THE UNIVERSITY OF IOWA
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

FINAL DELIVERABLE

Title	City of Beacon City Hall Design
Completed By	Christopher Fojtik, Dante Arguello, Emerson Jordan-Wood
Date Completed	December 2019
UI Department	Department of Civil & Environmental Engineering
Course Name	CEE:4850:0001 Project Design & Management
Instructor	Paul Hanley
Community Partners	City of Beacon, Pathfinders RC&D

This project was supported by the Iowa Initiative for Sustainable Communities (IISC), a community engagement program at the University of Iowa. IISC partners with rural and urban communities across the state to develop projects that university students and IISC pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.

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UNIVERSITY OF IOWA

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

PROJECT DESIGN AND MANAGEMENT

CEE:4850:0001

BEACON CITY HALL

DESIGN REPORT

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Section I - Executive Summary

1. **Project Purpose**

As requested, our engineering services for both the structural and site design work for the new city hall building to be in the town of Beacon, Iowa at 409 Reid Street has been completed. The current city hall building is beginning to show multiple signs of wear, and the construction of a brand-new city hall building is appropriate. The overall goal is to construct a new, larger building with similar features to the city hall that currently exists on the property, and for the new building to be both cost effective and low maintenance. The client specifically requested that the new building should include an office space, kitchen, utility room, restroom, and a large gathering space. The new space will be used for both city council meetings and as a rental hall for anyone who wants to host events such as birthdays and graduation parties. The client requested that the building be at least 60' x 36' with a 10' overhang on the south side of the building. All preliminary design work has been completed for the new building, and the project can now move forward to the next steps if desired.

Multiple building alternatives were presented, and the final design of the building was then chosen by the city council as whole. The alternatives included different floor plan layouts, building locations and orientations, and aesthetic features including roof orientation and types of siding. The final design of the building is for it to be located along the south side of the property with the entrance facing Reid St. The location of the new building was chosen to efficiently use the space on the site, provide adequate stormwater flow paths, and to provide room on the property for future use and expansion of the site to the north, if desired. It was also important to minimize the changes to the grading on the site since there was recently work done on the property. On the west side of the property, additional parking was appropriately designed as well as additional sidewalk access for easy access to and from the building. The new parking lot will provide plenty of parking for the new building and can accommodate any type of event that may be held here. As for the interior of the building, the floor plan was designed in similar fashion to the current city hall, as requested. The open layout will allow for space to be maximized for events such as meetings or rentals for social gatherings. The office space will have room for a desk, shelf space, and location to store city files, while the bathroom will have some storage space and be ADA compliant. The new kitchen will be open to the meeting space with a large island countertop separating the two. The structural analysis of the building was done component by component starting from the roof and traversing down to the foundation. Each component was designed in accordance with ASCE 7-16 and the International Building Code. All site work for the project was completed in accordance with the Iowa Statewide Urban Design and Specifications Manual.

After running a cost analysis based off typical components and the required elements for the project, the total cost for this project is estimated to be approximately $232,000. This price includes the material costs, the cost of instillation, contingency, and overhead for profit. This comes out to be around $100 per square foot to construct the new city hall.

Section II – Organization Qualifications and Experience

1. **Name of Organization**

Elite Design Consulting

2. **Organization Location and Contact Information**

Elite Design Consulting
Seamans Center
Iowa City, Iowa 52240

Emerson Jordan-Wood
Project Manager
(630) 280-0604
ej-jordan-wood@uiowa.edu

3. **Organization and Design Team Description**

Elite Design Consulting consists of a team of engineering students at the University of Iowa who are currently in their senior year capstone design class. The members of the team are Christopher Fojtik, studying civil engineering with a focus in structural design, Dante Arguello, studying civil engineering with a focus in site design and transportation, and Emerson Jordan-Wood, with a focus in site design and architecture. Christopher led the structural design work on the project, Dante led the site design work, and Emerson performed the cost estimate.

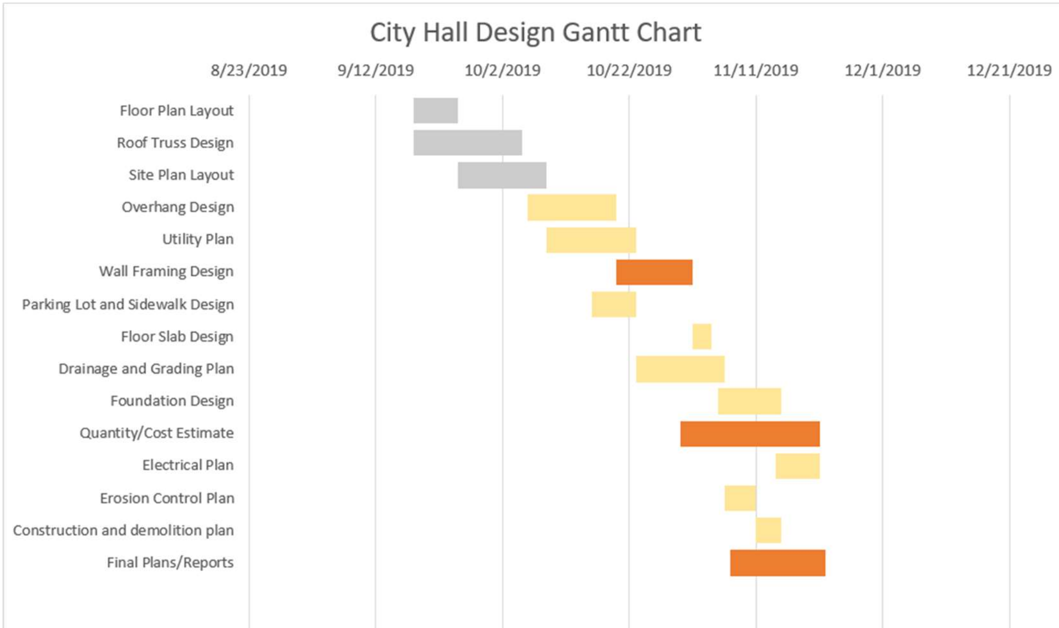
Section III – Design Services

1. **Project Scope**

Elite Design Consulting has completed a preliminary design of the new Beacon City Hall building and parking lot addition. The interior layout of the building was chosen based off the desired features and the size of the building that was specified. The new building will include a large gathering space with an open kitchen, an office space with room for storage, a utility room, and an ADA compliant restroom. Structural design calculations were performed to ensure that the building can support all loads acting upon it. Once the building was designed, our team was able to determine the best location for the new building and parking lot, and how these new features will fit into the exiting site. It was determined that the building would best fit in between the current existing city hall building and the existing storage shed on the site. The building will be oriented long ways east to west with the entrances facing the south side of the property toward the existing parking lot. The building will be offset from the parking lot to provide room for vegetation in front of the building and allow for an accessible route up to the building. There will be a 5:1 grading around the perimeter of the new building which will allow for adequate drainage away from and around the building. The stormwater will drain to the northwest corner of the property to utilize the already existing stormwater intake that is located there. As for the parking lot, there will be approximately 2,600 square feet of additional parking added to the west side of the property along Grant Street. The parking lot was designed according to SUDAS and will be 6" thick PCC on a 12" prepared subgrade that drains to the northwest corner. Our team also recommends painted stalls to be added to both the new and existing parking lots to maximize the number of vehicles that can park here. With the addition of painted stalls, approximately 28 cars or trucks can fit in the lot at any given time. A drawing sheet set will be included along with this report that details the design work that was completed for this project. This includes sets of both structural and architectural plans, along with a set of site plans required to move forward in creating a final design for the project. The structural components of the building were all designed using both Allowable Stress Design and Load and Resistance Factor Design methods in combination with the State of Iowa Building Codes. All site design work was completed in accordance with the Iowa Statewide Urban Design and Specifications Manual. The structural plans show all components necessary for proper construction of the building and the site plan sets show how the new building, sidewalks, and parking will all interact with and change the site geometry and its current features. This includes the location of the proposed building footprint, parking and sidewalk additions, proposed utility locations, grading and landscape features, and the path of flow for stormwater runoff. All values gathered from the designs were included in a cost estimate that is shown in detail later in the report.

2. **Work Plan**

The following chart lays out a schedule of the major design tasks that our team completed and the approximate duration of each task. The project started with the design of different design alternatives for the building. After presenting those alternatives our team compiled a final floor plan based off the response from the city council. After obtaining all components requested the structural design, starting from the roof then down to the foundation, was completed. Being done simultaneously to the structural design was the site design. This consisted of utilities layout to the best of our knowledge as well as the parking and sidewalk addition.



Section IV – Constraints, Challenges, and Impacts

Constraints

One of the primary constraints facing this project was the amount of time that was given to complete the preliminary designs. The starting date for the project was September 13, 2019 and the ending date was December 13, 2019, which gave our team 3 months to complete the work. Each member of our team was also enrolled full time at the University of Iowa, so there was other work we had to complete during the entirety of the process. Time is always a constraint for these types of projects and finding balance between all courses and working efficiently was a key to completing this project. Another constraint was the amount of space that we had to work with on the site. Our team was given a rough idea of where the new building is to be located, so therefore the project was constrained to this area. Similarly, the size of the building was also a constraint. A building size of 60'x36' was specified so the design features were limited to the amount of space given.

Challenges

One challenged that arose was not knowing the exact location, elevation, and size of the existing water main, sanitary sewer main, and storm sewers that already exist on and around the site. The only information that was given was the approximate location of where each of the lines run. Although this prevented some amount of design work, enough information was provided in the plan sheets in order to complete the new designs once the locations of each are field verified. One final challenge that can arise during construction is the possibility of elements unknown to us during design. If unknown elements are faced, contact the civil engineer as soon as possible to get a resolution.

Section V – Alternative Solutions That Were Considered

A variety of alternatives were used to create the preliminary designs for the city hall. All desired and requested features and each of their constraints were considered when creating alternative designs. It was specifically requested that a building size of 60’x36’ with a 10’ overhang along the front to be used. Initially three different layouts were presented, each having similar features but different layouts and materials. Variances in layouts consisted of different possible locations of the building itself, different room layouts, open styles of the main area, and the possibility of a basement for additional storage. The final design was then chosen based on the pros and cons of each alternative and what was feasible. The final design was a combination of all alternatives put together into one. The final design consists of a building with no basement, a location to the west of the current city hall running long ways east to west, and an open style interior with all rooms that were requested.

Section VI – Final Design Details

Floor Plan Layout

Three initial floor plans were proposed, and ideas from each of the floor plans were combined to create one final floor plan with an open layout. Room sizing and building requirement were taken from the 2015 IBC for Iowa. As requested, the rooms that are contained in the City Hall are a bathroom, a storage room for cleaning items and mechanical equipment, an office space for a desk and storage, and finally an open style kitchen. The remaining space will be open style to serve the purpose of recreational activities and city hall meetings. The final floor plan layout can be seen in our construction drawings sheet A101 with more specific details.

Building Size and Location

The client specifically requested that the building should be sized at 60’ by 36’ with a 10’ overhang along the south side, and that the building be ran longways east to west. It was determined that the best location for the building was approximately 12.5’ north of the existing parking lot and 15’ to the west of the existing city hall building. This was done in order to provide a small front yard that could be used for vegetation and be more aesthetically pleasing compared to having the building in direct contact with the parking lot. This location also allowed for appropriate grading to be designed to ensure that stormwater runs off in the desired directions without having to perform substantial earthwork to the already existing slopes on the site. The location of the building can be found on sheet C101 in the drawing sheet set.

Parking Lot Addition with Stalls

The site currently has a concrete parking lot on the south side of the property along Reid Street that serves the existing city hall building. The client requested that additional parking be added to the west side of the property along Grant Street. The parking lot pavement was designed in accordance with the Iowa SUDAS manual. A parking lot pavement thickness of 6” PCC on a 12” prepared subgrade was chosen since the expected volume of cars is low. The location and other details including slopes and elevations can be found in the attached site drawings set. The previously existing parking lot was not marked with parking stalls and adding painted stalls will better regulate parking and maximize the space of the lot, providing for up to 28 full size parking stalls. The location of this addition can be found on sheet C101, with more specific details including elevations and slopes on sheets C101 and C102.

Sidewalk Layout and Design

Two sections of new sidewalks were added to the site plan in order to provide access routes to and from both the existing and proposed parking lots. Both sidewalks run directly along the parking lots and are ADA compliant with maximum slopes no greater than 3% and cross slopes no greater than 2%. More specific details including size, thickness, location, spot elevations, and addition slope information can be found on sheets C101 and C102 in the drawing sheet set. Due to the location of the sidewalk and addition parking, some trees on the site may need to be relocated or removed based on their size. All tree locations should be verified before any further planning and design.

Utility Information

The utilities to be supplied to and from the building include a water service line, a gas line, and a sanitary sewer pipe. All utilities are designed and to be constructed in accordance with the Iowa SUDAS Manual and 2012 International Building Code. The water service line that will be used is a ¾” service line, and it will provide more than enough flow for the demands of the building. The sanitary sewer service line shall be 4” PVC pipe with 2-5% slopes. This was chosen as a low cost and effective solution to provide sanitary services to the building. Regarding the stormwater runoff, the Rational Method was used to calculate the estimated direct runoff before and after construction and demolition activities. It was determined that for a 25-year design storm with a concentration time of 5 minutes and a rainfall intensity of 9.53 in/hr, there will be a 0.532 cfs increase in flow. The stormwater will be directed to the existing inlet on site, which has a 4’x4’ opening. The size of the stormwater pipe underneath the inlet was not provided, so a field inspection is recommended before moving forward with the design process.

Structural Design Components

The governing resource used for the structural analysis was the 2015 version of the International Building Code (IBC). Other main resources used, but not limited to, were American Society of Civil Engineers 7-16 (ASCE 7-16), National Design Specification (NDS), National Design

Specification Supplement, American Concrete Institution (ACI), and the Concrete Reinforcing Steel institute (CRSI). All design calculations can be seen in appendix B and structural diagrams and components can be seen in the plan sheets submitted. All wood construction was designed to be Douglas Fir Larch N. 01 or better and initial loading values for dead, live, snow, and wind loads were taken from the ASCE 7-16 design loading tables. These loadings were factored accordingly and applied to each component based on loading areas.

The structural analysis stated with the roof design. The roof spans the 36' section of the building and is spaced at 16" on center along the 60' section of the building. From gravity and wind load analysis the final roof truss system was designed to be a Howe (K) 4 panel truss comprised of top and bottom cord being 2x6 sawn lumber and web members being 2x4 sawn lumber. The truss system was spaced at 16" on center. After the truss system was designed, the overhang was designed next. Using similar load analysis as the roof, with some changes due to orientation and geometry, the overhang designed was made of a horizontal V shaped section of two (2) 2x4 sawn pieces of lumber at a ten (10) degree angle. The supporting beam for the overhang part of the roof was designed to be a 60' spanning beam at size 5.5"x9" and column supports for the beam are 4"x4" spaced at 15' apart. Wall construction was based off load path from the roof analysis. To maintain simplicity all the walls were designed the same at 2x6 sections of sawn lumber spaced at 16" on center for proper room for insulation and interior electrical components need be. Interior partition walls, being non load bearing, are framed with 2x4 sawn lumber components at 24" on center in order to help with overall cost. Once the walls, roof, and overhang were all completed the floor slab came next. Typical interior floor slabs are of 4" thickness. In order to increase the lifespan of the floor slab and resist cracking, there is reinforcement of W2.9 section wire fabric at 4"x4" square grids. Lastly, the foundation was designed as a continuous footing all the way around the load bearing (60'x36') section of the walls. Concrete Sonotubes were designed for the column supports. All foundation dimensions and structural components can be seen in appendix B and construction plan sheets submitted.

VII – Engineer's Cost Estimate

The cost estimate was made using RSMeans data - Square Foot Costs. All of the assembly pieces were chosen based on our designs and quantities were estimated from the drawing sets. The HVAC system, roofing insulation, and tree removal were not in the RSMeans book, so they were estimated using online resources. The prices included are the raw material costs for all of the products and the cost for instillation of the materials. Factored into the final price was an additional 10% for contingencies like unforeseen construction costs, and an additional 25% for overhead and profit. After all of this, the final estimated cost for the project is $232,000.

Item	Description	Unit	Unit Price			Quantity	Total Price		
			Material Price	Instillation Price	Total Price		Material Price	Instillation Price	Total Price
Substructure									
Wall Foundation	4', direct chute, .123 concrete, 10" thick	LF	$ 27.00	$ 59.50	$ 86.50	192	$ 5,184.00	$ 11,424.00	$ 16,608.00
Strip Footing	Load 5.1 KLF, soil capacity 3 KSF, 24"widex12"deep, reinf	LF	$ 18.90	$ 25.00	$ 43.90	192	$ 3,628.80	$ 4,800.00	$ 8,428.80
Slab on Grade	4" thick, light industrial, reinforced	SF	$ 3.07	$ 4.01	$ 7.08	2160	$ 6,631.20	$ 8,661.60	$ 15,292.80
Excavation & Backfill	per 1000 sq.ft, 4' sand,gravel, or common earth, clay excavation, bank run gravel borrow for backfill	SF	$ 2.05	$ 2.40	$ 4.45	1000	$ 2,050.00	$ 2,400.00	$ 4,450.00
Shell									
Wood Columns	4"x4", 10'x8' bay size, 10' height	SF	$ 0.04	$ 0.03	$ 0.07	400	$ 15.11	$ 12.44	$ 27.56
Wood Pitched Roof	2"x6", 16" O.C.	SF	$ 1.42	$ 1.74	$ 3.16	2909	$ 4,133.50	$ 5,059.55	$ 9,193.05
Exterior Walls	2"x6" studs, 16"O.C, 8" fiber cement siding	SF	$ 4.99	$ 11.10	$ 16.09	1920	$ 9,580.80	$ 21,312.00	$ 30,892.80
Wood Windows	Double Hung, insulated glass, 3'x5'6"	per unit	$ 360.00	$ 310.00	$ 670.00	2	$ 720.00	$ 620.00	$ 1,340.00
Wood Windows	Casement, insulated glass, 7'11"x6'3"	per unit	$ 1,375.00	$ 365.00	$ 1,740.00	1	$ 1,375.00	$ 365.00	$ 1,740.00
Wood Windows	Casement, insulated glass, 5'11"x5'2"	per unit	$ 960.00	$ 305.00	$ 1,265.00	4	$ 3,840.00	$ 1,220.00	$ 5,060.00
Wood Exterior Doors	Birch, Single Door, Hinged, 2'6"x	per opening	$ 2,100.00	$ 340.00	$ 2,440.00	2	$ 4,200.00	$ 680.00	$ 4,880.00
Shingles	Asphalt Roofing,Strip Shingles, 4"Slope, inorganic class A 210-235 psf	SF	$ 0.93	$ 1.26	$ 2.19	2909	$ 2,705.64	$ 3,665.71	$ 6,371.35
Roof Insulation	Sprayed Foam, Open-Cell	Board Ft	$ 0.50	$ 1,500.00	$ 0.50	17456	$ 8,727.88	$ 1,500.00	$ 10,227.88
Interiors									
Walls	5/8" FR drywall, 2x4 @ 24"O.C., nothing	SF	$ 1.23	$ 2.89	$ 4.12	1692	$ 2,081.16	$ 4,889.88	$ 6,971.04
Walls	5/8" FR drywall, 2x4 @ 24"O.C., same	SF	$ 2.08	$ 4.78	$ 6.86	517.5	$ 1,076.40	$ 2,473.65	$ 3,550.05
Interior Doors	Single Leaf Wood, 3'x7', birch, hollow core	per opening	$ 435.00	$ 223.00	$ 658.00	4	$ 1,740.00	$ 892.00	$ 2,632.00
Bath	Dispenser, towel, surface mounted	each	$ 47.50	$ 39.00	$ 86.50	1	$ 47.50	$ 39.00	$ 86.50
Bath	Grab bar, 1-1/4" diam., 12" long	each	$ 33.00	$ 26.00	$ 59.00	2	$ 66.00	$ 52.00	$ 118.00
Bath	Mirror, framed with shelf, 18"x24"	each	$ 204.00	$ 31.50	$ 235.50	1	$ 204.00	$ 31.50	$ 235.50
Bath	Toilet paper dispenser	each	$ 19.45	$ 21.00	$ 40.45	1	$ 19.45	$ 21.00	$ 40.45
Paint	Primer + 1 coat	SF	$ 0.14	$ 0.80	$ 0.94	2727	$ 381.78	$ 2,181.60	$ 2,563.38
Floor Finish	Vinyl, composition tile, maximum	SF	$ 1.91	$ 1.13	$ 3.04	2160	$ 4,125.60	$ 2,440.80	$ 6,566.40
Ceiling Finish	5/8" FR drywall, 1"x3" wood, 16" O.C, wood	SF	$ 1.00	$ 3.91	$ 4.91	2160	$ 2,160.00	$ 8,445.60	$ 10,605.60
Services									
Toilet	Tank type, floor mounted, two piece close coupled	each	$ 705.00	$ 855.00	$ 1,560.00	1	$ 705.00	$ 855.00	$ 1,560.00
Bath Sink	Wall hung,Vitreous China, 20"x27", handicap	each	$ 1,575.00	$ 985.00	$ 2,560.00	1	$ 1,575.00	$ 985.00	$ 2,560.00
Kitchen Sink	Countertop, PE on CI, 32"x21" double bowl	each	$ 765.00	$ 955.00	$ 1,720.00	1	$ 765.00	$ 955.00	$ 1,720.00
Water Heater	Gas Fired WH, residential, 100F rise, 30 gal tank	each	$ 2,675.00	$ 1,575.00	$ 4,250.00	1	$ 2,675.00	$ 1,575.00	$ 4,250.00
HVAC	48,000 BTU system	each	$ 3,500.00	$ 2,500.00	$ 6,000.00	1	$ 3,500.00	$ 2,500.00	$ 6,000.00
Sprinklers	Wet pipe, light hazard, 2000 SF	SF	$ 5.75	$ 3.59	$ 9.34	2160	$ 12,420.00	$ 7,754.40	$ 20,174.40
Eqipment & Furnishing									
Kitchen	Single Oven, 30"wide, economy	each	$ 945.00	$ 119.00	$ 1,064.00	1	$ 945.00	$ 119.00	$ 1,064.00
Kitchen	Refrigerator, no frost, 10-12 CF, economy	each	$ 495.00	$ 99.50	$ 594.50	1	$ 495.00	$ 99.50	$ 594.50
Kitchen	Sink Base Cabinet, 36" wide, average	per unit	$ 565.00	$ -	$ 565.00	1	$ 565.00	$ -	$ 565.00
Kitchen	Base Unit, 24" deep, 35" high, one door below 18"wide, average	per unit	$ 425.00	$ -	$ 425.00	12	$ 5,100.00	$ -	$ 5,100.00
Kitchen	Base Unit, 24" deep, 35" high, one door below 15"wide, average	per unit	$ 400.00	$ -	$ 400.00	2	$ 800.00	$ -	$ 800.00
Kitchen	Wall Unit, 12" deep, 30" high, two doors, 36" wide, average	per unit	$ 575.00	$ -	$ 575.00	2	$ 1,150.00	$ -	$ 1,150.00
Kitchen	Countertop, Stock plastic laminate, 24" wide	LF	$ 35.00	$ -	$ 35.00	14	$ 490.00	$ -	$ 490.00
Site Work									
Flagpole	Aluminum, tapered, 20' high	each	$ 1,200.00	$ 720.00	$ 1,920.00	1	$ 1,200.00	$ 720.00	$ 1,920.00
Demolition	Single Family, 1 story, wood, 1600SF	each	$ 2,325.00	$ 2,200.00	$ 4,525.00	1	$ 2,325.00	$ 2,200.00	$ 4,525.00
Parking Lot	Concrete, Slip Form, 12' pass, unreinforced, 6"	SY	$ 25.00	$ 0.72	$ 25.72	2000	$ 50,000.00	$ 1,440.00	$ 51,440.00
Tree Removal	Removal of trees	each	$ 500.00	$ -	$ 500.00	7	$ 3,500.00	$ -	$ 3,500.00

Material & Installation	Cost		
Substructure	$ 35,200.00		
Shell	$ 54,400.00		
Interior	$ 25,800.00		
Services	$ 31,600.00		
Equipment & Furnishing	$ 8,500.00		
Site Work	$ 16,100.00		
Contingency (10%)	$ 17,200.00	Contingency (10%)	$ 15,600.00
Overhead and Profit (25%)	$ 42,900.00	Overhead and Profit (25%)	$ 38,900.00
Total Price	**$ 232,000.00**	**Total Price**	**$ 210,000.00**
			$ 97.22

Phase 1	Cost	Phase 2	Cost
Substructure	$ 35,200.00	Site Work	$ 10,200.00
Shell	$ 54,400.00	Contingency (10%)	$ 1,000.00
Interior	$ 25,800.00	Overhead and Profit (25%)	$ 2,600.00
Services	$ 31,600.00	**Total Price**	**$ 14,000.00**
Equipment & Furnishing	$ 8,500.00		
Site Work	$ 5,900.00		
Contingency (10%)	$ 16,100.00		
Overhead and Profit (25%)	$ 40,400.00		
Total Price	**$ 218,000.00**		

Appendices

Appendix A – References

2010 ADA Standards for Accessible Design:
BNi Building News. (2012). *2010 Ada standards for accessible design with commentary*. Anaheim, CA.

Iowa SUDAS 2019 Edition:
Iowa State University. (2019). *Iowa Sudas Design Manual* (2019th ed.). Ames, IA.

2012 IBC:
International Code Council. (2012). *International building code: 2012*. Country Club Hills, IL.

ASCE 7-16:
American Society of Civil Engineers. (2017). *Minimum design loads and associated criteria for buildings and other structures*. Reston, VA.

NDS:
The Association. (1986). *National design specification: wood construction: structural lumber, glued laminated timber, timber pilings, fastenings: recommended practice*. Washington, D.C. (1619 Mass. Ave., N.W., Washington 20036).
CRSI:
Concrete Reinforcing Steel Institute. (2008). *Crsi design handbook 2008: based on the 2008 Aci building code*. Schaumburg.

ACI:
American Concrete Institute. (2004). *American Concrete Institute: 2004 catalog*. Farmington, MI.

RSMeans:
Hamitou, Wafaa. *Square Foot Costs with RSMeans Data 2018*. 39th ed., R S Means Co, 2018.

Appendix B City Hall Design Calculations:

Chris Fojtik
Ej Jordan-Wood
Dante Arguello

Location: Beacon Iowa (450 people)
wood reference design values:

$F_b := 1000\ psi$ $F_c := 1500\ psi$ $F_t := 675\ psi$ $F_{c.parallel} := 625\ psi$

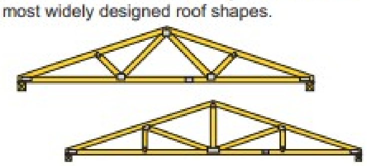
$E_{min} := 620000\ psi$ $E := 1700000\ psi$ $F_v := 180\ psi$

Roof design:

Howie (K) Truss- 4 panel

Alpine truss designs are engineered to meet specific span, configuration and load conditions. The shapes and spans shown here represent only a fraction of the millions of designs produced by Alpine engineers.

Common -- Truss configurations for the most widely designed roof shapes.



Total load(PSF) / **Duration factor** / Live load(PSF) / Roof type	55 / 1.15 / 40 snow shingle; 55 / 1.15 / 30 snow tile			47 / 1.15 / 30 snow shingle			40 / 1.15 / 20 snow shingle			40 / 1.25 / 20 ** shingle; **construction or rain, not snow load		
Top Chord	2x4	2x6	2x6	2x4	2x6	2x6	2x4	2x6	2x6	2x4	2x6	2x6
Bottom Chord	2x4	2x4	2x6	2x4	2x4	2x6	2x4	2x4	2x6	2x4	2x4	2x6
Pitch	**Spans in feet to out of bearing**											
2/12	24	24	33	27	27	37	31	31	43	33	33	46
2.5/12	29	29	39	33	33	45	37	38	52	39	40	55
3/12	34	34	46	37	39	53	40	44	60	43	46	64
3.5/12	39	39	53	41	44	61	44	50	65	47	52	70
4/12	41	43	59	43	49	64	46	56	69	49	57	74
5/12	44	52	67*	46	58	69*	49	66	74*	53	66	80*
6/12	46	60*	69*	47	67*	71*	51	74*	76*	55	74*	82*
7/12	47	67*	70*	48*	72*	72*	52*	77*	77*	56*	80*	83*

-60'x36' with 10ft overhang on south side(60ft)
-Pitch: 4/12 (not too steep not to flat) (roof height 6FT ft)
-10ft overhang has 2/12 slope
-Risk Category II based off of max people occupying the space

for load calculator:
-spacing 16 in OC
-prelimenary based off the table 2x4 should work for cords and web
-thin waterprooping membrane under shingles
-roof sheating needs consideration
-Regular ashpalt shingles

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Truss Design Calculations

Initial load takedown: $Spacing := 16\ in$

Snow Loading:

Factors for calculation:

Building is to occupy around 100 people maximum at any given time putting the city hall into risk category II

$I_{s.snow} := 1.0$

exposure: Building has some surrounding structures on the land plot so it is in exposure catagory B (partially exposed) with surface soucgness category B (urban/suburban area)

$C_e := 1.0$

Therman condition: Heated structure kept well above freezing

$C_t := 1.0$

Slope factor: roof pitch of 4 to 12

$C_s := 1.0$

Snow load(ground):

$$p_g := 25\ \frac{lbf}{ft^2}$$

Snow load (sloped)

$$p_s := (0.7) \cdot (C_s) \cdot (C_e) \cdot (C_t) \cdot (I_{s.snow}) \cdot (p_g) = 17.5\ psf$$

$$p_m := I_{s.snow} \cdot 20\ psf = 20\ psf$$

Snow load(horizontal plane):

$$P_{s.sloped} := p_m \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 21.082\ psf$$

$$P_{snow} := P_{s.sloped} \cdot Spacing = 28.109\ plf$$

unbalanced(case 1):

w is < 20ft (18ft) therefore case 1

$$p_{unbalanced} := I_{s.snow} \cdot p_g = 25\ psf$$

acts on full 18ft section with orientation depending on wind direction

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Wind Loading:

Exposure: Category C

mean roof height:

$h_{mean} := 13\ ft + 4\ in$

$\lambda := 1.21$ $\qquad K_{zt} := 1$

Risk category II basic wind speed map (ASCE 26.5-1B)

$V := 107\ mph$

after to get the values needed at 107 mph wind and 18 degrees from the horizontal:

		Location							
wind spee	angle	A	B	C	D	E	F	G	H
107	18.43	32.54278	-9.23763	21.63685	-5.1428	-29.0909	-19.8167	-20.1931	-15.1036

$W_a := 32.54\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = 52.498\ \frac{lbf}{ft}$ $\qquad W_{s.a} := W_a \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 55.338\ plf$

$W_b := -6.93\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = -11.18\ \frac{lbf}{ft}$ $\qquad W_{s.b} := W_b \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = -11.785\ plf$

$W_e := -21.84\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = -35.235\ \frac{lbf}{ft}$ $\qquad W_{s.e} := W_e \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = -37.141\ plf$

$W_f := -14.877\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = -24.002\ \frac{lbf}{ft}$ $\qquad W_{s.f} := W_f \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = -25.3\ plf$

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Live loads:

Roof:

typical roof live load:

$L_{roof} := 20\ psf$ not intended for occupancy but possible maintenance

$L_{bottom} := L_{roof} \cdot Spacing = 26.667\ plf$

$L_{top} := L_{roof} \cdot Spacing \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 28.109\ plf$

Dead Loads:

dead load calculator:

roof:

$D_{upper} := 7\ psf$ $D_{upper} \cdot Spacing = 9.333\ plf$ (horizontal plane)

$D_{lower} := 9.75\ psf$ $D_{lower} \cdot Spacing = 13\ plf$

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Roof Truss

top cord analysis: (2x6) compression

$S := 7.56\ in^3$ $I := 20.80\ in^4$ $A := 8.25\ in^2$

$C_m := 1.0$ $C_d := 1.6$ $C_{fu} := 1.0$ $C_{fb} := 1.3$ $C_r := 1.0$

$C_t := 1.0$ $C_l := 1.0$ $C_{ft} := 1.3$ $C_{fc} := 1.1$ $C_i := 1.0$

$P_c := 3125\ lbf$ $M := 500\ lbf \cdot ft$

$E_{min}' := E_{min} \cdot C_m \cdot C_t \cdot C_i = (6.2 \cdot 10^5)\ psi$ $F_{cstar} := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i = (2.64 \cdot 10^3)\ psi$

$$F_{ce} := \frac{(0.822 \cdot E_{min}')}{\left(\frac{9.5\ ft}{5.5\ in}\right)^2} = (1.186 \cdot 10^3)\ psi$$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot 0.8} = 0.906 \qquad \beta := \frac{\left(\frac{F_{ce}}{F_{cstar}}\right)}{0.8} = 0.562$$

$$C_p := \alpha - (\alpha^2 - \beta)^{0.5} = 0.397$$

$$F_c' := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i \cdot C_p = (1.048 \cdot 10^3)\ psi$$

$$F_b' := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_l \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = (2.08 \cdot 10^3)\ psi$$

$$f_c := \frac{P_c}{A} = 378.788\ psi \qquad f_b := \frac{M}{S} = 793.651\ psi$$

$f_c < F_c' = 1$ $f_b < F_b' = 1$

$$\frac{f_c}{F_c'} = 0.361 \qquad \frac{f_b}{F_b'} = 0.382$$

$$\beta := \left(1 - \frac{f_c}{F_{ce}}\right)^{-1} = 1.469$$

$$\left(\frac{f_c}{F_c'}\right)^2 + \beta \cdot \left(\frac{f_b}{F_b'}\right) = 0.691$$

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bottom cord analysis: (2x6) tension

$l_e := 9.0\ ft = 9\ ft$

$C_m := 1.0$ $C_d := 1.6$ $C_{fu} := 1.0$ $C_{fb} := 1.3$ $C_r := 1.0$

$C_t := 1.0$ $C_l := 1.0$ $C_{ft} := 1.3$ $C_{fc} := 1.1$ $C_i := 1.0$

$P_t := 3000\ lbf$ $M := 450\ lbf \cdot ft$

$$F_{bstar} := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(2.08 \cdot 10^3\right)\ psi$$

$$R_b := \left(\frac{l_e \cdot 5.5\ in}{(1.5\ in)^2}\right)^{0.5} = 16.248 \qquad F_{be} := \frac{1.2 \cdot E_{min}}{R_b^{\ 2}} = \left(2.818 \cdot 10^3\right)\ psi$$

$$\alpha := \frac{1 + \frac{F_{be}}{F_{bstar}}}{1.9} = 1.239 \qquad \beta := \frac{\left(\frac{F_{be}}{F_{bstar}}\right)}{0.95} = 1.426$$

$$C_l := \alpha - \left(\alpha^2 - \beta\right)^{0.5} = 0.908$$

$$F_t' := F_t \cdot C_d \cdot C_m \cdot C_t \cdot C_{ft} \cdot C_i = \left(1.404 \cdot 10^3\right)\ psi$$

$$F_b' := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_l \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(1.888 \cdot 10^3\right)\ psi$$

$$f_t := \frac{P_t}{A} = 363.636\ psi \qquad f_b := \frac{M}{S} = 714.286\ psi$$

$$f_t < F_t' = 1 \qquad f_b < F_b' = 1$$

$$\frac{f_t}{F_t'} = 0.259 \qquad \frac{f_b}{F_{bstar}} = 0.343$$

$$\frac{f_t}{F_t'} + \frac{f_b}{F_{bstar}} = 0.602$$

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Web member analysis: (2x4)

Case 4 gives the maximum tension value in the web
Case 4 Gives the maximum compression value in the web

$T := 1118\ lbf$ $A := 5.25\ in^2$ $C := 1171\ lbf$

$f_t := \frac{T}{A} = 212.952\ psi$ $f_c := \frac{C}{A} = 223.048\ psi$

$\frac{f_t}{F_t'} = 0.152$ $\frac{f_c}{F_c'} = 0.213$

Deflection analysis:

$L := 36\ ft$

$\delta_{allowtotal} := \frac{L}{240} = 1.8\ in$ $\delta_{allowservice} := \frac{L}{360} = 1.2\ in$

$ST_{top} := 0.12\ in$ $LT_{top} := 0.23\ in$ $\delta_{tot} := 1.5 \cdot LT_{top} + ST_{top} = 0.465\ in$

$ST_{bot} := 0.13\ in$ $LT_{bot} := 0.24\ in$ $\delta_{tot} := 1.5 \cdot LT_{bot} + ST_{bot} = 0.49\ in$

Overhang Calculations

Initial load takedown: $Spacing := 16\ in$

Snow Loading:

Factors for calculation:

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$I_{s.snow} := 1.0$

exposure: Building has some surrounding structures on the land plot so it is in exposure catagory B (partially exposed) with surface soucgness category B (urban/suburban area)

$C_e := 1.0$

Therman condition: Heated structure kept well above freezing

$C_t := 1.0$

Slope factor: roof pitch of 4 to 12

$C_s := 1.0$

Snow load(ground):

$$p_g := 25\ \frac{lbf}{ft^2}$$

Snow load (sloped)

$$p_s := (0.7) \cdot (C_s) \cdot (C_e) \cdot (C_t) \cdot (I_{s.snow}) \cdot (p_g) = 17.5\ psf$$

$$p_m := I_{s.snow} \cdot 20\ psf = 20\ psf$$

Snow load(horizontal plane):

$$P_{s.sloped} := p_m \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 21.082\ psf$$

$$P_{snow} := P_{s.sloped} \cdot Spacing = 28.109\ plf$$

unbalanced(case 1):

w is < 20ft (18ft) therefore case 1

$$p_{unbalanced} := I_{s.snow} \cdot p_g = 25\ psf$$

acts on full 18ft section with orientation depending on wind direction

Wind Loading:

Exposure: Category C

mean roof height:

$h_{mean} := 13\ ft + 4\ in$

$\lambda := 1.21$ $K_{zt} := 1$

Risk category II basic wind speed map (ASCE 26.5-1B)

$V := 107\ mph$

$W_b := -6.93\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = -11.18\ \dfrac{lbf}{ft}$ $W_{s.b} := W_b \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \dfrac{1}{12}\right) = -11.785\ plf$

$W_e := -21.84\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = -35.235\ \dfrac{lbf}{ft}$ $W_{s.e} := W_e \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \dfrac{1}{12}\right) = -37.141\ plf$

reference design values:

$F_b := 1000\ psi$ $F_c := 1500\ psi$ $F_t := 675\ psi$ $F_{c.parallel} := 625\ psi$

$E_{min} := 620000\ psi$ $E := 1700000\ psi$ $F_v := 180\ psi$

Overhang

snow:

$$p_m := 20\ psf = 20\ psf$$

$$P_{s.sloped.overhang} := p_m \cdot \left(\left(2^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 20.276\ psf$$

$$P_{s.overhang} := P_{s.sloped.overhang} \cdot Spacing = 27.035\ plf$$

$$p_f := (0.7) \cdot (C_e) \cdot (C_t) \cdot (I_{s.snow}) \cdot (p_g) = 17.5\ psf$$

$$p_{sliding} := 0.4 \cdot p_f \cdot 18\ ft = 126\ plf$$

$$P_{overhang} := \frac{p_{sliding}}{15\ ft} \cdot \left(\frac{10}{15} \right) = 5.6\ psf$$

$$P_{sliding} := P_{overhang} \cdot Spacing = 7.467\ plf$$

$$P_{OH} := P_{sliding} + P_{s.overhang} = 34.501\ plf$$

wind:

$$W_{s.b} := W_b \cdot \left(\left(2^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = -11.335\ plf$$

$$W_{s.e} := W_e \cdot \left(\left(2^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = -35.721\ plf$$

$$W_{under} := W_{s.e} \cdot 0.7 = -25.005\ plf$$

Live:

$$L_{roof} := 20\ psf$$

$$L_{top} := L_{roof} \cdot Spacing \cdot \left(\left(2^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 27.035\ plf$$

Dead Loads:

$D_{upper} := 4.5\ psf$ $\qquad$ $D_{upper} \cdot Spacing = 6\ plf$

$D_{lower} := 2\ psf$ $\qquad$ $D_{lower} \cdot Spacing = 2.667\ plf$

top cord analysis: (2x4) compression

$S := 3.06\ in^3$ $\quad I := 5.36\ in^4$ $\quad A := 5.25\ in^2$

$C_m := 1.0$ $\quad C_d := 1.6$ $\quad C_{fu} := 1.15$ $\quad C_{fb} := 1.5$ $\quad C_r := 1.15$

$C_t := 1$ $\quad C_l := 0.87$ $\quad C_{ft} := 1.5$ $\quad C_{fc} := 1.15$ $\quad C_i := 1.0$

$P_c := 37\ lbf$ $\quad M := 520\ lbf \cdot ft$

$E_{min}' := E_{min} \cdot C_m \cdot C_t \cdot C_i = \left(6.2 \cdot 10^5\right)\ psi$ $\quad F_{cstar} := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i = \left(2.76 \cdot 10^3\right)\ psi$

$$F_{ce} := \frac{\left(0.822 \cdot E_{min}'\right)}{\left(\frac{10\ ft}{3.5\ in}\right)^2} = 433.548\ psi$$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot 0.8} = 0.723 \qquad \beta := \frac{\left(\frac{F_{ce}}{F_{cstar}}\right)}{0.8} = 0.196$$

$$C_p := \alpha - \left(\alpha^2 - \beta\right)^{0.5} = 0.152$$

$$F_c' := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i \cdot C_p = 418.582\ psi$$

$$F_b' := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_l \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(2.761 \cdot 10^3\right)\ psi$$

$$f_c := \frac{P_c}{A} = 7.048\ psi \qquad f_b := \frac{M}{S} = \left(2.039 \cdot 10^3\right)\ psi$$

$f_c < F_c' = 1$ $\quad f_b < F_b' = 1$

$$\frac{f_c}{F_c'} = 0.017 \qquad \frac{f_b}{F_b'} = 0.738$$

$$\beta := \left(1 - \frac{f_c}{F_{ce}}\right)^{-1} = 1.017$$

$$\left(\frac{f_c}{F_c'}\right)^2 + \beta \cdot \left(\frac{f_b}{F_b'}\right) = 0.751$$

bottom cord analysis: (2x4) tension

$l_e := 10.0\ ft$

$C_m := 1.0$ $C_d := 1.6$ $C_{fu} := 1.15$ $C_{fb} := 1.5$ $C_r := 1.15$

$C_t := 1$ $C_l := 1.0$ $C_{ft} := 1.5$ $C_{fc} := 1.15$ $C_i := 1.0$ $C_p := 1.0$

$P_t := 37\ lbf$ $M := 165\ lbf \cdot ft$

$$F_{bstar} := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(3.174 \cdot 10^3\right)\ psi$$

$$R_b := \left(\frac{l_e \cdot 3.5\ in}{(1.5\ in)^2}\right)^{0.5} = 13.663 \qquad F_{be} := \frac{1.2 \cdot E_{min}}{{R_b}^2} = \left(3.986 \cdot 10^3\right)\ psi$$

$$\alpha := \frac{1 + \frac{F_{be}}{F_{bstar}}}{1.9} = 1.187 \qquad \beta := \frac{\left(\frac{F_{be}}{F_{bstar}}\right)}{0.95} = 1.322$$

$$C_l := \alpha - \left(\alpha^2 - \beta\right)^{0.5} = 0.891$$

$$F_t' := F_t \cdot C_d \cdot C_m \cdot C_t \cdot C_{ft} \cdot C_i \cdot C_p = \left(1.62 \cdot 10^3\right)\ psi$$

$$F_b' := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_l \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(2.828 \cdot 10^3\right)\ psi$$

$$f_t := \frac{P_t}{A} = 7.048\ psi \qquad f_b := \frac{M}{S} = 647.059\ psi$$

$$f_t < F_t' = 1 \qquad f_b < F_b' = 1$$

$$\frac{f_t}{F_t'} = 0.004 \qquad \frac{f_b}{F_{bstar}} = 0.204$$

$$\frac{f_t}{F_t'} + \frac{f_b}{F_{bstar}} = 0.208$$

Overhang beam

$L_{beam} := 60\ ft$ $L_{unsupported} := 15\ ft$ $S := 16\ in$

snow:

$$P_{s.sloped.overhang} := p_m \cdot \left(\left(2^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 20.276\ psf$$

$$p_f := (0.7) \cdot (C_e) \cdot (C_t) \cdot (I_{s.snow}) \cdot (p_g) = 17.5\ psf$$

$$p_{sliding} := 0.4 \cdot p_f \cdot 18\ ft = 126\ plf$$

$$P_{overhang} := \frac{p_{sliding}}{15\ ft} \cdot \left(\frac{10}{15} \right) = 5.6\ psf$$

$$S_{overhang} := P_{overhang} + P_{s.sloped.overhang} = 25.876\ psf$$

wind:

$$W_a := 32.54\ psf \cdot \lambda \cdot K_{zt} = 39.373\ psf$$

Live:

$$L_{overhang} := L_{roof} \cdot \left(\left(2^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 20.276\ psf$$

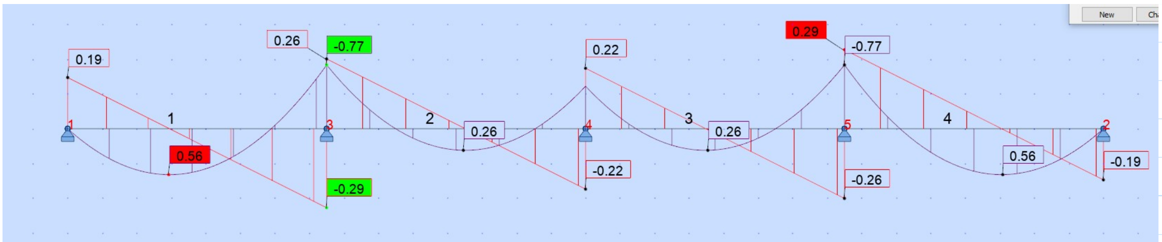
Dead Loads:

$$D_{overhang} := 6.5\ psf$$

$$L_{overhang} \cdot 5\ ft = 101.379\ plf$$

$$D_{overhang} \cdot 5\ ft = 32.5\ plf$$

$$S_{overhang} \cdot 5\ ft = 129.379\ plf$$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0.22
0.29
-0.77
1
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3
4
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-0.29
0.26
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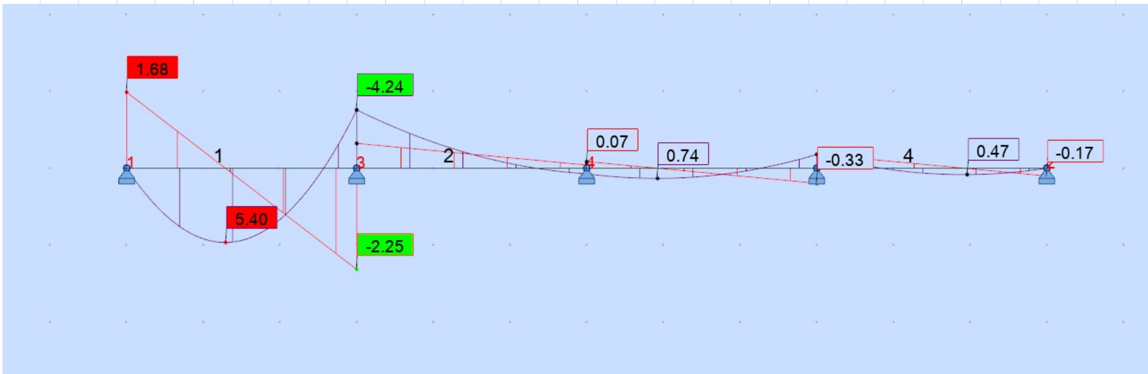
0.26
-0.26
0.56
-0.19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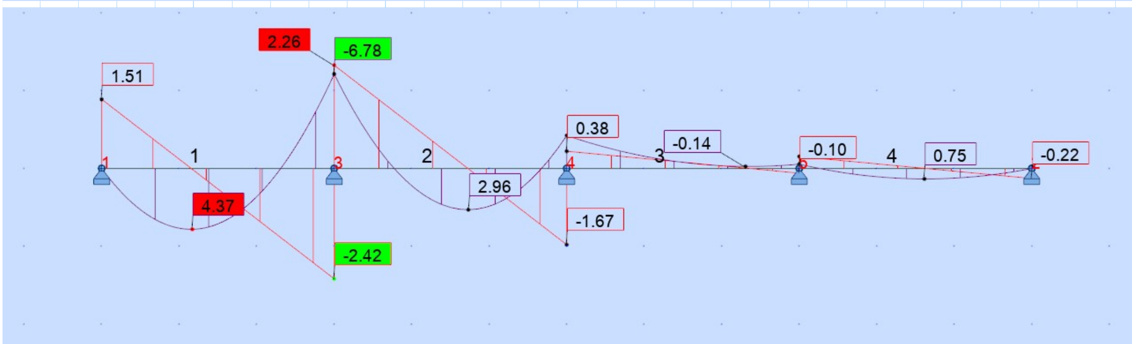
5.40
-2.25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3
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4
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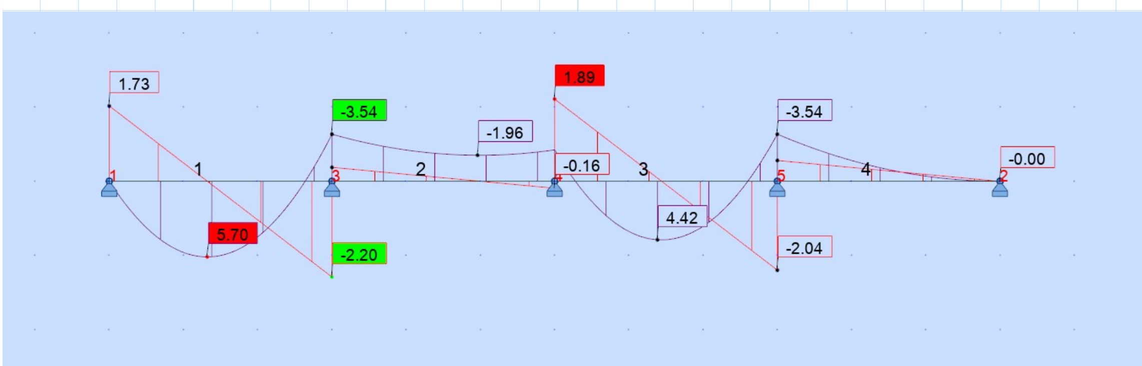
-1.67
-2.42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-3.54
1.89
-1.96
-3.54
1
2
-0.16
3
4
-0.00
5.70
4.42
-2.20
-2.04

Beam applied loads and required Sx:

$V := 2.5\ kip$ $M_{pos} := 5.70\ kip \cdot ft$ $M_{neg} := 6.78\ kip \cdot ft$ $\frac{M_{neg}}{F_b} = 81.36\ in^3$

Gluelam 5.5x9.5 properties:

$A := 52.25\ in^2$ $S := 82.73\ in^3$ $I := 393\ in^4$ $L_u := 15\ ft$

$d := 9.5\ in$ $b := 5.5\ in$ $\frac{d}{b} = 1.727$ $A_b := d \cdot b = 52.25\ in^2$

glulam reference design values:

$C_d := 1.15$ $C_m := 1.0$ $C_t := 1.0$ $C_v := 1.0$ $C_{fu} := 1.0$ $C_c := 1.0$

$l_e := 10\ ft = 10\ ft$ $F_{bstar} := F_b \cdot C_d = \left(1.15 \cdot 10^3\right)\ psi$

$$R_b := \left(\frac{l_e \cdot d}{(b)^2}\right)^{0.5} = 6.139$$

$$F_{be} := \frac{1.2 \cdot E_{min}}{{R_b}^2} = \left(1.974 \cdot 10^4\right)\ psi$$

$$\alpha := \frac{1 + \frac{F_{be}}{F_{bstar}}}{1.9} = 9.562$$

$$\beta := \frac{\left(\frac{F_{be}}{F_{bstar}}\right)}{0.95} = 18.071$$

$$C_l := \alpha - \left(\alpha^2 - \beta\right)^{0.5} = 0.997$$

Beam Design Checks:

bending:

$$f_{bpos} := \frac{M_{neg}}{S} = 983.44\ psi$$

$$F_b := F_{bstar} \cdot C_l = \left(1.146 \cdot 10^3\right)\ psi$$

$$f_{bneg} := \frac{M_{pos}}{S} = 826.786\ psi$$

$$f_{bpos} \le F_b = 1$$

$$f_{bneg} \le F_b = 1$$

Shear:

$$f_v := \frac{3 \cdot (V)}{2 \cdot d \cdot b} = 71.77\ psi$$

$$F_v' := F_v \cdot C_d = 207\ psi$$

$$f_v \le F_v' = 1$$

parallel compression:

$$f_{c.parallel.int} := 5\ \frac{kip}{A_b} = 95.694\ psi$$

$$F_{c.parallel}' := F_{c.parallel} = 625\ psi$$

$$f_{c.parallel.ext} := 1.73\ \frac{kip}{A_b} = 33.11\ psi$$

$$f_{c.parallel.int} < F_{c.parallel}' = 1$$

$$f_{c.parallel.ext} < F_{c.parallel}' = 1$$

Deflection limits:

$$\frac{L_u}{240} = 0.75\ in \qquad \frac{L_u}{180} = 1\ in$$

$$\delta st := 0.46\ in \qquad \delta lt := 0.24\ in \qquad \delta_{total} := 1.5 \cdot \delta lt + \delta st = 0.82\ in$$

$$\delta st \le \frac{L_u}{240} = 1 \qquad \delta lt \le \frac{L_u}{180} = 1 \qquad \delta_{total} \le \frac{L_u}{180} = 1$$

overhang column

$A := 12.25\ in^2$ $I := 12.5\ in^4$ $S := 7.15\ in^3$

$C_m := 0.8$ $C_d := 1.15$ $C_{fu} := 1.15$ $C_{fb} := 1.3$ $C_r := 1.0$

$C_t := 1.0$ $C_l := 1.0$ $C_{ft} := 1.3$ $C_{fc} := 1.1$ $C_i := 1.0$

$W_a \cdot 8\ in = 26.249\ plf$ $L_{column} := 7\ ft + 8.75\ in$

$$M := \left(W_a \cdot 4.\ in\right) \cdot \frac{{L_{column}}^2}{8} = 98.007\ lbf \cdot ft \qquad P_c := 5000\ lbf$$

$$E_{min}' := E_{min} \cdot C_m \cdot C_t \cdot C_i = \left(4.96 \cdot 10^5\right)\ psi \qquad F_{cstar} := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i = \left(1.518 \cdot 10^3\right)\ psi$$

$$F_{ce} := \frac{\left(0.822 \cdot E_{min}'\right)}{\left(\frac{L_{column}}{4\ in}\right)^2} = 758.308\ psi$$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot 0.8} = 0.937 \qquad \beta := \frac{\left(\frac{F_{ce}}{F_{cstar}}\right)}{0.8} = 0.624$$

$$C_p := \alpha - \left(\alpha^2 - \beta\right)^{0.5} = 0.433$$

$$F_c' := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i \cdot C_p = 657.732\ psi$$

$$F_b' := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_l \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(1.577 \cdot 10^3\right)\ psi$$

$$f_c := \frac{P_c}{A} = 408.163\ psi \qquad f_b := \frac{M}{S} = 164.487\ psi$$

$f_c < F_c' = 1$ $f_b < F_b' = 1$

$$\frac{f_c}{F_c'} = 0.621 \qquad \frac{f_b}{F_b'} = 0.104$$

$$\beta := \left(1 - \frac{f_c}{F_{ce}}\right)^{-1} = 2.166$$

$$\left(\frac{f_c}{F_c'}\right)^2 + \beta \cdot \left(\frac{f_b}{F_b'}\right) = 0.611$$

Wall Framing Calculations

Initial load takedown: $Spacing := 16\ in$ $L_{wall} := 10\ ft$

Snow Loading:

Factors for calculation:

Building is to occupy around 100 people maximum at any given time putting the city hall into risk category II

$I_{s.snow} := 1.0$

exposure: Building has some surrounding structures on the land plot so it is in exposure catagory B (partially exposed) with surface soucgness category B (urban/ suburban area)

$C_e := 1.0$

Therman condition: Heated structure kept well above freezing

$C_t := 1.0$

Slope factor: roof pitch of 4 to 12

$C_s := 1.0$

Snow load(ground):

$$p_g := 25\ \frac{lbf}{ft^2}$$

Snow load (sloped)

$$p_s := (0.7) \cdot (C_s) \cdot (C_e) \cdot (C_t) \cdot (I_{s.snow}) \cdot (p_g) = 17.5\ psf$$

$$p_m := I_{s.snow} \cdot 20\ psf = 20\ psf$$

Snow load(horizontal plane):

$$P_{s.sloped} := p_m \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 21.082\ psf$$

$$P_{snow} := P_{s.sloped} \cdot Spacing = 28.109\ plf$$

unbalanced(case 1):

w is < 20ft (18ft) therefore case 1

$$p_{unbalanced} := I_{s.snow} \cdot p_g = 25\ psf$$

acts on full 18ft section with orientation depending on wind direction

Wind Loading:

Exposure: Category C

mean roof height:

$h_{mean} := 13\ ft + 4\ in$

$\lambda := 1.21$ $K_{zt} := 1$

Risk category II basic wind speed map (ASCE 26.5-1B)

$V := 107\ mph$

after to get the values needed at 107 mph wind and 18 degrees from the horizontal:

		Location							
wind spee	angle	A	B	C	D	E	F	G	H
107	18.43	32.54278	-9.23763	21.63685	-5.1428	-29.0909	-19.8167	-20.1931	-15.1036

$$W_a := 32.54\ psf \cdot Spacing \cdot \lambda \cdot K_{zt} = 52.498\ \frac{lbf}{ft}$$

Live loads:

Roof:

typical roof live load:

$L_{roof} := 20\ psf$ not intended for occupancy but possible maintenance

$L_{bottom} := L_{roof} \cdot Spacing = 26.667\ plf$

$L_{top} := L_{roof} \cdot Spacing \cdot \left(\left(4^2 + 12^{(2)}\right)^{0.5} \cdot \frac{1}{12} \right) = 28.109\ plf$

Dead Loads:

dead load calculator:

roof:

$D_{upper} := 7\ psf$

$D_{lower} := 9.75\ psf$

Overhang:

$D_{upper.oh} := 4.5\ psf$

$D_{lower.oh} := 2\ psf$

initial section 2x6:

$S := 7.56\ in^3$ $I := 20.80\ in^4$ $A := 8.25\ in^2$

reference design values

$F_b := 1000\ psi$ $F_c := 1500\ psi$ $F_t := 675\ psi$ $F_{c.parallel} := 625\ psi$

$E_{min} := 620000\ psi$ $E := 1700000\ psi$ $F_v := 180\ psi$

wall Loading based on tributary area:

$$A_{trib} := \left(\frac{36\ ft}{2} + 5\ ft\right) \cdot Spacing = 30.667\ ft^2$$

$$DL := \left((7\ psf + 9.75\ psf) \cdot \frac{36\ ft}{2} + (4.5\ psf + 2\ psf) \cdot 5\ ft\right) \cdot Spacing = 445.333\ lbf$$

$$LL := 28\ psf \cdot A_{trib} = 858.667\ lbf$$

$$SL := P_{s.sloped} \cdot A_{trib} = 646.51\ lbf$$

$$WL := 55\ plf$$

wall load cases:

$$c1 := DL = 445.333\ lbf$$
$$c2 := DL + LL = \left(1.304 \cdot 10^3\right)\ lbf$$

$$c3 := DL + SL = \left(1.092 \cdot 10^3\right)\ lbf$$

$$c4 := DL + 0.75 \cdot (LL + SL) = \left(1.574 \cdot 10^3\right)\ lbf$$

$$c5 := DL = 445.333\ lbf$$
$$c5w := 0.6 \cdot WL = 33\ plf$$

$$c6 := DL + 0.75 \cdot (LL + SL) = \left(1.574 \cdot 10^3\right)\ lbf$$
$$c6w := 0.4 \cdot WL = 22\ plf$$

$$c7 := 0.6 \cdot DL = 267.2\ lbf$$
$$c7w := 0.6 \cdot WL = 33\ plf$$

Sheathing Analysis loads:

$$L_l := 60\ ft \qquad L_t := 36\ ft$$

$$DL := ((7\ psf + 9.75\ psf) + (4.5\ psf + 2\ psf)) = 23.25\ psf$$

$$LL := 28\ psf = 28\ psf$$

$$DL + LL = 51.25\ psf$$

$$SL := P_{s.sloped} = 21.082\ psf \qquad WL := 32.5\ psf = 32.5\ psf$$

wall framing 2x6 @16" OC analysis:

$$P := c6 = \left(1.574 \cdot 10^{3}\right)\ lbf \qquad M := (c5w) \cdot \frac{L_{wall}^{2}}{8} = 412.5\ lbf \cdot ft$$

$$f_c := \frac{P}{A} = 190.814\ psi \qquad f_b := \frac{M}{S} = 654.762\ psi$$

$$C_m := 1.0 \qquad C_d := 1.6 \qquad C_{fu} := 1.0 \qquad C_{fb} := 1.3 \qquad C_r := 1.0$$
$$C_t := 1.0 \qquad C_l := 1.0 \qquad C_{fc} := 1.1 \qquad C_i := 1.0$$

$$F_{bstar} := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(2.08 \cdot 10^{3}\right)\ psi$$

$$E_{min}' := E_{min} \cdot C_m \cdot C_t \cdot C_i = \left(6.2 \cdot 10^{5}\right)\ psi \qquad F_{cstar} := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i = \left(2.64 \cdot 10^{3}\right)\ psi$$

$$F_{ce} := \frac{\left(0.822 \cdot E_{min}'\right)}{\left(\frac{10\ ft}{5.5\ in}\right)^{2}} = \left(1.071 \cdot 10^{3}\right)\ psi$$

$$\alpha := \frac{1 + \frac{F_{ce}}{F_{cstar}}}{2 \cdot 0.8} = 0.878 \qquad \beta := \frac{\left(\frac{F_{ce}}{F_{cstar}}\right)}{0.8} = 0.507$$

$$C_p := \alpha - \left(\alpha^{2} - \beta\right)^{0.5} = 0.364$$

$$F_c' := F_c \cdot C_d \cdot C_m \cdot C_t \cdot C_{fc} \cdot C_i \cdot C_p = 960.683\ psi$$

$$F_b' := F_b \cdot C_d \cdot C_m \cdot C_t \cdot C_l \cdot C_{fb} \cdot C_{fu} \cdot C_i \cdot C_r = \left(2.08 \cdot 10^{3}\right)\ psi$$

$$\beta := \left(1 - \frac{f_c}{F_{ce}}\right)^{-1} = 1.217$$

$$\left(\frac{f_c}{F_c'}\right)^{2} + \beta \cdot \left(\frac{f_b}{F_b'}\right) = 0.423$$

Headers above walls and windows:

Design for longest span: initial section 2x6

$S:=7.56\ in^3 \quad I:=20.80\ in^4 \quad A:=8.25\ in^2 \quad b:=1.5\ in \quad d:=5.5\ in$

$L_{window}:=96\ in$

$LL_{header}:=P_{snow}+L_{top}=56.218\ plf$

$DL_{header}:=6.25\ psf \cdot Spacing=8.333\ plf$

Header Bending:

$$M:=\frac{\left(DL_{header}+LL_{header}\right)\cdot L_{window}^{2}}{8}=516.413\ lbf\cdot ft$$

$$f_b:=\frac{M}{S}=819.703\ psi$$

$$F_{bstar}:=F_b\cdot C_d=\left(1.6\cdot 10^3\right)\ psi$$

$$R_b:=\left(\frac{L_{window}\cdot d}{(b)^2}\right)^{0.5}=15.319 \qquad F_{be}:=\frac{1.2\cdot E_{min}}{R_b^{\,2}}=\left(3.17\cdot 10^3\right)\ psi$$

$$\alpha:=\frac{1+\dfrac{F_{be}}{F_{bstar}}}{1.9}=1.569 \qquad \beta:=\frac{\left(\dfrac{F_{be}}{F_{bstar}}\right)}{0.95}=2.086$$

$$C_l:=\alpha-\left(\alpha^2-\beta\right)^{0.5}=0.956$$

$$F_b':=F_b\cdot C_d\cdot C_m\cdot C_t\cdot C_l\cdot C_{fb}\cdot C_{fu}\cdot C_i\cdot C_r=\left(1.987\cdot 10^3\right)\ psi$$

$$f_b\le F_b'=1$$

header shear:

$$V := \left(DL_{header} + LL_{header}\right) \cdot \frac{L_{window}}{2} = 258.206\ lbf$$

$$f_v := \frac{3 \cdot V}{2 \cdot b \cdot d} = 46.947\ psi \qquad F_v = 180\ psi$$

$$f_v \le F_v = 1$$

header deflection:

$$\delta_{st} := \frac{5 \cdot \left(0.5 \cdot LL_{header}\right) \cdot L_{window}^{\ 4}}{384 \cdot E \cdot I} = 0.073\ in$$

$$\delta_{st.allow} := \frac{L_{window}}{360} = 0.267\ in$$

$$\delta_{st} \le \delta_{st.allow} = 1$$

$$\delta_{lt} := \frac{5 \cdot \left(0.5 \cdot LL_{header} + DL_{header}\right) \cdot L_{window}^{\ 4}}{384 \cdot E \cdot I} = 0.095\ in$$

$$\delta_{total.allow} := \frac{L_{window}}{240} = 0.4\ in$$

$$\delta_{total} := 1.5 \cdot \delta_{lt} + \delta_{st} = 0.216\ in$$

$$\delta_{total} \le \delta_{total.allow} = 1$$

Double top plate cord/collector verification: $L_l := 60\ ft$ $L_t := 36\ ft$ $C_{ft} := 1.5$

$$W_a := 32.54\ psf \cdot 5\ ft \cdot \lambda \cdot K_{zt} = 196.867\ \frac{lbf}{ft}$$

cord analysis: $A = 8.25\ in^2$

$$M_{long} := W_a \cdot \frac{L_l^{\,2}}{8} = \left(8.859 \cdot 10^4\right)\ lbf \cdot ft \qquad M_{trav} := W_a \cdot \frac{L_t^{\,2}}{8} = \left(3.189 \cdot 10^4\right)\ lbf \cdot ft$$

$$V_{long} := W_a \cdot \frac{L_t}{2} = \left(3.544 \cdot 10^3\right)\ lbf \qquad V_{trav} := W_a \cdot \frac{L_l}{2} = \left(5.906 \cdot 10^3\right)\ lbf$$

$$F_{max.l} := \frac{M_{long}}{L_t} = \left(2.461 \cdot 10^3\right)\ lbf \qquad F_{max.t} := \frac{M_{trav}}{L_l} = 531.541\ lbf$$

$$f_{f.l} := \frac{F_{max.l}}{A} = 298.283\ psi \qquad f_{f.t} := \frac{F_{max.t}}{A} = 64.429\ psi$$

$$F_t' := F_t \cdot C_d \cdot C_m \cdot C_t \cdot C_{ft} \cdot C_i \cdot C_p = 589.51\ psi$$

$$f_{f.l} \le F_t' = 1 \qquad f_{f.t} \le F_t' = 1$$

panel shear:

$$V_{reaction.long} := W_a \cdot \frac{L_l}{2} = \left(5.906 \cdot 10^3\right)\ lbf \qquad V_{reaction.trav} := W_a \cdot \frac{L_t}{2} = \left(3.544 \cdot 10^3\right)\ lbf$$

$$V_{unit.long} := \frac{V_{reaction.long}}{L_t} = 164.056\ plf \qquad V_{unit.trav} := \frac{V_{reaction.trav}}{L_l} = 59.06\ plf$$

using 8d nailing @ 3/8"thick sheathing:

$V_w := 670\ plf$ $C_{sg} := 1 - (0.5 - 0.5) = 1$ $C_{asd} := 0.5$

$$V_w' := V_w \cdot C_{sg} \cdot C_{asd} = 335\ plf$$

$$V_{unit.long} \le V_w' = 1 \qquad V_{unit.trav} \le V_w' = 1$$

Diaphragm deflection longitudinal:

$$V_{unit.long} := \frac{V_{reaction.long}}{L_t} = 164.056\ plf$$

$$S_{cn} := \left(\left(\frac{1}{32}\ in\right)\left(\frac{L_t}{2}\right) \cdot 2\right) = 0.009\ m^2$$

$$\Delta_b := \frac{5 \cdot \left(V_{unit.long}\right) \cdot \left(L_l\right)^3}{8 \cdot E \cdot 2 \cdot A \cdot L_t} = 0.263\ in$$

$$\Delta_{sv} := \frac{.25 \cdot \left(V_{unit.long}\right) \cdot \left(L_l\right)}{\left(9\ \frac{kip}{ft}\right)} = 3.281\ in$$

$$\Delta_c := \frac{S_{cn}}{2 \cdot L_t} = 0.016\ in$$

$$\delta_{dia} := \Delta_b + \Delta_{sv} + \Delta_c = 3.56\ in$$

$$\delta_{allow} := \frac{L_l}{180} = 4\ in$$

$$\delta_{dia} < \delta_{allow} = 1$$

Diaphragm deflection traverse:

$$V_{unit.trav} := \frac{V_{reaction.trav}}{L_t} = 98.434\ plf$$

$$S_{cn} := \left(\left(\frac{1}{32}\ in\right)\left(\frac{L_l}{2}\right) \cdot 2\right) = 0.015\ m^2$$

$$\Delta_b := \frac{5 \cdot \left(V_{unit.trav}\right) \cdot \left(L_t\right)^3}{8 \cdot E \cdot 2 \cdot A \cdot L_l} = 0.02\ in$$

$$\Delta_{sv} := \frac{.25 \cdot \left(V_{unit.long}\right) \cdot \left(L_t\right)}{\left(9\ \frac{kip}{ft}\right)} = 1.969\ in$$

$$\Delta_c := \frac{S_{cn}}{2 \cdot L_l} = 0.016\ in$$

$$\delta_{dia} := \Delta_b + \Delta_{sv} + \Delta_c = 2.005\ in$$

$$\delta_{allow} := \frac{L_t}{180} = 2.4\ in$$

$$\delta_{dia} < \delta_{allow} = 1$$

shear wall deflection:

60ft direction:

$$\delta_b := \frac{8 \cdot V_{unit.long} \cdot 10\ ft^3}{E \cdot \left(2 \cdot 8.25\ in^2\right) \cdot 60\ ft} = \left(9.358 \cdot 10^{-5}\right)\ in$$

$$\delta_{un} := \frac{V_{unit.long} \cdot 10\ ft}{1000 \cdot 14\ \frac{kip}{in}} = \left(1.172 \cdot 10^{-4}\right)\ in$$

$$\delta_a := \frac{10\ ft}{60\ ft} \cdot (0.135\ in) = 0.023\ in$$

$$\delta_b + \delta_{un} + \delta_a = 0.023\ in$$

36ft direction:

$$\delta_b := \frac{8 \cdot V_{unit.trav} \cdot 10\ ft^3}{E \cdot \left(2 \cdot 8.25\ in^2\right) \cdot 36\ ft} = \left(9.358 \cdot 10^{-5}\right)\ in$$

$$\delta_{un} := \frac{V_{unit.trav} \cdot 10\ ft}{1000 \cdot 14\ \frac{kip}{in}} = \left(7.031 \cdot 10^{-5}\right)\ in$$

$$\delta_a := \frac{10\ ft}{36\ ft} \cdot (0.135\ in) = 0.038\ in$$

$$\delta_b + \delta_{un} + \delta_a = 0.038\ in$$

bearing walls of 2x6@16"OC to match the roof framing with a green treated 2x6 single bottom plate and 2x6 double top in both directions verified for cord and collector moment and shear strength as well as endposts consisting of two(2) 2x6 framing members using HTT5 uplift connection for shear walls.

APA load span tables: minnimum sheathing span rating of 32/16 x 15/32" structural I 8d nailing, 6in spacing @ panel edges, and 12" spacing for intermideate supports

longitudinal collector direction:

$$V_r := \frac{V_{long}}{L_l} = 59.06\ plf$$

$$V_w := \frac{V_{long}}{L_t} = 98.434\ plf$$

$$V_{long} = \left(3.544 \cdot 10^3\right)\ lbf$$

$$V_{trav} = \left(5.906 \cdot 10^3\right)\ lbf$$

$$P_l := \left(V_w\right) \cdot L_l = \left(5.906 \cdot 10^3\right)\ lbf$$

$$P_t := \left(V_w\right) \cdot L_t = \left(3.544 \cdot 10^3\right)\ lbf$$

$$F_l := \frac{P_l}{A} = 715.88\ psi$$

$$F_t' = 589.51\ psi$$

$$F_t := \frac{P_t}{A} = 429.528\ psi$$

$$F_l < F_t' = 0$$

$$F_t < F_t' = 1$$

traverse collector direction:

$$V_r := \frac{V_{trav}}{L_l} = 98.434\ plf$$

$$V_w := \frac{V_{trav}}{L_t} = 164.056\ plf$$

$$P_l := \left(V_w\right) \cdot L_l = \left(9.843 \cdot 10^3\right)\ lbf$$

$$P_t := \left(V_w\right) \cdot L_t = \left(5.906 \cdot 10^3\right)\ lbf$$

$$F_l := \frac{P_l}{2 \cdot A} = 596.567\ psi$$

$$F_t' = 589.51\ psi$$

$$F_t := \frac{P_t}{A} = 715.88\ psi$$

$$F_l < F_t' = 0$$

$$F_t < F_t' = 0$$

Interior Slab Design

$t := 4\ in$ (typical interior construction slab on grade with correct base compaction)

longitudinal direction reinforcement:

$L_{long} := 60\ ft$

$A_l := t \cdot L_{long} = 20\ ft^2$

traverse direction reinforcement:

$L_{width} := 46\ ft$

$A_t := t \cdot L_{width} = 15.333\ ft^2$

Grade 60 bar used so area ratio of 0.0018 is applied

$A_{long} := A_l \cdot 0.0018 = 5.184\ in^2$

$\frac{A_{long}}{L_{long}} = 0.086\ \frac{in^2}{ft}$

$A_{side} := A_t \cdot 0.0018 = 3.974\ in^2$

$\frac{A_{side}}{L_{width}} = 0.086\ \frac{in^2}{ft}$

wire sizing is based off of in^2/ft of each span direction. Grade 60 W2.9 wire at 4"x4" will be sufficient reinforcement for a 4" thick slab and the reinforcement will be places in the middle of the slab (2" deep)

Foundation Calculations

$P_{wind} := 32.54\ psf$

$P_{snow} := 22\ psf$

$D_{upper} := 7\ psf$

$D_{lower} := 9.75\ psf$

$D_{upper.oh} := 4.5\ psf$

$D_{lower.oh} := 2\ psf$

$L_{roof} := 20\ psf$

$\gamma_{site} := 100\ pcf$ rough estimate of insitu clay

$\gamma_c := 150\ pcf$ rough estimate on backfill soil

$\phi' := 18\ deg$

$q_{allowable} := 1500\ psf$

$\mu_s := 0.4$

$C_u := 130\ psf$

$E_s := 500\ \frac{tonf}{ft^2}$

$D_f := 4\ ft$ $\quad t_f := 16\ in$

$t_{stem} := 10\ in$ $\quad H_{stem} := D_f - t_f = 2.667\ ft$

Loads for the 60ft span on continuous foundation :

$Wind := P_{wind} \cdot 5\ ft = 162.7\ plf$ $\quad L_{footing1} := 64\ ft$

$Snow := P_{snow} \cdot \frac{36}{2}\ ft = 396\ plf$ $\quad B := 2.5\ ft$

$$Dead := \left(D_{upper} + D_{lower} + D_{upper.oh} + D_{lower.oh}\right) \cdot \frac{36}{2}\ ft = 418.5\ plf$$

$$Live := L_{roof} \cdot \frac{36}{2}\ ft = 360\ plf$$

$$P_{vert} := 1.2 \cdot Dead + 1.6 \cdot Live + 0.5 \cdot Snow = 1.276\ klf$$

$$V_{hor} := Wind = 0.163\ klf$$

Factor of safety against bearing:

$q_{allowable} = \left(1.5 \cdot 10^3\right)\ psf$ $\quad q_{bearing} := \frac{P_{vert}}{B} = 510.48\ psf$

$$FS := \frac{q_{allowable}}{q_{bearing}} = 2.938$$

Factor of safety against sliding:

$$V_{slide} := V_{hor} \cdot L_{footing1} = 10.413\ kip$$

$$V_{allowable} := C_u \cdot B \cdot L_{footing1} + 0.25 \cdot C_u \cdot B \cdot D_f = 21.125\ kip$$

$$F.S_v := \frac{V_{allowable}}{V_{slide}} = 2.029$$

settlement :

$\alpha := 4$ $N := \frac{5 \cdot B}{0.5 \cdot B} = 10$ $M := \frac{L_{footing1}}{B} = 25.6$ $I_f := 1$

$$I_1 := \left(\frac{1}{\pi}\right) \cdot \left(M \cdot \ln\left(\frac{\left(1+\sqrt{M^2+1}\right) \cdot \sqrt{M^2+N^2}}{M \cdot \left(1+\sqrt{M^2+N^2+1}\right)}\right) + \ln\left(\frac{\left(M+\sqrt{M^2+1}\right) \cdot \sqrt{1+N^2}}{\left(M+\sqrt{M^2+N^2+1}\right)}\right)\right) = 0.745$$

$$I_2 := \frac{N}{2 \cdot \pi} \operatorname{atan}\left(\frac{M}{N \cdot \sqrt{M^2+N^2+1}}\right) = 0.148$$

$$I_s := I_1 + \left(\frac{1-2 \cdot \mu_s}{1-\mu_s}\right) \cdot I_2 = 0.794$$

$$\delta_{e1} := \frac{\left(q_{bearing} \cdot \alpha \cdot I_s \cdot I_f \cdot \left(1-{\mu_s}^2\right)\right)}{E_s} \cdot 0.5 \cdot B \cdot 0.93 = 0.019\ in$$

Loads on the 36ft span on continous foundation:

$Wind2 := P_{wind} \cdot 5\ ft = 162.7\ plf$ $L_{footing2} := 40\ ft$

$Snow2 := P_{snow} \cdot \frac{60}{2}\ ft = 660\ plf$ $B := 2.5\ ft$

$$Dead2 := \left(D_{upper} + D_{lower} + D_{upper.oh} + D_{lower.oh}\right) \cdot \frac{60}{2}\ ft = 697.5\ plf$$

$$Live2 := L_{roof} \cdot \frac{60}{2}\ ft = 600\ plf$$

$$P_{vert2} := 1.2 \cdot Dead2 + 1.6 \cdot Live2 + 0.5 \cdot Snow2 = \left(2.127 \cdot 10^3\right)\ plf$$

$$V_{hor2} := 0.5 \cdot Wind2 = 81.35\ plf$$

Factor of safety against bearing:

$q_{allowable} = \left(1.5 \cdot 10^3\right)\ psf$ $q_{bearing} := \frac{P_{vert2}}{B} = 850.8\ psf$

$$FS := \frac{q_{allowable}}{q_{bearing}} = 1.763$$

Factor of safety against sliding:

$$V_{slide} := V_{hor} \cdot L_{footing2} = 6.508 \; kip$$

$$V_{allowable} := C_u \cdot B \cdot L_{footing2} + 0.25 \cdot C_u \cdot B \cdot D_f = 13.325 \; kip$$

$$F.S_v := \frac{V_{allowable}}{V_{slide}} = 2.047$$

settlement :

$$\alpha := 4 \qquad N := \frac{5 \cdot B}{0.5 \cdot B} = 10 \qquad M := \frac{L_{footing2}}{B} = 16 \qquad I_f := 1$$

$$I_1 := \left(\frac{1}{\pi}\right) \cdot \left(M \cdot \ln\left(\frac{\left(1 + \sqrt{M^2 + 1}\right) \cdot \sqrt{M^2 + N^2}}{M \cdot \left(1 + \sqrt{M^2 + N^2 + 1}\right)}\right) + \ln\left(\frac{\left(M + \sqrt{M^2 + 1}\right) \cdot \sqrt{1 + N^2}}{\left(M + \sqrt{M^2 + N^2 + 1}\right)}\right)\right) = 0.756$$

$$I_2 := \frac{N}{2 \cdot \pi} \operatorname{atan}\left(\frac{M}{N \cdot \sqrt{M^2 + N^2 + 1}}\right) = 0.134 \qquad I_s := I_1 + \left(\frac{1 - 2 \cdot \mu_s}{1 - \mu_s}\right) \cdot I_2 = 0.8$$

$$\delta_{e1} := \frac{\left(q_{bearing} \cdot \alpha \cdot I_s \cdot I_f \cdot \left(1 - {\mu_s}^2\right)\right)}{E_s} \cdot 0.5 \cdot B \cdot 0.93 = 0.032 \; in$$

sonotube footing for the exterior

$$d := 24 \; in \qquad L := 4 \; ft \qquad P := 4500 \; lbf$$

Factor of safety against bearing:

$$q_{allowable} = \left(1.5 \cdot 10^3\right) \; psf \qquad q_{bearing} := \frac{P}{\pi \cdot \left(\frac{d}{2}\right)^2} = \left(1.432 \cdot 10^3\right) \; psf$$

$$FS := \frac{q_{allowable}}{q_{bearing}} = 1.047$$

concrete design :

$$C := \pi \cdot \left(\frac{d}{2}\right)^2 \cdot L = 0.465\ yd^3$$

$$A := 5 \cdot C = 2.327\ yd^3$$

$$B := (62.5\ ft \cdot 2.5\ ft \cdot 16\ in) \cdot 2 = 15.432\ yd^3$$

$$C := (33.5\ ft \cdot 2.5\ ft \cdot 16\ in) \cdot 2 = 8.272\ yd^3$$

$$D := (36\ ft \cdot 2.666667\ ft \cdot 10\ in) \cdot 2 = 5.926\ yd^3$$

$$E := (60\ ft \cdot 2.666667\ ft \cdot 10\ in) \cdot 2 = 9.877\ yd^3$$

$$T_{foundation} := A + B + C + D + E = 41.833\ yd^3$$ @3000psi strength w/ air

$$F := (60\ ft \cdot 46\ ft \cdot 4\ in) = 34.074\ yd^3$$ @4000psi w/o air

$$G := 2611\ ft^2 \cdot 6\ in = 48.352\ yd^3$$ @4000psi w/ air

$$T_{concrete} := A + B + C + D + E + F + G = 124.259\ yd^3$$

$$T_{concrete} \cdot \frac{100}{yd^3} = 1.243 \cdot 10^4$$

$ReturnPeriod := 25\ yr$

$T_{Concentration} := 5\ min$

$i := 9.53\ \frac{in}{hr}$

Pre-Development Runoff

$A_{Lot} := 58298\ ft^2$ $\quad A_{ImpPre} := 9108.34\ ft^2$

$A_{Perm} := A_{Lot} - A_{ImpPre} = \left(4.919 \cdot 10^4\right)\ ft^2$

$C_{Imp} := 0.90 \quad C_{Lawn} := 0.22$

$$C_{Pre} := \frac{\left(C_{Imp} \cdot A_{ImpPre} + C_{Lawn} \cdot A_{Perm}\right)}{A_{Lot}} = 0.326$$

$$Q_{Pre} := C_{Pre} \cdot i \cdot A_{Lot} = 4.196\ \frac{ft^3}{s}$$

Post-Development Runoff

11932.1971

$A_{Lot} = \left(5.83 \cdot 10^4\right)\ ft^2$ $\quad A_{ImpDev} := 12652.1971\ ft^2$

$A_{PermDev} := A_{Lot} - A_{ImpDev} = \left(4.565 \cdot 10^4\right)\ ft^2$

$C_{Imp} := 0.90 \quad C_{Lawn} := 0.22$

$$C_{Dev} := \frac{\left(C_{Imp} \cdot A_{ImpDev} + C_{Lawn} \cdot A_{PermDev}\right)}{A_{Lot}} = 0.368$$

$$Q_{Dev} := C_{Dev} \cdot i \cdot A_{Lot} = 4.727\ \frac{ft^3}{s}$$

$$Q_{increase} := Q_{Dev} - Q_{Pre} = 0.532\ \frac{ft^3}{s}$$