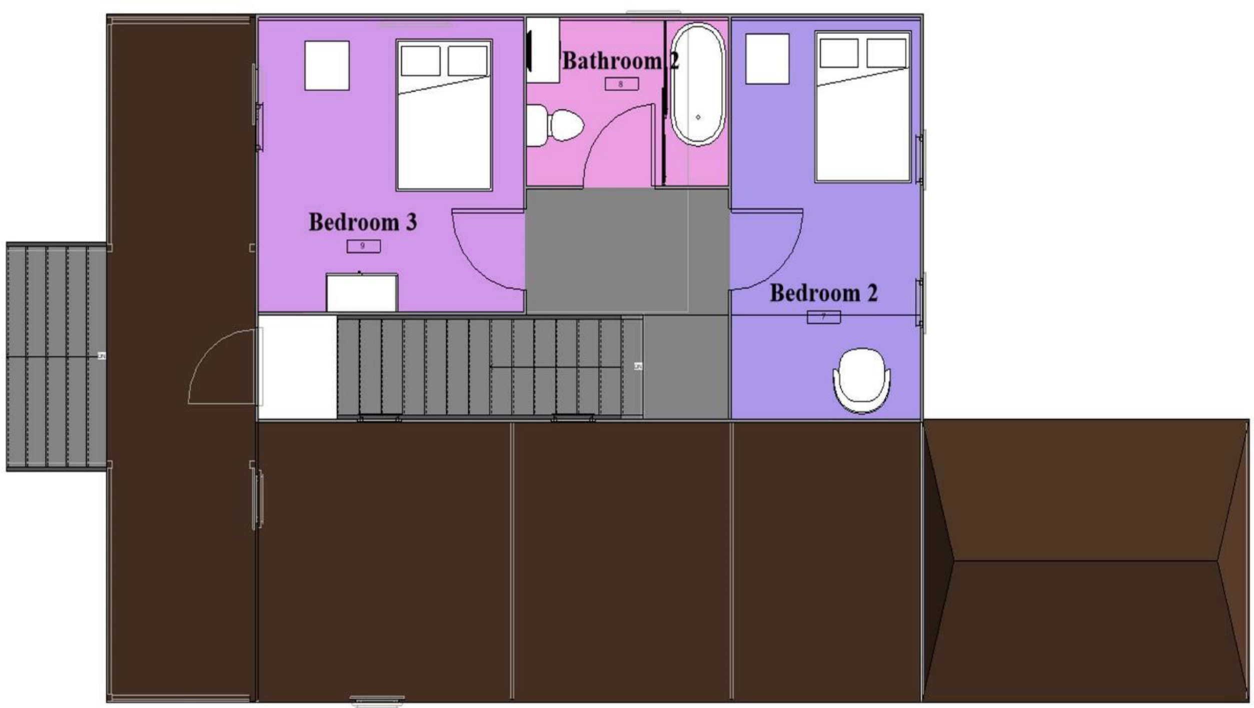


Figure G: Architectural layout of second floor for two-story home

Figure H: Framing of two-story home

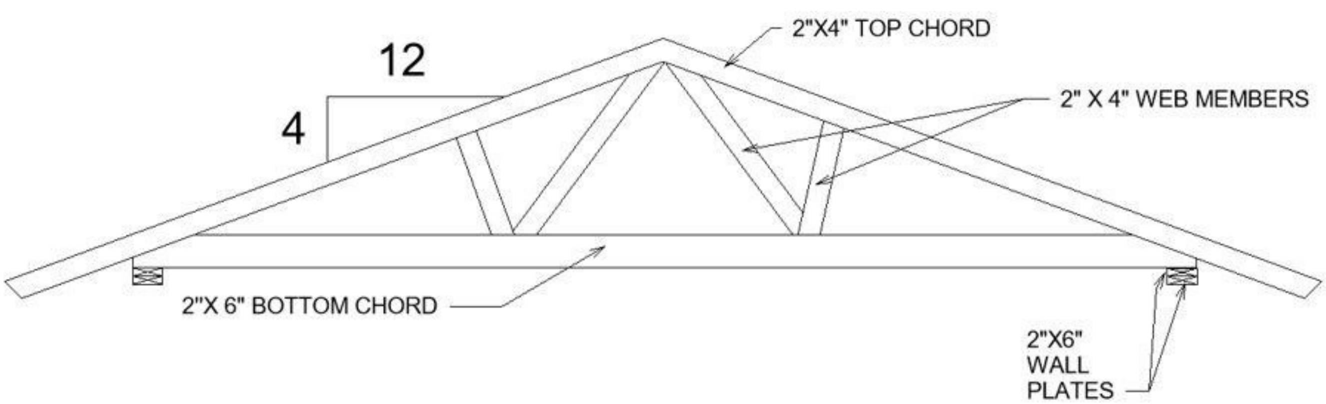


Figure I: Fink Truss – 16’4” Span

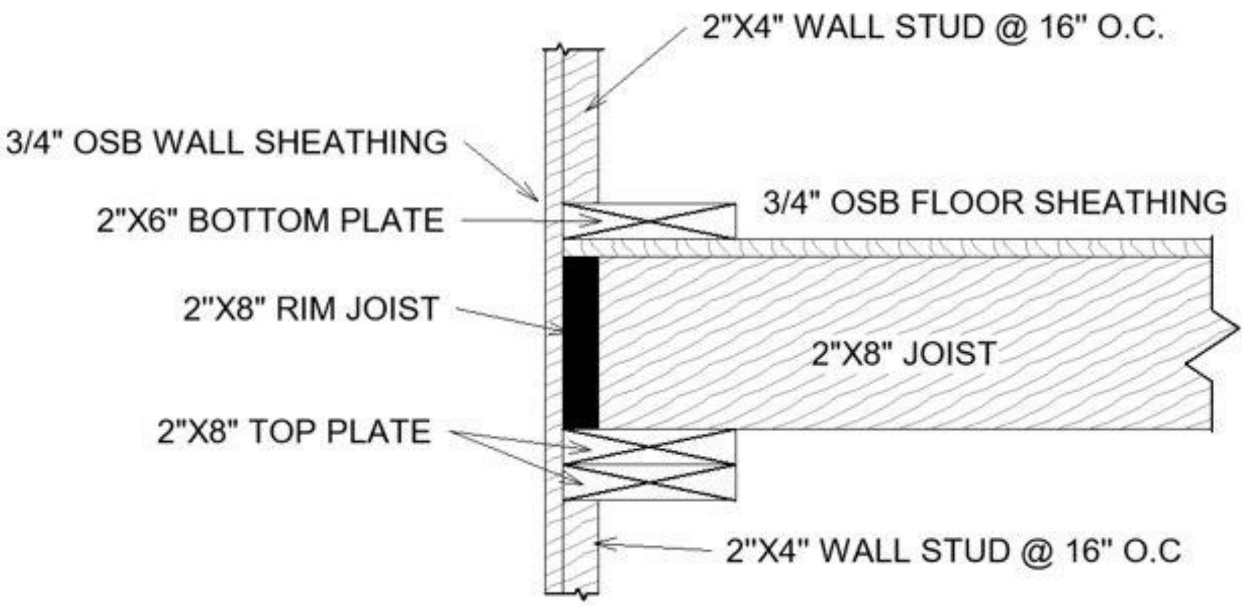


Figure J: Wall Framing

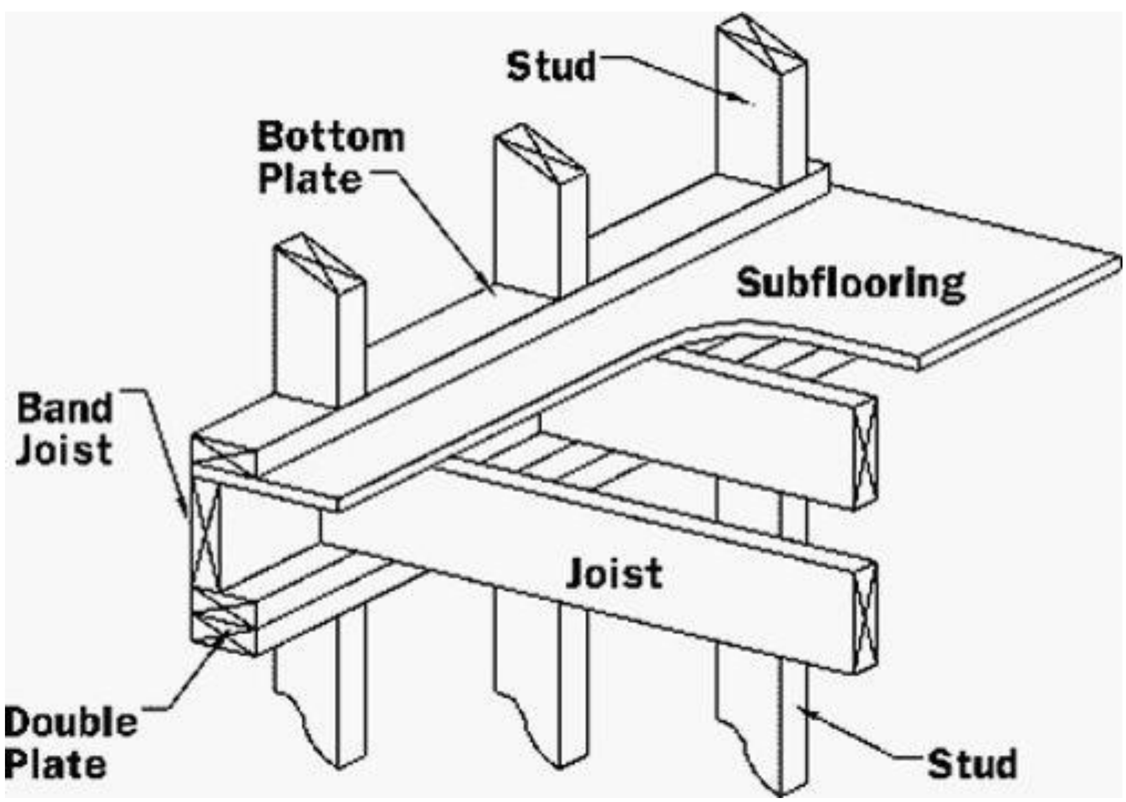


Figure K: Floor System

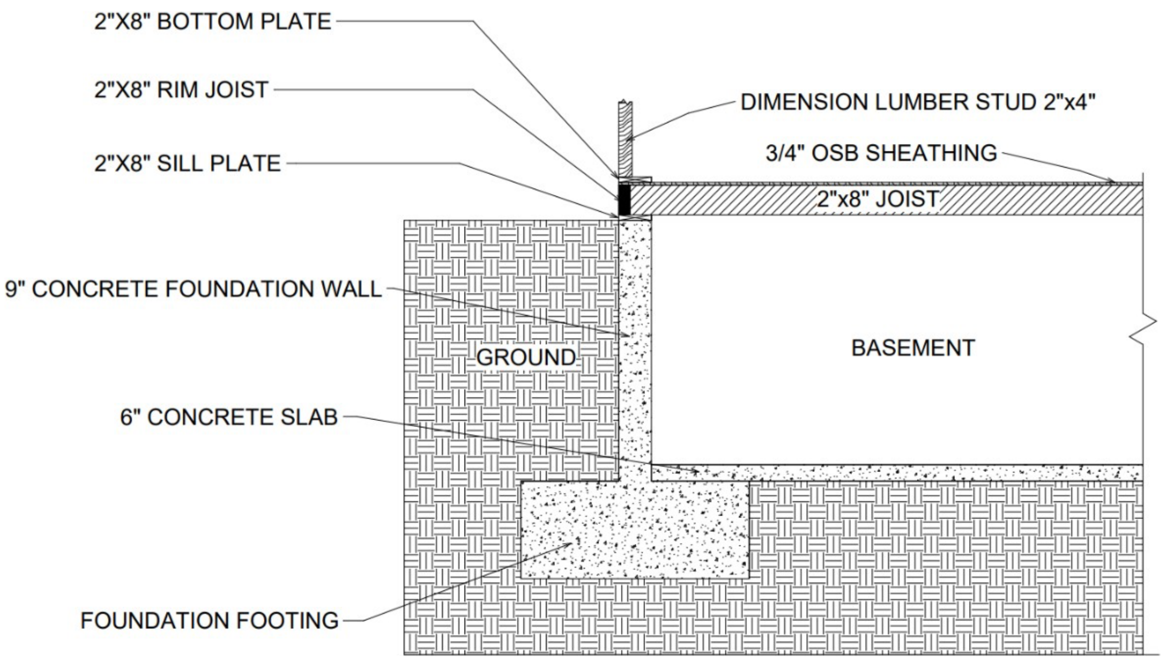


Figure L: Foundation

Design Calculation Report

Clinton Infill: 2-Story House

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Calculation Report of Design Loads:

Calculation Report of Roof Framing Design:

Calculation Report of Lateral Loads:

Calculation Report of Foundation:

Calculation of Floor Framing Design:

Calculation Report of Design Loads

Clinton Infill

Dead loads Upper Roof:

Table C3-1: Minimum Design Dead Loads (ASCE 7-22 chap.3)

- Asphalt Shingles: $D_{L\_tiles} := 2\ psf$
- Self-adhering waterproofing membrane: $D_{L\_wm} := 0.7\ psf$
- 1/2" OSB roof sheathing: $D_{L\_roofsheathing} := 0.4\ psf \cdot 4 = 0.011\ psi$
- Trusses@24" O.C (based on Southern Pine and Top chord 2x6):

$$D_{L\_Truss} := 3.5\ psf + 1.5\ psf = 5\ psf$$

WOOD TRUSSES - (APPROXIMATE)

Based on Southern Pine

Top Chord	Bottom Chord	PLF	24" oc.
2x4	2x4	5.2	2.6
2x6	2x4	6.1	3.1
2x6	2x6	6.9	3.5
2x8	2x6	7.8	3.9
2x8	2x8	8.5	4.3
2x10	2x8	9.3	4.7
2x10	2x10	10.1	5.2
2x12	2x10	10.9	5.5
2x12	2x12	11.6	5.8

We suggest the addition of 1.5 psf for misc. dead loads

$$D_{L\_UpperRoof} := D_{L\_tiles} + D_{L\_wm} + D_{L\_roofsheathing} + \frac{D_{L\_Truss}}{2} = 6.8\ psf$$

Calculate the Upper roof dead load on horizontal plane:

$$b := \sqrt[2]{4^2 + 12^2} = 12.649$$

$$D_{L\_UpperRoof} := \left(\left(D_{L\_tiles} + D_{L\_wm} + D_{L\_roofsheathing}\right)\right) \cdot \left(\frac{b}{12}\right) + \frac{D_{L\_Truss}}{2} = 7.033\ psf$$

$$D_{L\_UpperRoof} := 6.304\ psf$$

Dead Loads Lower Roof:

- 20" blown-in cellulose insulation: $D_{L\_insulation} := 0.14 \cdot 20\ psf = 2.8\ psf$
- 5/8" gypsum board: $D_{L\_gypsumboard} := 2.75\ psf$
- Trusses@24" O.C (Southern Pine and bottom chord 2x6): $D_{L\_Truss} := 3.5\ psf + 1.5\ psf = 5\ psf$
- Plumbing Equipment : $D_{L\_plumbing} := 1\ psf$
- Lighting: $D_{L\_lighting} := 4\ psf$
- Mechanical Equipment: $D_{L\_mechanical} := 1\ psf$

$$D_{L\_LowerRoof} := D_{L\_mechanical} + D_{L\_plumbing} + D_{L\_lighting} + D_{L\_insulation} + D_{L\_gypsumboard} + \frac{D_{L\_Truss}}{2} = 14.05\ psf$$

$$D_{L\_LowerRoof} := 14.05\ psf$$

Dead Load Floor: (ASCE 7-22, Chap.3)

- Floor Finish bathroom:

3/8" ceramic tile: $D_{L\_ceramictile} := 4.7\ psf$

3/8" mortar bed: $D_{L\_mortarbed} := 12\ psf \cdot \frac{3}{8} = 4.5\ psf$

- Floor Finish other:

3/4" hardwood flooring: $D_{L\_hardwoodflooring} := 4\ psf \cdot \frac{3}{4} = 3\ psf$

- Subfloor: 3/4" OSB sheathing: $D_{L\_OSBsheathing} := 2.5\ psf$

- Floor Framing:

2x8 Joist @16": $D_{L\_Joist} := 2.2\ psf$

Partition Wall: $D_{L\_PartitionWall} := 20\ psf$

- Plumbing Equipment : $D_{L\_plumbing} := 1\ psf$

- Lighting: $D_{L\_lighting} := 4\ psf$

- Mechanical Equipment: $D_{L\_mechanical} := 1\ psf$

$$D_{1floorbathroom} := D_{L\_ceramictile} + D_{L\_mortarbed} + D_{L\_Joist} + D_{L\_OSBsheathing} + D_{L\_lighting} + D_{L\_mechanical} = 18.9\ psf$$

$$D_{1Ceramicfloor} := 19\ psf$$

$$D_{1floor} := D_{L\_hardwoodflooring} + D_{L\_Joist} + D_{L\_plumbing} + D_{L\_OSBsheathing} + D_{L\_lighting} + D_{L\_mechanical} = 13.7\ psf$$

$$D_{1Hardwoodfloor} := 14\ psf$$

$$D_{1floor\_withPartitionWall} := D_{L\_hardwoodflooring} + D_{L\_Joist} + D_{L\_plumbing} + D_{L\_OSBsheathing} + D_{L\_lighting} + D_{L\_mechanical} + D_{L\_PartitionWall} = 33.7\ psf$$

$$D_{1floor\_withPartitionWall} := 33.7\ psf$$

Live Loads: ASCE 7-22, Chap.4

Residential	
One- and two-family dwellings	
Uninhabitable attics without storage	10 (0.48)
Uninhabitable attics with storage	20 (0.96)
Habitable attics and sleeping areas	30 (1.44)
All other areas except stairs	40 (1.92)
All other residential occupancies	
Private rooms and corridors serving them	40 (1.92)
Public rooms	100 (4.79)
Corridors serving public rooms	100 (4.79)

$L_{residential} := 40\ psf$ $L_{garage} := 40\ psf$

$L_{roof} := 20\ psf$

$L_{Porch} := 5\ psf$

Roofs	
Ordinary flat, pitched, and curved roofs	20 (0.96)

Balanced Snow Load: ASCE 7-22: Chap.7

Importance Factor: $I_s := 1.0$

Risk Category II: Residential Building

Ground Snow Load: $P_g := 47\ \dfrac{lbf}{ft^2}$

Exposure Factor: $C_e := 1$ Assumption: The surface roughness category is B and exposure condition partially exposed.

Thermal Factor: $C_t := 1.1$

Slope Factor: $C_s := 1$ Rough roof surface and slope of< $18.435\ °$

$$\alpha := \mathrm{atan}\left(\frac{4}{12}\right) = 18.435\ deg$$

Calculation of Flat Roof Snow Load: $P_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot P_g = 36.19\ psf$

Calculation of Sloped Roof Snow Load: $P_s := C_s \cdot P_f = 36.19\ psf$

$P_s := 36.19\ psf$

Unbalanced Snow Load: ASCE 7-16 Chap.7 $d := FIF$ "38'4" $= 38.333\ ft$

$w := \frac{d}{2}\ ft <$ 20ft $b := FIF$ "27'8" $= 27.667\ ft$

Importance Factor: $I_s := 1.0$

Risk Category II: Residential Building

Ground Snow Load: $P_g = 47\ psf$

$P_u := P_g \cdot I_s = 47\ psf$

$P_u := 47\ psf$

No calculations were made for sliding snow consideration.

Summary of Wind Pressures:

Wind Direction A

	Surface			
Wall	1	2	3	4
P_{ext} (psf)	9.143	-8	-5.714	-8
P_{int} (psf)	±2.42	±2.42	±2.42	±2.42

	Surface				
Roof	1	2	3	4	4
(ft)				$0<x<h/2$	$x>h/2$
P_{ext_CP1}	-7.743	-6.719	-6.719	-13.083	-8.887
P_{ext_CP2}	-2.057			-2.057	-2.057
P_{int} (psf)	±2.42	±2.42	±2.42	±2.42	±2.42

Wind Direction B

	Surface			
Wall	1	2	3	4
P_{ext} (psf)	-8	9.143	-8	-4.833
P_{int} (psf)	±2.42	±2.42	±2.42	±2.42

	Surface		
Roof	1 & 2 & 3		4
(ft)	$0<x<h/2$	$x>h/2$	
P_{ext_CP1}	-11.033	-9.913	-6.558
P_{ext_CP2}	-2.057	-2.057	
P_{int} (psf)	±2.42	±2.42	±2.42

Wind Direction C

	Surface			
Wall	3	2	1	4
P_{ext} (psf)	9.143	-8	-5.714	-8
P_{int} (psf)	±2.42	±2.42	±2.42	±2.42

	Surface				
Roof	1	2	3	4	4
(ft)				$0<x<h/2$	$x>h/2$
P_{ext_CP1}	-6.719	-7.743	-7.743	-13.083	-8.887
P_{ext_CP2}		-2.057	-2.057	-2.057	-2.057
P_{int} (psf)	±2.42	±2.42	±2.42	±2.42	±2.42

Wind Direction D

	Surface			
Wall	1	2	3	4
P_{ext} (psf)	-8	-4.833	-8	9.143
P_{int} (psf)	±2.42	±2.42	±2.42	±2.42

	Surface		
Roof	1 & 2 & 3		4
(ft)	$0<x<h/2$	$x>h/2$	
P_{ext_CP1}	-11.033	-9.913	-6.205
P_{ext_CP2}	-2.057	-2.057	-2.057
P_{int} (psf)	±2.42	±2.42	±2.42

Wind Load Calculations:

1) Building Classification:

Risk Category II: Residential building

2) Mean roof height: $h_{ridge} := FIF$ “23'8 41/64” $= 23.72\ ft$

$h_e := FIF$ “20'10 63/128” $= 20.874\ ft$

$$h := \frac{\left(\left(h_{ridge} + h_e\right)\right)}{2} = 22.297\ ft$$

3) Wind Load Parameters: (ASCE 7-22)

- Wind speed: $V := 108\ mph$
- Topography factor: $K_{zt} := 1$
- Directional factor: $K_d := 0.85$
- Exposure B: Suburban Area
- Ground Elevation Factor: $z_{ground} := 593$ ft

$$K_e := e^{-0.0000362 \cdot z_{ground}} = 0.979$$

- Velocity Pressure Coefficient:

$\alpha := 7.5$ $z_g := 3280\ ft$

$$K_{z@he} := 2.41 \cdot \left(\frac{\left(\left(h_e\right)\right)}{\left(z_g\right)}\right)^{\frac{2}{\alpha}} = 0.626$$

$$K_{z@h} := 2.41 \cdot \left(\frac{h}{\left(z_g\right)}\right)^{\frac{2}{\alpha}} = 0.637$$

4) Velocity Pressure:

$$q_{z@he} := \left(0.00256 \frac{psf}{mph^2}\right) \cdot K_{z@he} \cdot K_{zt} \cdot K_d \cdot K_e \cdot V^2 = 15.543 \ psf$$

$$q_{z@h} := \left(0.00256 \frac{psf}{mph^2}\right) \cdot K_{z@h} \cdot K_{zt} \cdot K_e \cdot K_d \cdot V^2 = 15.819 \ psf$$

5) Gust Effect Factor: (ASCE 7-22: Section 26.11.1)

$G := 0.85$

6) Internal Pressures: Enclosed building

$GC_{pi} := -0.18$ or $GC_{pi} := 0.18$ (ASCE 7-22: Table 26.13-1)

Wind Direction A: $B := FIF$ "38'4" $L := FIF$ "27'8" $\frac{L}{B} = 0.722$

Wall Pressures:

$$PlusMinus\left(GC_{pi}\right) := \begin{bmatrix} GC_{pi} \\ -\left(GC_{pi}\right) \end{bmatrix}$$

Surface 1 (Windward wall): $C_p := 0.8$ (ASCE 7-22: Figure 27.3-1)

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_p\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} 6.723 \\ 11.563 \end{bmatrix} psf$$

Surface 2&4 (Side): $\boxed{C_p} := -0.7$ (ASCE 7-22: Figure 27.3-1)

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_p\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -10.42 \\ -5.58 \end{bmatrix} psf$$

Surface 3 (Leeward): $\boxed{C_p} := -0.5$ (ASCE 7-22: Figure 27.3-1)

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_p\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -8.135 \\ -3.294 \end{bmatrix} psf$$

Roof Pressures:

$h = 22.297\ ft$ $L = 27.667\ ft$ $\frac{h}{L} = 0.806$

Surface 1 (Windward): (ASCE 7-22: Figure 27.3-1 + Interpolation)

$$\theta := \text{atan}\left(\frac{4\ in}{12\ in}\right) = 18.435\ deg$$

Interpolation of C_p between angle θ:

$y_1 := -1$ $x_1 := 15$ $y_2 := -0.7$ $x_2 := 20$ $x := 18.435$

$$C_{p1.1} := y_1 + \left(x - x_1\right) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.794$$

$\boxed{y_1} := -0.18$ $\boxed{x_1} := 15$ $\boxed{y_2} := -0.18$ $\boxed{x_2} := 20$ $\boxed{x} := 18.435$

$$C_{p2.1} := y_1 + \left(x - x_1\right) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$$

$\boxed{y_1} := -0.7$ $\boxed{x_1} := 15$ $\boxed{y_2} := -0.4$ $\boxed{x_2} := 20$ $\boxed{x} := 18.435$

$$C_{p1.0.5} := y_1 + \left(x - x_1\right) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.494$$

$C_{p2.0.5} := -0.18$

Interpolation of C_p between $\frac{h}{L}$:

$y_1 := C_{p1.0.5}$ $x_1 := 0.5$ $y_2 := C_{p1.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.677$

$y_1 := C_{p2.0.5}$ $x_1 := 0.5$ $y_2 := C_{p2.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -10.163 \\ -5.322 \end{bmatrix} psf$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p2}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

Surface 2&3 (Leeward): (ASCE 7-22: Figure 27.3-1)

Interpolation of C_p between angle θ:

$y_1 := -0.6$ $x_1 := 15$ $y_2 := -0.6$ $x_2 := 20$ $x := 18.435$

$C_{p1.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.6$

$y_1 := -0.5$ $x_1 := 15$ $y_2 := -0.6$ $x_2 := 20$ $x := 18.435$

$C_{p1.0.5} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.569$

Interpolation of C_p between $\frac{h}{L}$:

$y_1 := C_{p1.0.5}$ $x_1 := 0.5$ $y_2 := C_{p1.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.588$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -9.139 \\ -4.298 \end{bmatrix} psf$

Surface 4 (side): (ASCE 7-22: Figure 27.3-1) $h = 22.297\ ft$ $\dfrac{h}{L} = 0.806$

- From $0\ ft < x < \dfrac{h}{2}$:

$y_1 := -0.9$ $x_1 := 0.5$ $y_2 := -1.3$ $x_2 := 1$ $x := \dfrac{h}{L}$

$$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -1.145$$

$y_1 := -0.18$ $x_1 := 0.5$ $y_2 := -0.18$ $x_2 := 1$ $x := \dfrac{h}{L}$

$$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$$

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p1}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -15.503 \\ -10.663 \end{bmatrix} psf$$

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p2}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$$

- From $x < \dfrac{h}{2}$:

$y_1 := -0.9$ $x_1 := 0.5$ $y_2 := -0.7$ $x_2 := 1$ $x := \dfrac{h}{L}$

$$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.778$$

$y_1 := -0.18$ $x_1 := 0.5$ $y_2 := -0.18$ $x_2 := 1$ $x := \dfrac{h}{L}$

$$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$$

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p1}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -11.308 \\ -6.467 \end{bmatrix} psf$$

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p2}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$$

Wind Direction B: $L := FIF$ "38'4" $B := FIF$ "27'8" $\frac{L}{B} = 1.386$

Wall Pressures:

$$PlusMinus(GC_{pi}) := \begin{bmatrix} GC_{pi} \\ -(GC_{pi}) \end{bmatrix}$$

Surface 2 (Windward wall): $C_p := 0.8$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} 6.723 \\ 11.563 \end{bmatrix} psf$$

Surface 1&3 (Side): $C_p := -0.7$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -10.42 \\ -5.58 \end{bmatrix} psf$$

Surface 4 (Leeward): (ASCE 7-22: Figure 27.3-1)

$y_1 := -0.5$ $x_1 := 1$ $y_2 := -0.3$ $x_2 := 2$ $x := \frac{L}{B}$

$$C_p := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.423$$

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -7.253 \\ -2.413 \end{bmatrix} psf$$

Roof Pressures: $h = 22.297\ ft$ $L = 38.333\ ft$ $\frac{h}{L} = 0.582$

(Windward): None

$$\theta := \operatorname{atan}\left(\frac{4\ in}{12\ in}\right) = 18.435\ deg$$

Surface 4 (Leeward): (ASCE 7-22: Figure 27.3-1)

Interpolation of C_p between angle θ:

$y_1 := -0.6$ $x_1 := 15$ $y_2 := -0.6$ $x_2 := 20$ $x := 18.435$

$$C_{p1.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.6$$

$y_1 := -0.5$ $x_1 := 15$ $y_2 := -0.6$ $x_2 := 20$ $x := 18.435$

$$C_{p1.0.5} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.569$$

Interpolation of C_p between $\frac{h}{L}$:

$y_1 := C_{p1.0.5}$ $x_1 := 0.5$ $y_2 := C_{p1.1}$ $x_2 := 1$ $x := \frac{h}{L} = 0.582$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.574$

$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p1}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -8.978 \\ -4.138 \end{bmatrix} psf$

Surface 1&2&3 (side): (ASCE 7-22: Figure 27.3-1) $h = 22.297\ ft$ $\frac{h}{L} = 0.582$

- From $0\ ft < x < \frac{h}{2}$:

$y_1 := -0.9$ $x_1 := 0.5$ $y_2 := -1.3$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.965$

$y_1 := -0.18$ $x_1 := 0.5$ $y_2 := -0.18$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p1}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -13.453 \\ -8.612 \end{bmatrix} psf$

$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p2}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

- From $x > \frac{h}{2}$:

$y_1 := -0.9$ $x_1 := 0.5$ $y_2 := -0.7$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.867$

$y_1 := -0.18$ $x_1 := 0.5$ $y_2 := -0.18$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p1}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -12.333 \\ -7.492 \end{bmatrix} psf$

$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p2}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

Wind Direction C: $B := FIF$ "38'4" $L := FIF$ "27'8" $\frac{L}{B} = 0.722$

Wall Pressures: $PlusMinus(GC_{pi}) := \begin{bmatrix} GC_{pi} \\ -(GC_{pi}) \end{bmatrix}$

Surface 3 (Windward wall): $C_p := 0.8$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} 6.723 \\ 11.563 \end{bmatrix} psf$$

Surface 2&4 (Side): $C_p := -0.7$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -10.42 \\ -5.58 \end{bmatrix} psf$$

Surface 1 (Leeward): $C_p := -0.5$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -8.135 \\ -3.294 \end{bmatrix} psf$$

Roof Pressures: $h = 22.297\ ft$ $L = 27.667\ ft$ $\frac{h}{L} = 0.806$

<u>Surface 2&3 (Windward):</u> (ASCE 7-22: Figure 27.3-1 + Interpolation)

$$\theta := \mathrm{atan}\left(\frac{4\ in}{12\ in}\right) = 18.435\ deg$$

Interpolation of C_p between angle θ:

$y_1 := -1$ $x_1 := 15$ $y_2 := -0.7$ $x_2 := 20$ $x := 18.435$

$$C_{p1.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.794$$

$y_1 := -0.18$ $x_1 := 15$ $y_2 := -0.18$ $x_2 := 20$ $x := 18.435$

$$C_{p2.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$$

$y_1 := -0.7$ $x_1 := 15$ $y_2 := -0.4$ $x_2 := 20$ $x := 18.435$

$$C_{p1.0.5} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.494$$

$C_{p2.0.5} := -0.18$

Interpolation of C_p between $\frac{h}{L}$:

$y_1 := C_{p1.0.5}$ $x_1 := 0.5$ $y_2 := C_{p1.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.677$

$y_1 := C_{p2.0.5}$ $x_1 := 0.5$ $y_2 := C_{p2.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -10.163 \\ -5.322 \end{bmatrix} psf$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p2}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

<u>Surface 1 (Leeward):</u> (ASCE 7-22: Figure 27.3-1)

Interpolation of C_p between angle:

$y_1 := -0.5$ $x_1 := 15$ $y_2 := -0.6$ $x_2 := 20$ $x := 18.435$

$C_{p1.0.5} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.569$

$y_1 := -0.6$ $x_1 := 15$ $y_2 := -0.6$ $x_2 := 20$ $x := 18.435$

$C_{p1.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.6$

Interpolation of C_p between $\frac{h}{L}$:

$y_1 := C_{p1.0.5}$ $x_1 := 0.5$ $y_2 := C_{p1.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.588$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -9.139 \\ -4.298 \end{bmatrix} psf$

Surface 4 (side): (ASCE 7-22: Figure 27.3-1)

- From $0\ ft < x < \frac{h}{2}$:

$y_1 := -0.9 \quad x_1 := 0.5 \quad y_2 := -1.3 \quad x_2 := 1 \quad x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -1.145$

$y_1 := -0.18 \quad x_1 := 0.5 \quad y_2 := -0.18 \quad x_2 := 1 \quad x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -15.503 \\ -10.663 \end{bmatrix} psf$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p2}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

- From $x < \frac{h}{2}$:

$y_1 := -0.9 \quad x_1 := 0.5 \quad y_2 := -0.7 \quad x_2 := 1 \quad x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.778$

$y_1 := -0.18 \quad x_1 := 0.5 \quad y_2 := -0.18 \quad x_2 := 1 \quad x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -11.308 \\ -6.467 \end{bmatrix} psf$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p2}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

Wind Direction D: $L := FIF$ “38'4” $B := FIF$ “27'8” $\frac{L}{B} = 1.386$

Wall Pressures: $PlusMinus(GC_{pi}) := \begin{bmatrix} GC_{pi} \\ -(GC_{pi}) \end{bmatrix}$

Surface 4 (Windward wall): $C_p := 0.8$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} 6.723 \\ 11.563 \end{bmatrix} psf$$

Surface 1&3 (Side): $C_p := -0.7$ (ASCE 7-22: Figure 27.3-1)

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -10.42 \\ -5.58 \end{bmatrix} psf$$

Surface 2 (Leeward): (ASCE 7-22: Figure 27.3-1)

$y_1 := -0.5$ $x_1 := 1$ $y_2 := -0.3$ $x_2 := 2$ $x := \frac{L}{B}$

$$C_p := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.423$$

$$p := (q_{z@h} \cdot K_d \cdot G \cdot C_p) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -7.253 \\ -2.413 \end{bmatrix} psf$$

Roof Pressures: $h = 22.297\ ft$ $L = 38.333\ ft$ $\frac{h}{L} = 0.582$

Surface 4 (Windward): $\theta := \text{atan}\left(\frac{4\ in}{12\ in}\right) = 18.435\ deg$

Interpolation of C_p between angle θ:

$y_1 := -1$ $x_1 := 15$ $y_2 := -0.7$ $x_2 := 20$ $x := 18.435$

$$C_{p1.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.794$$

$y_1 := -0.18$ $x_1 := 15$ $y_2 := -0.18$ $x_2 := 20$ $x := 18.435$

$$C_{p2.1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$$

$y_1 := -0.7$ $x_1 := 15$ $y_2 := -0.4$ $x_2 := 20$ $x := 18.435$

$$C_{p1.0.5} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.494$$

$C_{p2.0.5} := -0.18$

Interpolation of C_p between $\frac{h}{L}$:

$y_1 := C_{p1.0.5}$ $x_1 := 0.5$ $y_2 := C_{p1.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.543$

$y_1 := C_{p2.0.5}$ $x_1 := 0.5$ $y_2 := C_{p2.1}$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -8.625 \\ -3.785 \end{bmatrix} psf$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p2}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

Surface 1&2&3 (side): (ASCE 7-22: Figure 27.3-1)

- From $0\ ft < x < \frac{h}{2}$:

$y_1 := -0.9$ $x_1 := 0.5$ $y_2 := -1.3$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.965$

$y_1 := -0.18$ $x_1 := 0.5$ $y_2 := -0.18$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p1}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -13.453 \\ -8.612 \end{bmatrix} psf$

$p := (q_{z@h} \cdot K_d \cdot G \cdot C_{p2}) - (q_{z@h} \cdot K_d \cdot (PlusMinus(GC_{pi}))) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$

- From $x < \frac{h}{2}$:

$y_1 := -0.9$ $x_1 := 0.5$ $y_2 := -0.7$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p1} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.867$

$y_1 := -0.18$ $x_1 := 0.5$ $y_2 := -0.18$ $x_2 := 1$ $x := \frac{h}{L}$

$C_{p2} := y_1 + (x - x_1) \cdot \left(\frac{y_2 - y_1}{x_2 - x_1}\right) = -0.18$

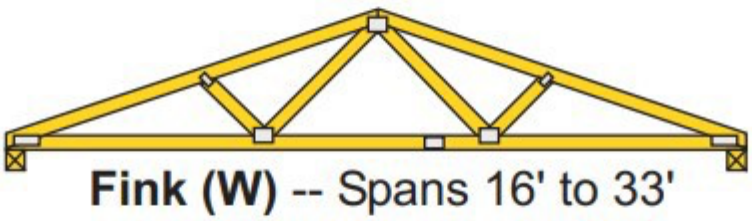
$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p1}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -12.333 \\ -7.492 \end{bmatrix} psf$$

$$p := \left(q_{z@h} \cdot K_d \cdot G \cdot C_{p2}\right) - \left(q_{z@h} \cdot K_d \cdot \left(PlusMinus\left(GC_{pi}\right)\right)\right) = \begin{bmatrix} -4.477 \\ 0.363 \end{bmatrix} psf$$

Calculation Report of Roof Framing

Clinton Infill

Fink Truss Geometry (Main Roof):



$$\alpha := \operatorname{atan}\left(\frac{4}{12}\right) = 18.435\ deg$$

$$L_{truss} := FIF\ \text{“16'4”} = 16.333\ ft$$

$$L_{btw} := \frac{L_{truss}}{3} = 5.444\ ft$$

$$h_{trussC} := \left(\frac{L_{truss}}{2} \cdot \tan\ \alpha\right) = 2.722\ ft$$

Angles: $\Theta_{BAG} := 18.43\ deg$ $\Theta_{DEF} := 18.43\ deg$

Point B:

$$h_{trussB} := \frac{1}{2} \cdot h_{trussC} = 1.361\ ft$$

$$x_{AB'} := \frac{h_{trussB}}{\tan\left(\left(\Theta_{BAG}\right)\right)} = 4.085\ ft$$

Point D:

$$h_{trussD} := \frac{1}{2} \cdot h_{trussC} = 1.361\ ft$$

$$x_{AD'} := L_{truss} - \frac{h_{trussD}}{\tan\left(\left(\Theta_{DEF}\right)\right)} = 12.249\ ft$$

Point G:

$$h_{trussG} := \frac{2}{3} \cdot h_{trussC} = 1.815\ ft$$

$$x_{AG'} := \frac{h_{trussG}}{\tan\left(\left(\Theta_{BAG}\right)\right)} = 5.446\ ft$$

Point F:

$$h_{trussF} := \frac{2}{3} \cdot h_{trussC} = 1.815\ ft$$

$$x_{AF'} := L_{truss} - \frac{h_{trussF}}{\tan\left(\left(\Theta_{DEF}\right)\right)} = 10.887\ ft$$

Point C:

$$h_{trussC} = 2.722\ ft$$

$$x_{AC'} := L_{truss} - \frac{h_{trussC}}{\tan\left(\left(\Theta_{BAG}\right)\right)} = 8.164\ ft$$

Calculation of Loads of Double Fink Truss :

Assumption: Maximum values found from earlier Load Calculations

$D_{upper} := 8\ psf$ $D_{lower} := 15\ psf$ $S_{unbal} := 50\ psf$ $w_{wind} := -15.503\ psf$

$L_{lower} := 20\ psf$ $L_{r\_upper} := 20\ psf$ $\Theta_{BAG} = 18.43\ deg$

Distributed Loads on the Truss:

$w_{D\_upper} := \left(\left(D_{upper}\right)\right) \cdot 2\ ft \cdot \cos\left(\left(\Theta_{BAG}\right)\right) = 0.015\ klf$

$w_{D\_lower} := \left(\left(D_{lower}\right)\right) \cdot 2\ ft = 0.03\ klf$

$w_L := \left(\left(L_{lower}\right)\right) \cdot 2\ ft = 0.04\ klf$

$w_{Lr} := \left(\left(\left(\left(L_{r\_upper}\right)\right) \cdot 2\ ft\right)\right) \cdot \cos\left(\left(\Theta_{BAG}\right)\right) = 0.038\ klf$

$w_{s\_unbal} := \left(\left(S_{unbal} \cdot 2\ ft\right)\right) \cdot \cos\left(\left(\Theta_{BAG}\right)\right) = 0.095\ klf$

$w_W := \left(\left(w_{wind}\right)\right) \cdot 2\ ft = -0.031\ klf$

$w_{ST1} := 0.5 \cdot w_{Lr} + 0.5 \cdot w_L = 0.039\ klf$

$w_{ST2} := 0.5 \cdot w_L + w_{s\_unbal} = 0.115\ klf$

$w_{LT} := 0.5 \cdot w_L + w_{D\_upper} + w_{D\_lower} = 0.065\ klf$

Note: To design our roof framing, we used ROBOT, a software that does structural analysis.

Roof Truss Structural Analysis

Design for Roof truss web members:

Structural Proportioning - Tension stress parallel to the grain 2X4 Southern Pine No.2

Section Properties: $d := 3.5\ in$

$b := 1.5\ in$

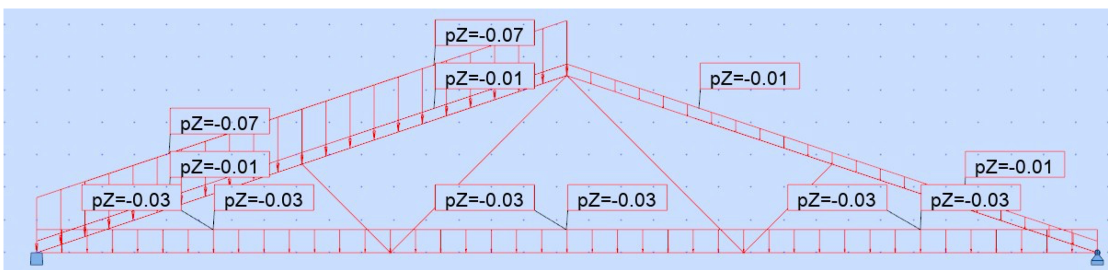
$A := d \cdot b = 5.25\ in^2$

Structural Analysis via Robot: $P_{w\_t} := 0.16\ kip = 160\ lbf$

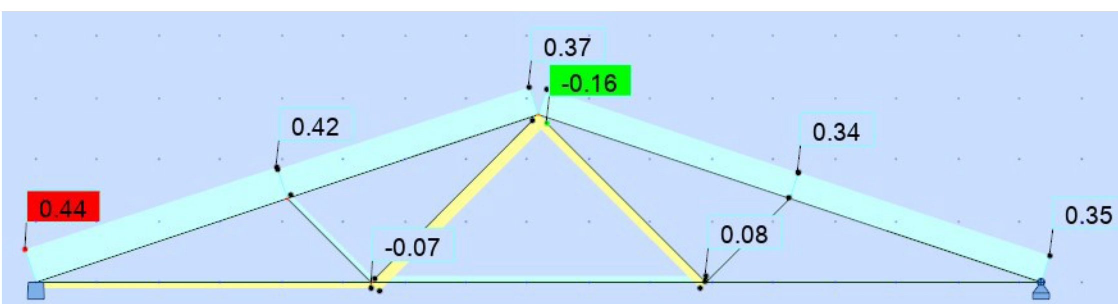
case: D+0.75L+0.75S

$$f_t := \frac{P_{w\_t}}{A} = 30.476\ psi$$

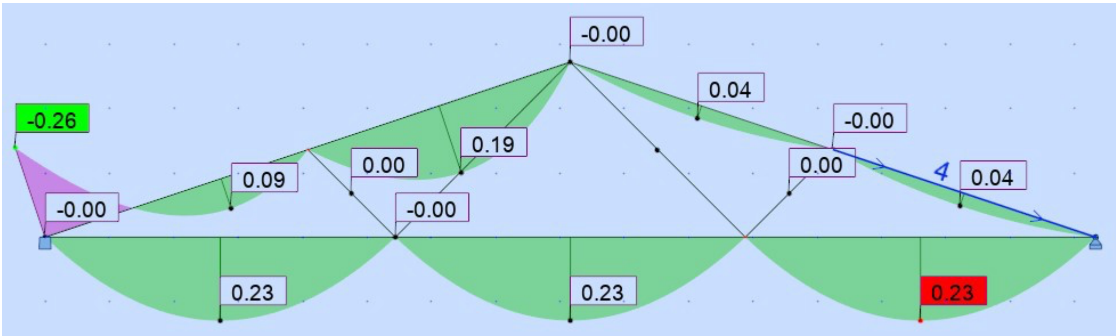
Loading Diagram: : D+0.75L+0.75S



Axial Diagram:



Moment Diagram:



Structural Proportioning:

Reference Design value: $F_t := 675\ psi$

Adjustment Factors: $C_M := 1$ $C_t := 1$ $C_F := 1$ $C_i := 1$ $C_D := 1.15$

Calculate F_t': $F_t' := F_t \cdot \left(\left(C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F\right)\right) = 776.25\ psi$

Check Design: $f_t \leq F_t'$

if $f_t \leq F_t'$
  "Design ok for Tension"
else
  "Design not ok for Tension"

= "Design ok for Tension"

$$DCR := \frac{f_t}{F_t'} = 0.039$$

if $DCR \leq 1$
  "Design ok for Tension"
else
  "Design not ok for Tension"

= "Design ok for Tension"

Structural Proportioning - Compression parallel to the grain   2X4 Southern Pine No.2

Section Properties:
$d := 3.5\ in$
$b := 1.5\ in$
$A := d \cdot b = 5.25\ in^2$
$E_{min} := 510000\ psi$
$E := 1400000\ psi$
$K_e := 1.0$
$c := 0.8 \qquad l_u := 5.446\ ft$

Structural Analysis via Robot:
case: D+0.75L+0.75S

$P_{w\_c} := 0.06\ kip = 60\ lbf$

$$f_c := \frac{P_{w\_c}}{A} = 11.429\ psi$$

Structural Proportioning:

Reference Design value: $F_c := 1450\ psi$

Adjustment Factors: $C_F := 1 \qquad C_D := 1.15 \qquad C_M := 1 \qquad C_t := 1 \qquad C_i := 1$

Calculate C_T: $K_M := 2300 \qquad K_T := 0.59$

Effective Length: $l_e := K_e \cdot l_u = 65.352\ in$

$$C_T := 1 + \frac{K_M \cdot \frac{l_e}{in}}{K_T \cdot \frac{E}{psi}} = 1.182$$

Calculate C_p:

$$E_{min}' := C_M \cdot C_t \cdot C_i \cdot C_T \cdot E_{min} = \left(6.028 \cdot 10^5\right)\ psi$$

$$F_{cE} := \frac{0.822 \cdot E_{min}'}{\left(\frac{l_e}{d}\right)^2} = \left(1.421 \cdot 10^3\right)\ psi$$

$$F_c° := F_c \cdot \left(C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F\right) = \left(1.668 \cdot 10^3\right)\ psi$$

$$C_p := \frac{1 + \left(\frac{F_{cE}}{F_c°}\right)}{2 \cdot c} - \sqrt{\left(\frac{1 + \left(\frac{F_{cE}}{F_c°}\right)}{2 \cdot c}\right)^2 - \left(\frac{\left(\frac{F_{cE}}{F_c°}\right)}{c}\right)} = 0.633$$

Calculate F_c': $F_c' := F_c \cdot \left(\left(C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F \cdot C_p\right)\right) = 1056.227\ psi$

Check Design: $f_c \le F_c'$

if $f_c \le F_c'$
 "Design ok for Compression"
else
 "Design not ok for Compression"

= "Design ok for Compression"

$DCR := \frac{f_c}{F_c'} = 0.011$

if $DCR \le 1$
 "Design ok for Compression"
else
 "Design not ok for Compression"

= "Design ok for Compression"

Design for the roof truss top chord:

Structural Proportioning - Combined bending and axial compression

2x4 Southern Pine No.2

Section Properties: $d := 3.5\ in$

$b := 1.5\ in$

$A := d \cdot b = 5.25\ in^2$

$c := 0.8$

$l_u := 4.3\ ft_2$

$S_{xx} := \frac{b \cdot d}{6} = 3.063\ in^3$

Structural Analysis via Robot: $M_{TC} := 0.26\ kip \cdot ft$

case: D+0.75L+0.75S

$P_{TC\_c} := 0.44\ kip$

$f_c := \frac{P_{TC\_c}}{A} = 83.81\ psi$

$f_b := \frac{M_{TC}}{S_{xx}} = \left(1.019 \cdot 10^3\right)\ psi$

Structural Proportioning:

Reference Design value: $F_c := 1450\ psi$

$F_b := 1100\ psi$

$E_{min} := 510000\ psi$

$E := 1400000\ psi$

$l_u := 4.03\ ft$

Adjustment Factors:

$C_{D\_axial} := 1.25$ $C_F := 1$ $C_t := 1$ $C_i := 1$ $C_M := 1$

$C_{D\_bending} := 1.25$ $C_{fu} := 1$ $C_L := 1$ $C_r := 1.15$

Calculate C_T: $K_M := 2300$ $K_T := 0.59$

Effective Length: $l_e := K_e \cdot l_u = 48.36\ in$

$$C_T := 1 + \frac{K_M \cdot \frac{l_e}{in}}{K_T \cdot \frac{E}{psi}} = 1.135$$

Calculate C_p:

$$E_{min}' := C_M \cdot C_t \cdot C_i \cdot C_T \cdot E_{min} = \left(5.787 \cdot 10^5\right)\ psi$$

$$F_{cE} := \frac{0.822 \cdot E_{min}'}{\left(\frac{l_e}{d}\right)^2} = \left(2.492 \cdot 10^3\right)\ psi$$

$$F_c° := F_c \cdot \left(C_{D\_axial} \cdot C_M \cdot C_t \cdot C_i \cdot C_F\right) = \left(1.813 \cdot 10^3\right)\ psi$$

$$C_p := \frac{1 + \left(\frac{F_{cE}}{F_c°}\right)}{2 \cdot c} - \sqrt{\left(\frac{1 + \left(\frac{F_{cE}}{F_c°}\right)}{2 \cdot c}\right)^2 - \left(\frac{\left(\frac{F_{cE}}{F_c°}\right)}{c}\right)} = 0.788$$

Adjusted Design Values:

$$F_c' := F_c \cdot \left(C_{D\_axial} \cdot C_M \cdot C_t \cdot C_F \cdot C_i \cdot C_p\right) = \left(1.429 \cdot 10^3\right)\ psi$$

$$F_b' := F_b \cdot \left(C_{D\_bending} \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r\right) = \left(1.581 \cdot 10^3\right)\ psi$$

Axial Compression Design Check:

if $f_c \le F_c'$
  "Design ok for Compression"
else
  "Design not ok for Compression"

= "Design ok for Compression"

$$DCR := \frac{f_c}{F_c'} = 0.059 \qquad <1 \text{ ok}$$

Bending Design Check:

if $f_b \le F_b'$
  "Design ok for Bending"
else
  "Design not ok for Bending"

= "Design ok for Bending"

$$DCR := \frac{f_b}{F_b'} = 0.644 \qquad <1 \text{ ok}$$

Combined Bending and Compression Check:

Calculate Amplification Factor: $d_1 := 3.5\ in$ $d_2 := 1.5\ in$ $l_{e1} := 4.31\ ft$

$$F_{cE1} := \frac{\left(0.822 \cdot E_{min}'\right)}{\left(\frac{l_{e1}}{d_1}\right)^2} = \left(2.178 \cdot 10^3\right)\ psi \qquad \beta_1 := \left(1 - \frac{f_c}{F_{cE1}}\right)^{-1} = 1.04$$

$$\left(\frac{f_c}{F_c'}\right)^2 + \beta_1 \cdot \left(\frac{f_b}{F_b'}\right) = 0.67351$$

$$\text{if } \left(\frac{f_c}{F_c'}\right)^2 + \beta_1 \cdot \left(\frac{f_b}{F_b'}\right) \le 1$$

"Design OK for Bending and Axial Compression"

else

"Design NOT OK for Bending and Axial Compression"

= "Design OK for Bending and Axial Compre

Design for the roof truss bottom chord: 2x4 Southern Pine No.2

Structural Proportioning - Combined bending and axial tension

Section Properties: $d := 3.5\ in$

$b := 1.5\ in$

$A_g := d \cdot b = 5.25\ in^2$

$c := 0.8$

$l_u := 5.446\ ft$

$$S_{xx} := \frac{b \cdot d^2}{6} = 3.063\ in^3$$

Structural Analysis via Robot: $M_{BC} := 0.26\ kip \cdot ft$

case: D+L

$P_{BC\_t} := 0.07\ kip$

$$f_t := \frac{P_{BC\_t}}{A_g} = 13.333\ psi$$

$$f_b := \frac{M_{BC}}{S_{xx}} = \left(1.019 \cdot 10^3\right)\ psi$$

Loading Diagram: : D+L

Axial Diagram:

Moment Diagram:

Structural Proportioning:

Reference Design value:

$F_t := 675\ psi$
$F_b := 1100\ psi$
$E_{min} = 510000\ psi$
$E := 1400000\ psi$
$l_u := 5.1\ ft$

Adjustment Factors:

$C_{D\_axial} := 1$ $C_F := 1$ $C_t := 1$ $C_i := 1$ $C_M := 1$

$C_{D\_bending} := 1$ $C_L := 1$ $C_{fu} := 1$ $C_r := 1.15$

Adjusted Design Values:

$F_b' := F_b \cdot C_{D\_bending} \cdot C_M \cdot C_t \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1265\ psi$
$F_b° := F_b \cdot C_{D\_bending} \cdot C_M \cdot C_t \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1265\ psi$
$F_b°° := F_b \cdot C_{D\_bending} \cdot C_M \cdot C_t \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r \cdot C_L = 1265\ psi$
$F_t' := F_t \cdot \left(\left(C_D \cdot C_M \cdot C_t \cdot C_i \cdot C_F\right)\right) = 776.25\ psi$

Axial Compression Design Check:

if $f_t \le F_t'$
    "Design ok for Tension"
else
    "Design not ok for Tension"

= "Design ok for Tension"

$DCR := \dfrac{f_t}{F_t'} = 0.017$ <1 ok

Bending Design Check:

if $f_b \le F_b'$
    "Design ok for Bending"
else
    "Design not ok for Bending"

= "Design ok for Bending"

$\boxed{DCR} := \frac{f_b}{F_b'} = 0.805$ <1 ok

Combined Bending and Tension Check:

$$\text{if } \frac{f_b - f_t}{F_b^{\circ\circ}} \le 1$$
"Design OK for Bending and Axial Tension"
else
"Design NOT OK for Bending and Axial Tension"

= "Design OK for Bending and Axial Tension"

$$\text{if } \frac{f_t}{F_t'} + \frac{f_b}{F_b^{\circ}} \le 1$$
"Design OK for Bending and Axial Tension"
else
"Design NOT OK for Bending and Axial Tension"

= "Design OK for Bending and Axial Tension"

Note: After Carefully doing Some more research, for our design we will use a 2x6 bottom Chord. This is the proffered option.

Double Fink Roof Truss Deflection Check:

Short Term Deflection:

$\delta_{ST1} := 0.0855\ in$

$\Delta_{ST} := \frac{348\ in}{360} = 0.967\ in$

if $\delta_{ST1} \le \Delta_{ST}$ = "ok"
‖ "ok"
else
‖ "revise"

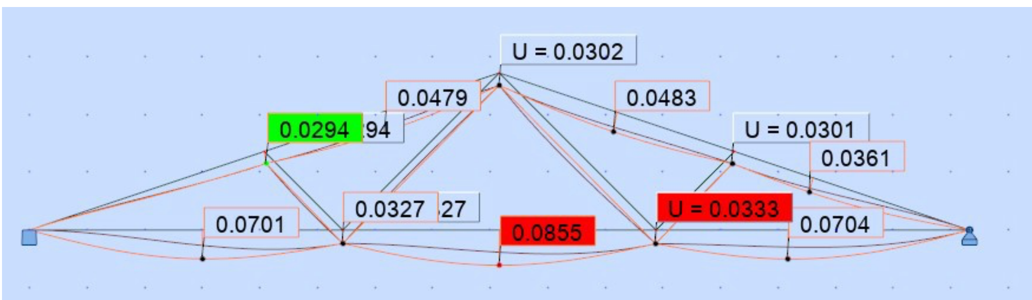
Short Term Deflection:

$\delta_{ST2} := 0.0877\ in$

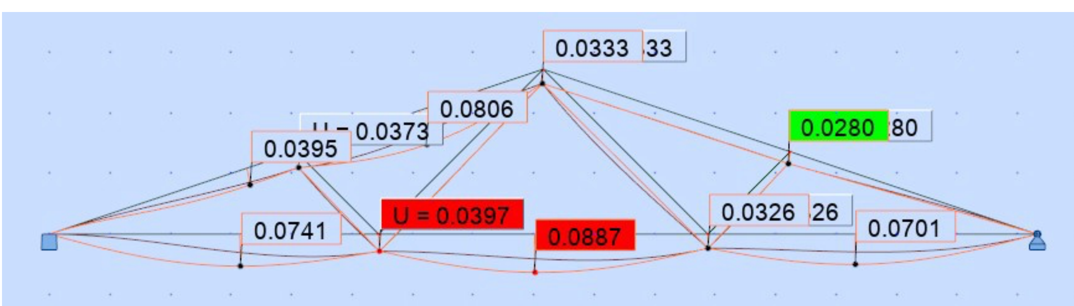
$\Delta_{ST} := \frac{348\ in}{360} = 0.967\ in$

if $\delta_{ST1} \le \Delta_{ST}$ = "ok"
‖ "ok"
else
‖ "revise"

Short Term Deflection #1 $w_{ST1} := 0.5 \cdot w_{Lr} + 0.5 \cdot w_L = 0.039\ klf$



Short Term Deflection #2 $w_{ST2} := 0.5 \cdot w_L + w_{s\_unbal} = 0.115\ klf$



$w_{LT} := 0.5 \cdot w_L + w_{D\_upper} + w_{D\_lower} = 0.065\ klf$

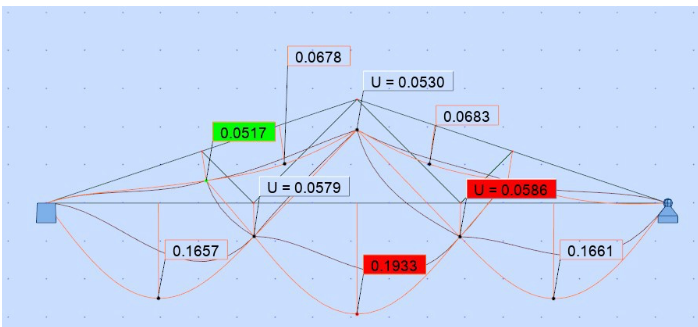
Total Deflection:

$\delta_{Tot1} := 0.1933\ in$

$\Delta_{Tot} := \dfrac{348\ in}{240} = 1.45\ in$

$$\text{if } \delta_{Tot1} \le \Delta_{Tot} \;\; \| \text{"ok"} \;\; \text{else} \;\; \| \text{"revise"} = \text{"ok"}$$

Total Deflection #1



Calculation Report of Lateral Loads

Clinton Infill

Lateral Load

Information from Wind Load Calculations: $P_{wall\sim max} := 9.143\ psf$ (Max Wall Pressure)

$P_{roof\sim max} := 13.083\ psf$ (Max Roof Pressure)

Height of Level 1: $H_1 := 9.20833\ ft$

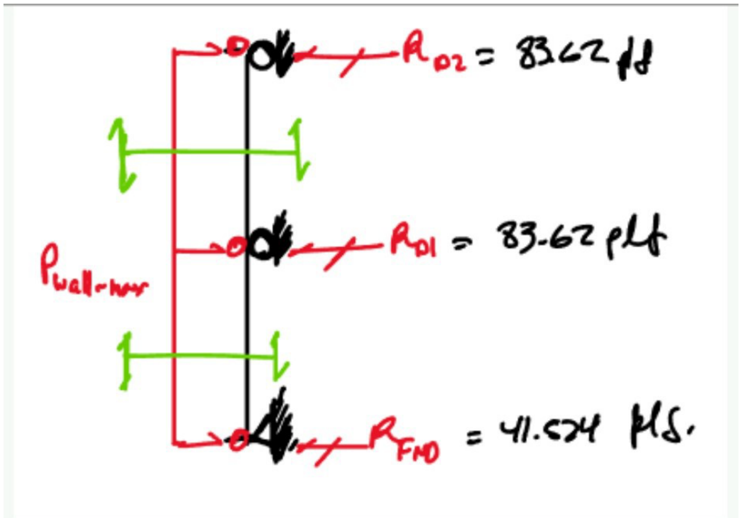
Height of Level 2: $H_2 := 9.08333\ ft$

Calculation of Reaction Forces using tributary area: $T_{W\sim 1} := 0.5\ H_1 = 4.604\ ft$
$T_{W\sim 2} := 0.5\ H_2 = 4.542\ ft$

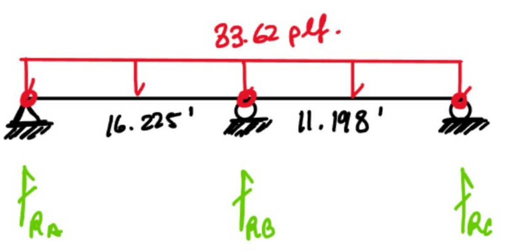
Reaction Forces $R_{D\sim 2} := P_{wall\sim max} \cdot \left(\left(0.5\ H_1 + 0.5\ H_2\right)\right) = 83.62\ plf$

$R_{D\sim 1} := P_{wall\sim max} \cdot \left(\left(0.5\ H_1 + 0.5\ H_2\right)\right) = 83.62\ plf$

$R_{FNDN} := P_{wall\sim max} \cdot 0.5\ H_2 = 41.524\ plf$



Diaphragm Level 1:



Distributed Load: $W := 83.62\ plf$

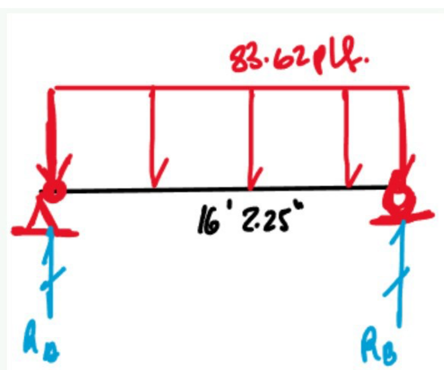
Length of Level 1 Diaphragm $L_1 := 16.225\ ft$ $L_2 := 11.198\ ft$

Reaction Forces $R_C := W \cdot ((0.5\ L_2)) = 468.188\ lbf$

$R_B := W \cdot ((0.5\ L_1 + 0.5\ L_2)) = 1146.556\ lbf$

$R_A := W \cdot ((0.5\ L_1)) = 678.367\ lbf$

Diaphragm Level 2:



Distributed Load: $W := 83.62\ plf$

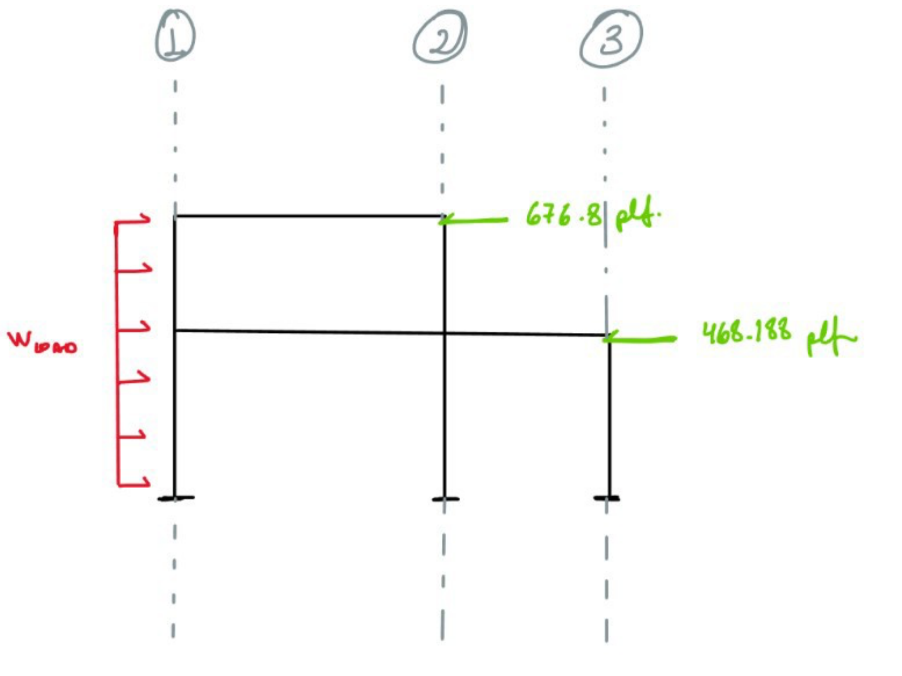
Length of Level 2 Diaphragm: $L := 16.1875\ ft$

Reaction Forces $P_{Load} := W \cdot L = 1353.599\ lbf$

$R_A := \frac{P_{Load}}{2} = 676.799\ lbf$

$R_B := R_A = 676.799\ lbf$

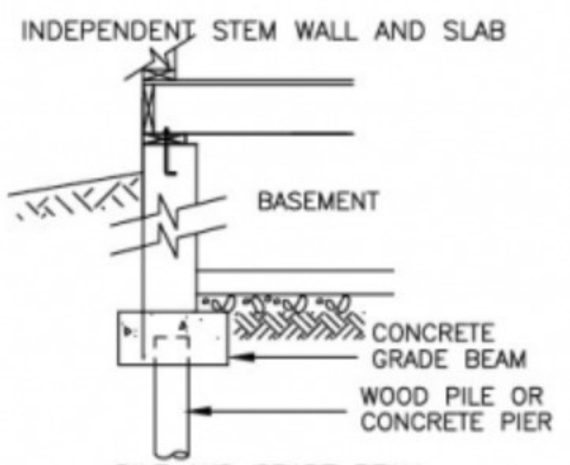
Summary:

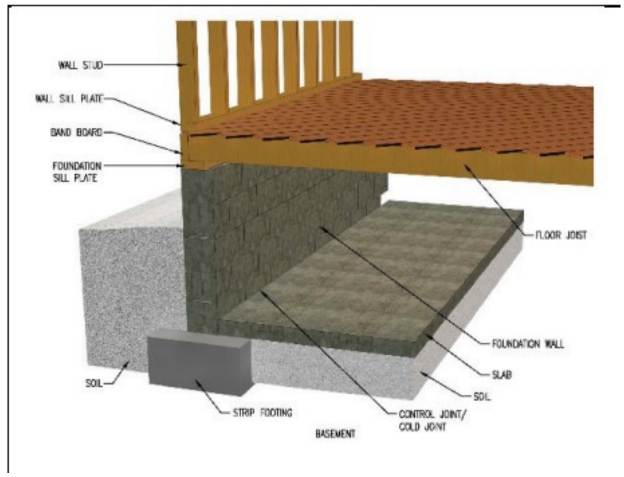


Calculation Report of Foundation: Clinton Infill

Foundation Report

Two-floor House with
Basement





Presumptive Load-Bearing Value $\gamma := 140\ pcf$ $\gamma_w := 62.4\ pcf$

Slab Thickness (Minimum according to IBC) $t_{slab} := 6\ in$

Height of the building $H := 18.3\ ft$

Depth of the footing (For a 2-story with garage the minimum is 4 ft. but one feet will be added for safety purposes) $D_f := 3\ ft$

Height of Foundation Wall (Minimum value using standard codes) $H_f := 8\ ft$

Effective friction angle of soil beneath (Assumed) $\phi := 0°$

Terzhaghi's Bearing Capacity Values $N_c := 5.7$ $N_q := 1$ $N_y := 0$

Effective Unit Weight of the Soil $\gamma' := \gamma - \gamma_w = 77.6\ pcf$

Effective Cohesion of Soil Beneath Footing $c' := 0\ psf$

Vertical Effective Stress at depth D below surface $\sigma'_{zD} := \gamma \cdot D_f = 420\ psf$

Loads acting on the foundation

Dead Loads

$D_{L\_UpperRoof} := 6.304\ psf$

$D_{L\_LowerRoof} := 14.05\ psf$

$D_{1floor\_withPartitionWall} := 33.7\ psf$

$$D_{Total} := D_{L\_UpperRoof} + D_{L\_LowerRoof} + D_{1floor\_withPartitionWall}$$

$D_{Total} = 54.054\ psf$

Live Loads

$L_{residential} := 40\ psf$

$L_{roof} := 20\ psf$

$L_{Porch} := 5\ psf$

$L_{garage} := 40\ psf$

$L_{Total} := L_{residential} + L_{roof} + L_{Porch} + L_{garage}$

$L_{Total} = 105\ psf$

Balanced Snow Loads $\quad P_s := 36.19\ psf$

Unbalanced Snow Loads $\quad P_u := 47\ psf$

Two-Story Total Load $\quad P_{Total} := D_{Total} + L_{Total} + P_s + P_u = 242.244\ psf$

Dimensions of the house $\quad L_1 := 30.25\ ft \qquad L_2 := 33.771\ ft$

Tributary Width

$$T_W := \begin{vmatrix} \text{if } L_1 > L_2 \\ \quad \| \ 0.5\ L_1 \\ \text{else} \\ \quad \| \ 0.5\ L_2 \end{vmatrix} = 16.886\ ft$$

Total Area $\quad A := L_1 \cdot L_2 = \left(1.022 \cdot 10^3\right)\ ft^2$

Tributary Area $\quad A_W := 0.5\ A = 510.786\ ft^2$

Point Load acting on floor $\quad P := P_{Total} \cdot T_W = 4090.4\ plf$

Factor of Safety (Between 2 and 4 is acceptable according to code) $F.S := 3$

Density of Concrete $w_c := 150\ pcf$

Since the basement foundation is a retaining wall in essence, Terzaghi's

$$q_u = cN_c + qN_q + \tfrac{1}{2}\gamma BN_\gamma$$

Width Of The Footing (Assumed value to run calculations)

$$B := 7\ ft$$

Allowable Bearing Capacity $q_a := \dfrac{\left(P + B \cdot w_c \cdot D_f\right)}{T_W} = 428.795\ psf$

Nominal Unit Bearing Capacity $q_n := F.S \cdot q_a = 1286.384\ psf$

Given the results shown above, the width size of the footing is under compliance for the basement structure, where a 4 in. slab is placed. The basement was treated as a retaining wall. Many assumptions were made, with respect to the angle of friction and the Terzaghis' coefficients. The height of the foundation wall was found using standard values (6-10 ft.) The height was found to be 8 ft. because it's approximate a third of the height of the house. Following the CABO One-and-Two-Family Dwelling Code, since the Net (or Nominal) Bearing Capacity was found to be around 1300 psf, the width of the foundation is over 19 in. (1.583 ft.) The Factor of Safety (F.S) was determined to be 3 which is acceptable because the range for a residential structure (2-4).

Minimum Width of Concrete or Masonry Footings (inches)						
	Load-Bearing Value of Soil (psf)					
	1,500	2,000	2,500	3,000	3,500	4,000
Conventional Wood Frame Construction						
1-story	16	12	10	8	7	6
2-story	19	15	12	10	8	7
3-story	22	17	14	11	10	9
4-Inch Brick Veneer Over Wood Frame or 8-Inch Hollow Concrete Masonry						
1-story	19	15	12	10	8	7
2-story	25	19	15	13	11	10
3-story	31	23	19	16	13	12
8-Inch Solid or Fully Grouted Masonry						
1-story	22	17	13	11	10	9
2-story	31	23	19	16	13	12
3-story	40	30	24	20	17	15
Source: Table 403.1; *CABO One- and Two- Family Dwelling Code*; 1995.						

Calculations Report
of
Floor Framing Design

Design Calculations: Dimension Lumber Joist:

2x10 Southern Pine No.1

Properties:

$d := 9.25\ in$

$b := 1.5\ in$

$E := 1600000\ psi$

$I := 98.93\ in^4$

$S_x := 21.39\ in^3$

Assumptions: $D := 20\ psf$ $L := 40\ psf$

Structural Analysis: $l := 16.333\ ft$ $c := 16\ in$

$$w_{selfweight} := b \cdot d \cdot \left(0.55 \cdot 62.4\ \frac{lbf}{ft^3}\right) = 0.003\ \frac{kip}{ft}$$

$$w_D := D \cdot c = 0.027\ \frac{kip}{ft} \qquad w_L := L \cdot c = 0.053\ \frac{kip}{ft}$$

$$w := w_D + w_L + w_{selfweight} = 0.083\ \frac{kip}{ft}$$

$$V_{max} := \frac{w \cdot l}{2} = 0.68\ kip$$

$$M_{max} := \frac{w \cdot l^2}{8} = 2.778\ kip \cdot ft$$

$$R := \frac{w \cdot l}{2} = 0.68\ kip$$

$$w_{LT} := w_D + 0.5 \cdot w_L = 0.053\ \frac{kip}{ft}$$

$$w_{ST} := 0.5 \cdot w_L = 0.027\ \frac{kip}{ft}$$

1. Design For Shear Stress: $f_v \le F_v'$

$$f_v := \frac{3 \cdot V_{max}}{2 \cdot b \cdot d} = 73.549\ psi$$

Reference design value: $F_v := 175\ psi$

Adjustment Factors: $C_D := 1$ $C_M := 1$ $C_t := 1$ $C_i := 1$

$$F_v' := F_v \cdot C_D \cdot C_M \cdot C_t \cdot C_i = 175\ psi$$

Design Check: if $f_v \le F_v'$
"Design ok for Shear Stress"
else
"Design not ok for Shear Stress"

= "Design ok for Shear Stress"

2. Design For Bending Stress: $f_b \le F_b'$

$$f_b := \frac{M_{max}}{S_x} = 1558.451\ psi$$

Reference design value: $F_b := 1200\ psi$

Adjustment Factors: $C_D := 1$ $C_M := 1$ $C_t := 1$ $C_F := 1$ $C_{fu} := 1$ $C_i := 1$ $C_r := 1.15$

$$F_b' := F_b \cdot C_D \cdot C_M \cdot C_t \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1380\ psi$$

Design Check: if $f_b \le F_b'$
"Design ok for Bending Stress"
else
"Design not ok for Bending Stress"

= "Design not ok for Bending Stress"

3. Design For Bearing Stress: $f_{cper} \le F_{cper}'$

Bearing Area:

$$A_{b\_Int} := 4 \cdot b \cdot b = 9\ in^2$$
$$A_{b\_Ext} := b \cdot 7.25\ in = 10.875\ in^2$$

Bearing Stress:

$$f_{cper\_Int} := \frac{R}{A_{b\_Int}} = 75.592\ psi \qquad f_{cper\_Ext} := \frac{R}{A_{b\_Ext}} = 62.559\ psi$$

Reference Design Value: $F_{cper} := 565\ psi$

Adjustment Factors: $C_M := 1$ $C_t := 1$ $C_i := 1$ $C_b := 1$

$F_{cper\_Int}' := F_{cper} \cdot C_M \cdot C_t \cdot C_i \cdot C_b = 565\ psi$

$F_{cper\_Ext}' := F_{cper} \cdot C_M \cdot C_t \cdot C_i \cdot C_b = 565\ psi$

Design checks:

if $f_{cper\_Int} \le F_{cper\_Int}'$
  "Design ok for interior Bearing Stress"
else
  "Design not ok for interior Bearing Stress"

= "Design ok for interior Bearing Stress"

if $f_{cper\_Ext} \le F_{cper\_Ext}'$
  "Design ok for exterior Bearing Stress"
else
  "Design not ok for exterior Bearing Stress"

= "Design ok for exterior Bearing Stress"

4. Design For Deflection:

$\delta_{ST} \le \Delta_{ST}$ $\delta_{TOT} \le \Delta_{TOT}$

$$\delta_{ST} := \frac{5 \cdot w_{ST} \cdot l^4}{384 \cdot E \cdot I} = 0.27\ in$$

$$\delta_{LT} := \frac{5 \cdot w_{LT} \cdot l^4}{384 \cdot E \cdot I} = 0.54\ in$$

$$\delta_T := 1.5 \cdot \delta_{LT} + \delta_{ST} = 1.079\ in$$

Limiting Joist Deflections:

$$\boxed{\Delta_{ST}} := \frac{l}{360} = 0.544\ in$$

$$\Delta_T := \frac{l}{240} = 0.817\ in$$

Design checks:

if $\delta_{ST} \le \Delta_{ST}$
  "Design ok for short term deflection"
else
  "Design not ok for short term deflection"

= "Design ok for short term deflection"

if $\delta_T \le \Delta_T$
  "Design ok for long term deflection"
else
  "Design not ok for long term deflection"

= "Design not ok for long term deflection"