The University of Iowa | Office of Outreach and Engagement

FINAL DELIVERABLE

Title	High Trestle Trail Information Center
Completed By	Conner Danielson, Samuel Hermanas, Thomas Fales
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Course Name	CEE:4850:0001 Senior Design
Instructor	Paul Hanley
Community Partners	Boone County Conservation

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High Trestle Trail Information Center

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TCS CONSULTING

UNIVERSITY OF IOWA

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

Project Design & Management

CEE:4850:0001

Final Design Report

High Trestle Trail Information Center

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Civil and Environmental Engineering

College of Engineering

The University of Iowa

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Section I: Executive Summary

1.1. Executive Summary

TCS consultants is located in the University of Iowa's Seamans Center on South Capitol Street, in Iowa City, Iowa. TCS is comprised of three senior civil engineering students at the University of Iowa pursuing a B.S.E in civil engineering. Our mission is to design and model our client's needs and requests in the most efficient and effective way possible with today's technology.

The following document is a complete report prepared by TCS Consultants for the preliminary design of the High Trestle Trail Information Center requested by the Boone County Conservation Board. The scope of work includes the design of a small but unique partially enclosed shelter. The shelter will provide a space for information to be displayed and amenities for trail users such as a bottle filling station, bike rack, and bike repair station. In addition, the 25 ft. by 47 ft. information center will provide shelter to trail users, and educational space. The 20 ft. by 10 ft. enclosed portion of the information center creates a space for trail users to learn more about the rich history of Boone County and the High Trestle Trail. The information center will be located at the Grant's Woods trailhead in Madrid, Iowa.

The High Trestle Trail information center project consisted of design alternatives for the building configuration, foundation, site location and parking lot. Each structural design alternative was discussed to narrow down a general layout to be utilized in our final proposed design. The request to keep the enclosed space limited to 200 square feet determined the size of our final proposed information center. The column spaces were kept limited to the perimeter of the pavilion, as well as within the walls of the enclosed space, to maximize the amount of open space. In addition to limiting the location of the columns a simple gable roof design was selected to maximize the sense of open space in the shelter. The gable roof design is comprised of a steel panel roof sitting on 2 x 8 southern pine rafters spaced 24" O.C.. The rafters were connected to the roof structure using Simpson Strong Tie wood connection manual to ensure resistance to uplift. The wood beams supporting the rafters run east to west with a maximum span of 44 ft. The wooden structural elements were left exposed to the interior of the structure to draw forth imagery of coal mining, which plays a large role in Boone County's history.

The foundation alternatives discussed were a continuous footing for the enclosed information center accompanied by spread footings for each column supporting the roof and beams. Our team quickly ran into sizing challenges of spacing each spread footing without overlapping one another. It became apparent that a combination footing would be most effective and efficient. The footings and foundation utilize the weight of the soil and concrete slab flooring above to resist overturning and uplift expected throughout the design.

The selected site location, just west of the existing gravel parking lot and north of the trail, allows for maximum use of already open space and provides a short access walk to the parking lot and proposed bathroom facility. The proximity to the bathroom facility and trail saves both time and money on site preparation and construction. The site location also allows for unique curb appeal by using native plant species around the information center.

While designing the structure, surfacing and paving of the information center was discussed with our client. The Client had indicated they were uninterested in an extensive pavement plan due to funding limitations. TCS concluded it was best to include two pavement designs. Alternative one included minimum paving to meet ADA compliance and add necessary access walk between adjacent buildings, allowing for a minimal design cost for the project. Alternative two included extending the existing parking lot north and surfacing the whole parking lot which included two rain gardens to assist with surface drainage.

Based on the previously discussed design considerations and challenges, TCS consultants recommend a small unique open rafter wood shelter covering 25ft x 47ft area just west of the Grant's Woods gravel parking lot and north of existing trail to be built in accordance to IBC 2015 standards. The paving design shall include paved access walks to and from the information center to the trail, parking lot, and restroom facility, as well as two ADA compliant spots on the west side of the existing gravel parking lot. Foundations will consist of continuous, combination and spread footings that will meet or exceed IBC 2015 standards. Landscaping shall be included to dress and accent the Grant's Woods area with native trees and plants to promote curb appeal and wildlife habitat. A paved parking lot and hydraulic runoff analysis shall be included for future growth considerations.

Figure 1.1 Proposed Information Center

Final cost estimates used RS Means Landscape and Site Work, 2016 edition and recent Bid Tabs provided by the Iowa DOT for all cost, labor, overhead and profit considerations. Due to the land already being owned by Boone County, no acquisitions were estimated for the design. See Table 1 below for the final engineering cost estimates.

Table 1.1 Final Construction Cost Estimate

Division of Cost	Site 1	Site 2
General Provisions	$15,500.00	$25,500.00
Site Development	$8,258.00	$101,351.13
Site Amenities	$17,350.00	$17,350.00
Landscaping	$5,350.00	$10,000.00
Information Center	$54,149.00	$54,149.00
Total (Including Contigencies & Administration)	$135,000	$275,000

<u>Section II:</u> Organization Qualifications & Experience

2.1. Name of Organization

TCS Consulting

2.2. Organization Location and Contact Information

103 S. Capitol Street
Iowa City, IA 52242
Project Manager (Tom Fales):
Thomas-Fales@uiowa.edu
(847)-946-1789

2.3. Organization Experience and Qualifications

Our team is composed of three driven seniors pursuing Bachelors of Science degrees in the University of Iowa's ABET accredited Department of Civil Engineering. TCS Consulting is composed of Tom Fales, Sam Hermanas, and Conner Danielson who are all currently in the capstone design class. Although we are a newly formed consulting team, we bring a highly diverse background in the field of civil engineering to the table. Over the last 4 years our team has worked with highly respected faculty and staff on projects that have pushed and developed our skills in the field of civil engineering. This work has included design of foundations for rural and urban buildings, use of structural analysis and modeling software to assist and facilitate design loads and deflections, and design using structural materials such as wood, steel and concrete. With our wide range of work throughout the last 4 years, we each have taken administrative roles to successfully provide our clients with our absolute best analysis and design. The administrative roles of our team are as follows; Tom Fales, who has a degree focus area of structures and mechanics, is the Project Manager, and was responsible for the bulk of the structural design of the information center. Sam Hermanas, who has a degree focus area of structures, is the Editor, and was responsible for the foundation design, transportation design and hydraulic analysis. Conner Danielson, who also has a degree focus area in structures, is the Technical support, and assisted Tom in the design of the information center and facilitated the presentation, poster and report.

<u>Section III:</u> Design Services

3.1. Project Scope

The proposed project consists of a small but unique partially enclosed shelter to be utilized as an information center and trail head for the High Trestle Trail located in Grant's Woods area. The unique aesthetic appeal comes from the use of exposed wood, stone covered pedestals, stone sidings, and lots of windows to incorporate natural lighting. TCS also included two different parking lot options that can be seen in site plans 1 and 2. Site plan 1 shows our first and recommended option of limited pavement added to the existing gravel parking lot. The paving would consist of a sidewalk added to the west side of the parking lot, access ways between both the trail and parking lot to the proposed information center, two ADA compliant parking spots and concrete slabs used as flooring in the information center. Site plan 2 shows the recommended future plan of the parking lot. This future plan proposes to expand and pave the parking lot with asphalt, two rain gardens in the middle to assist with runoff drainage, and some grass islands for landscaped aesthetic. Items incorporated with the design of the information center included but are not limited to:

- Site locations
- Construction site plan boundaries
- Existing and future utility locations
- Sidewalk/Trail ADA regulations met
- Optional Parking lot design
- Amenities and landscaping
- Hydraulic analysis of Parking lot design
- Foundation Design
- Final project grading
- Material lists
- Cost estimates

3.2. Work Plan

Located in Appendix, the design Gantt chart lays out each major task completed by TCS consultants during our capstone course. It is listed in chronological order and time allotted to each section included.

<u>Section IV:</u> Constraints, Challenges and Impacts

4.1. Constraints

The design of the High Trestle Trail information center included several constraints, which were considered in the creation and selection of the proposed design alternative. Constraints are based upon the allowable impact on the design or construction that an internal or external factor has on the proposed design. Each constraint will play a key role in the proposed final design for this project.

Site Location: Our project was to be constructed near three existing and previously known obstacles. The first of the obstacles was a historic ceremonial mound site located in the southwest corner of Grant's Woods field and directly west of the construction zone. The second and third obstacles to the information center was the septic field and bathroom facility that will be built north and northwest of the construction zone.

Building Size: It was requested to limit the interior building size to 20 feet by 10 feet. The interior space is sized to present information to a small number of trail users rather than a classroom of students or to host an indoor event.

Time: Due to the request to be unique and aesthetically pleasing, our group reached out to the artist David Dahlquist, who designed the famed High Trestle Trail Bridge. TCS consulting approached David Dahlquist late in the design process to inquire if he would be interested in designing art pieces, such as artistic facades for the columns and a border for the trail map. However, David suggested that a better approach is to design the structure to create a piece of artwork integral to the structure of the information center. Our design team is intrigued by this idea, however due to the semester long time constraint, TCS decided there was not enough time to redesign the structure. Yet, David would still like to be a part of the project in the future and will produce concept sketches for a modified information center.

4.2. Challenges

Structural Challenges: Due to an open building that maximizes natural lighting, size, and a wood framed structure, we encountered various design challenges. The rafters are unique in that they do not have web or bottom chord members like you would see in a standard truss frame. The columns are spaced to allow for an open feel to the structure and present a cantilever design to be analyzed. At the widest spacing the beams had a span of up to 40 ft.

Drainage Challenges: In the second site option, a larger parking lot was proposed, but this increased the flow rate from the hydraulic analysis. The large change in surface required a water quality volume analysis to be performed and to install rain gardens to control the flow rate leaving the site.

4.3. Social Impacts

Community: High Trestle Trail users will have a hub to access information previously not provided, along with an accessible place to fill a water bottle, hideout from the rain, lead a small nature education class, catch some shade, and possibly pump air into a bike tire. These new amenities along with landscaping should draw more visitors from out of town to the beautiful and scenic trail network. Feedback from the neighboring property owners has been considered by TCS consulting and the Boone county conservation board, resulting in a design that does not include camping, but does include ample parking. The increase in parking will limit overflow parking in front of neighboring properties. The existing trail at Grant’s Wood is planned to be connected to another existing trail network, expanding the range of the existing High Trestle Trail.

Traffic: The option to expand parking to this area in the future would allow for safer and more compliant trail parking for trail users. During peak days of trail use, parking can fill to capacity and overflow into the roadside ditch. Parking has not been a drastic issue as of now, but an increase in trial use is expected after the information center is built and landscaped.

Environment: Through the use of landscaping and conscious planning and design, the information center will limit the environmental impact from the construction and add to the environment from the use of native trees and shrubs in the landscaping around the information center. The center itself is small which allows it to have very little impact on the runoff into the nearby gullies. If paving of the parking lot were to happen in the future, the rain gardens would allow for natural filtration to occur and help the nearby water quality supply. The construction of the information center and possible paving of the existing parking lot will affect the noise and air pollution to community residents to some extent.

Economy: A small boost in the economy could be expected due to the increase in the user friendliness of the area. With a partially enclosed information shelter to hide from the sun and rain, people may be more inclined to travel to use the scenic trail network that is home to the famed High Trestle Trail Bridge.

General Public: Trail users would have a place to meet and tune their bikes before an afternoon on the High Trestle Trail network. The increase in curb appeal and the benefits provided by the shelter and landscaping are expected to increase interest from the general public, which in turn would increase notoriety of the famed bridge and Boone County.

<u>Section V:</u> Alternative Solutions That Were Considered

5.1. Park Information Structure Alternatives

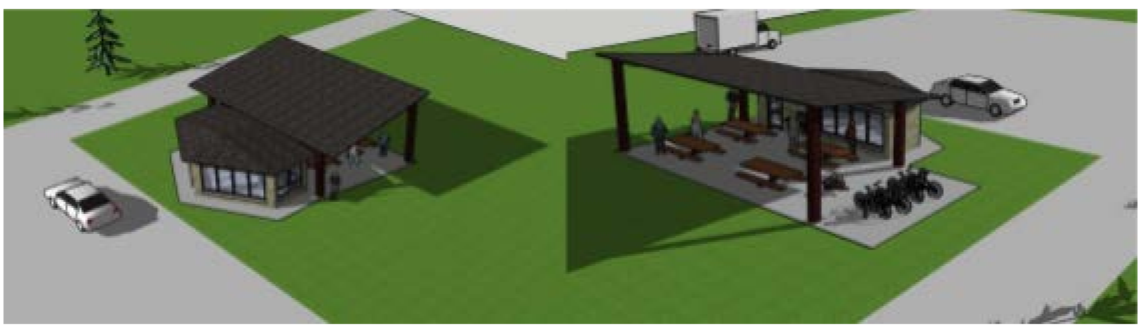

Figure 5.1.1 Building Alternative 1

One alternative concept design for the information center featured a larger interior space in a semicircular shape. The pavilion was to be covered by a roof supported by steel elements. This alternative solution provided the interior space with ample natural lighting, however left little room to install HVAC. Furthermore, the steel used to support the pavilion's roof would have a drastic increase on the cost of the design. Yet, the non-standard geometry of the interior space made this configuration a viable option.

Figure 5.1.2 Building Alternative 2

The second alternative was to simplify the shape of the interior space and retain the steel supported roof. The interior space became smaller, but the rectangular shape allowed for easier placement of HVAC systems, as well as room to display trail maps and information. However, the two separate structures, the enclosed information center and the pavilion, made for a structurally inefficient design. Configurations one and two both featured separate structures for the information center and the pavilion. This separation increases construction costs due to the need for separate structural systems. The exposed wood members featured in this configuration provided a chance to display attractive architectural elements.

Figure 5.1.3 Building Alternative 3

Building configuration three featured one roof for both the information center and the pavilion. The single roof design is the most structurally efficient of the three configurations. The continuous roof, as well as the wood members, made configuration three the most economical design. The third configuration also featured exposed wood members allowing for our client's architectural needs to be met. The rectangular design of the interior space allowed for easy placement of HVAC systems, as well as spots to display trail information. The four-quadrant configuration of the pavilion and information center allowed for a larger amount of outdoor seating that remained connected to the building.

5.2. Site Plan Alternatives

Site plan configuration 1 utilizes limited paving to save cost. Along with cost considerations, key location constraints were met by locating the information center near the west side edge of the existing gravel parking lot. This location works nicely with the proposed restroom facility just north of the proposed location and allowed maximum distance away from the ceremonial mounds circled in figure 5.2.1. The site location was proposed to TCS consultants by the Boone County Conservation board. Figure 5.2.2 shows the location of the restroom facility, the proposed location of the information center along with all the surfacing to be included in site plan 1's configuration.

Due to the small area of the proposed information center and the existing surface runoff already draining at the existing grade, no hydraulic analysis was carried out for the design in figure 5.2.2.

Figure 5.2.1 Location of Ceremonial Mounds

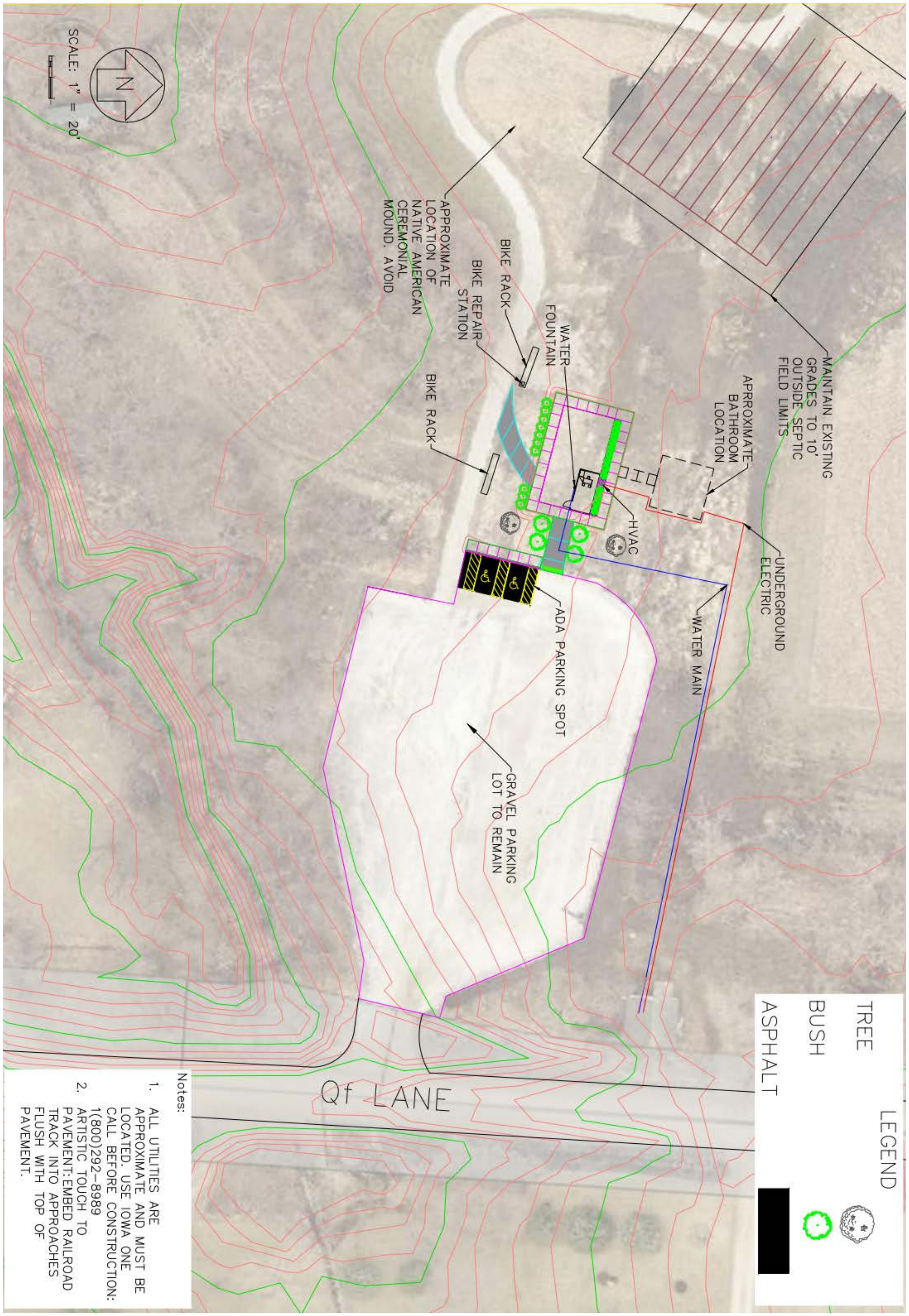

Figure 5.2.2 Site Plan 1 Configuration

Site configuration one is the basic design. The only thing within the parking lot that is altered from the existing parking lot are two accessible stalls for ADA compliance. This option also includes a sidewalk that runs for the length of the west side of parking lot and ends at the existing trail. The building footprint can be seen just to the west of the parking lot along with the location of the bathroom being built in the near future.

Site plan 2 configuration is a proposed future design to accommodate an expected increase in people accessing the trail. The parking lot is proposed to be expanded to the north and paved with 1.5” of asphalt and a 4.5” aggregate base. There are a proposed 55 parking spots that include 3 ADA accessible spots. For parking lot drainage, it is proposed to drain north to south while utilizing the rain gardens to absorb a portion of the runoff. The rest will flow into the low point of the parking toward the drainageway. Although both options include landscaping, this option includes more. However, the rain gardens also serve a functional purpose since they will be used for storm water treatment through filtration and drainage. Aesthetically, this is the better option; however, this option will cost a considerable amount more. The drastic increase in cost is largely due to paving the parking lot, which can be seen in Table 7.1.2.

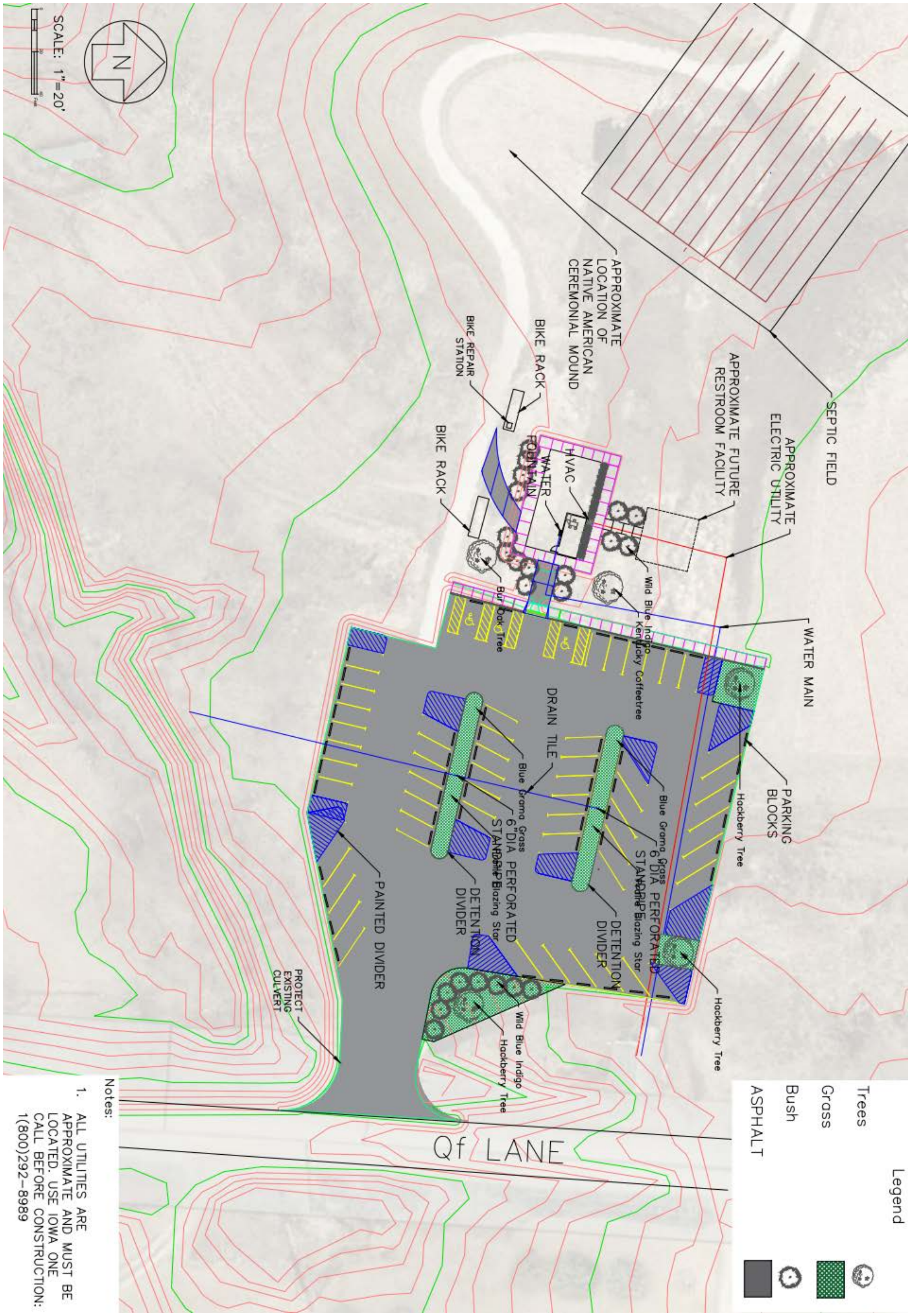

Figure 5.2.3 Site Plan 2 Configuration

5.3. Hydrology Considerations

Hydraulic design was implemented for site plan 2 configuration. It was determined by TCS consultants that the minimal footprint of the building would allow for the existing drainage volume to change very slightly. With site plan 2 configuration, intakes or rain gardens will have to be implemented throughout the parking lot to assist in the increased runoff volume. Intakes would allow standards to be met by the increase volume but would not add to the aesthetic appeal to the site plan. Rain gardens on the other hand would allow for increased runoff to pond and be filtered by native plants species. This filtration would play a very small role in cleaning the water runoff.

5.4 Landscaping and Amenities

Landscaping varied for each site plan configuration. Each option will include landscaping that will capture the essence of the information center and the culture of the surrounding people by using native species. Two ornamental trees can be seen in figures 5.2.2 and 5.2.3 northeast and southeast of the information center. The tree to the southeast will be a Bur Oak tree and the tree to the northeast will be a Kentucky Coffeetree. Each tree has a history of being used as railroad ties and will provide a unique addition to the surrounding forestry species. Additionally, each site plan included landscaping of any new construction areas, such as around the information center. TCS consulting used only native species to the Boone County area to have the maximum success in the durability and sustainability of the design. The Kentucky Coffeetree and the Bur Oak tree are known to be hardy native tree species to the area. Each is expected to live over 60 years and provide additional shade for trail users. Site plan 1 also includes blue wild indigo and cream false indigo to be planted as flowering plants around the information center. The blue wild indigo was used by the Native Americans as a source of blue dye for clothing. Hardwood mulch should be provided at a 2-3 inch depth to protect against weeds and hold additional moisture for the young native plant species. Site plan 2 will include Hackberry trees in additionally marked locations of trees around the parking lot. Hackberry trees provide additional shade and are especially liked by birds. The rain gardens located in the center of the paved parking lot in site plan 2 will consist of blue grama as a border on the slopes and prairie blazing star will be used in the expected ponding zones of the rain garden.

Bike racks, a bike repair station, water bottle filling stations and water fountains will be provided along the information center to give the trail users the absolute best experience possible. These amenities are provided in both site plans and were selected to best fit the needs of the trail users.

Section VI: Final Design Details

6.1. Structure Design Selection

The structure of the information center was the major component of this design project. The structure needed to consider each design solution and member size to produce an efficient product for our client. The primary goal for the design of the information center was to produce a small unique partially enclosed shelter. The shelter was to be designed with a cost conscious mind, ease of construction and to meet IBC standards throughout. To ease construction, standard size, material and component designs were utilized throughout.

The size of the structure and overall aesthetic appeal was discussed in a client meeting to determine which alternative Boone County Conservation most wanted us to develop. With the use of modeling software, multiple different roof layouts, building shapes and orientations were discussed thoroughly. From the general structure, finishes and materials were then considered to convey the correct style and look, our clients had envisioned. The challenges to be unique, and small, while capturing a theme that portrayed the rich railway and mining history of the county were achieved in the proposed design. Figure 6.1.1 is an example model of TCS Consultants' selected design.

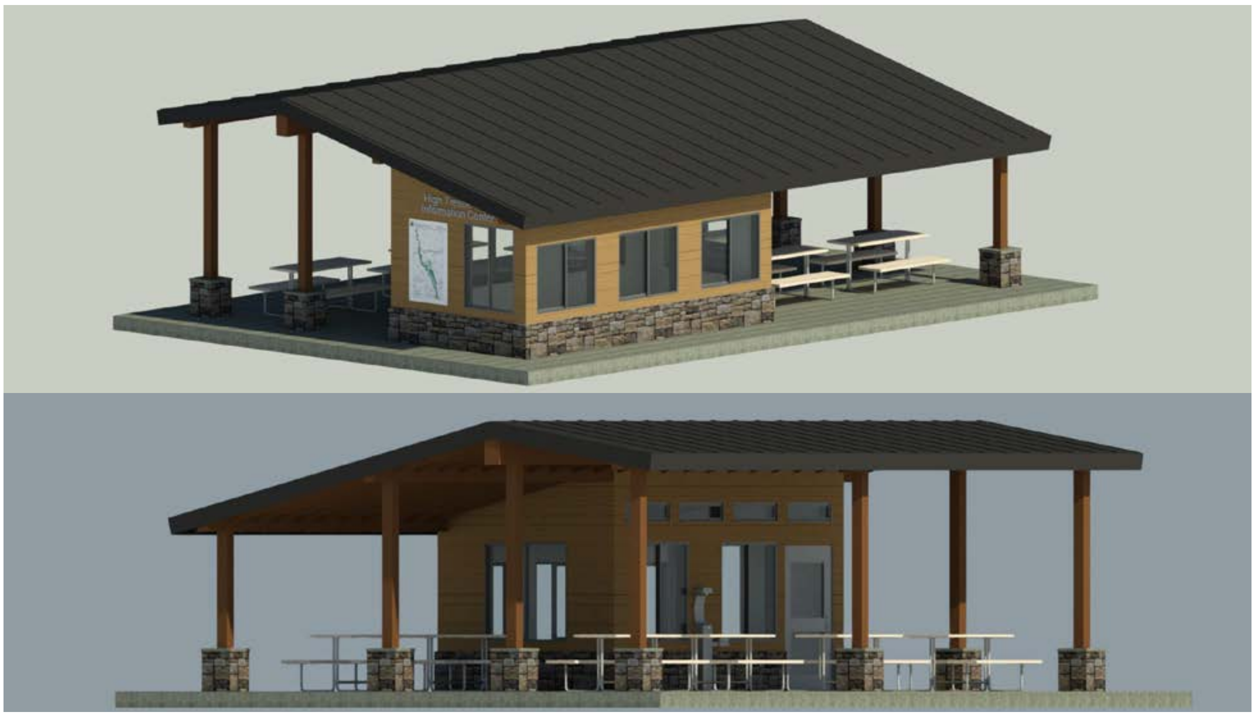

Figure 6.1.1 High Trestle Trail Information Center

6.2. Site Plan and Parking lot Design Selection

Each of the site plans consisted of unique parking lot designs that presented a limited cost design vs a design to meet future capacity. The biggest difference between each site plan was how much new pavement was included in the design. Site plan 1 included the minimum amount of pavement for the parking lot to meet ADA standards. Access walks were also provided to and from the shelter to surrounding structures like the restroom facility, parking lot and trail. Site Plan 2 expanded the Grant's Woods areas parking lot to the north while completely paving it. This pavement would require two minimally sized rain gardens in the center to aid in runoff drainage of the new surface. TCS consulting has selected site plan option 1 with limited paving, which allows the client to consider site plan option 2 in the future when a complete hard surface parking lot is wanted.

6.3. Structure Design Details

Roof design started with meeting the challenge of an open structure. This was accomplished by utilizing a single roof rafter design instead of a standard truss shape that is common in many wood structures. TCS decided to use diagonal 1 x 6 sheathing, that would be exposed due to the open rafter design, to dress up the inside roof appeal. Metal Panels would be used as the roofing material to contrast the wood structure and pay homage to the style of old mining shafts. The rafters would be hung using Simpson Strong-Tie hangers and straps. The straps would help the small overhangs resist moment forces expected from the design loads. The rafters experience critical shear and bending stress due to the applied design load combinations governed by Allowable Strength Design (ASD). TCS sized 2 x 8 pressure treated southern pine #1 graded dimensional lumber to be used for rafters to satisfy deflection, and allowable stress standards.

Beam design utilized Autodesk Robot Structural Analysis to analyze each beam to be used throughout the structure. Seen in figure 6.3.1 beam C is loaded with the ASD combination that will give the largest bending and shear stresses. These stresses calculated in Robot will be compared to the allowable stresses computed from the property tables in the National Design Specification (NDS) supplement. This ratio tells whether or not the size of lumber or glulam is too big or small.

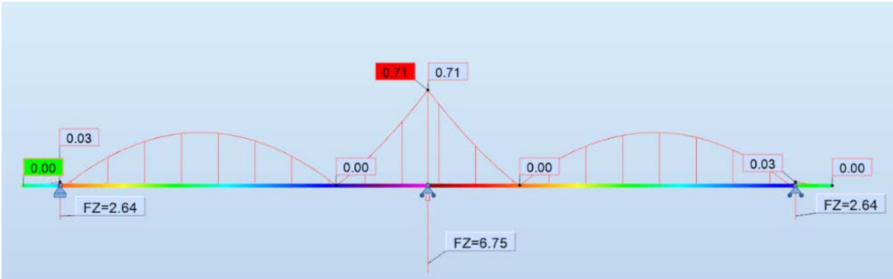

Figure 6.3.1 Beam C Robot Bending Stresses

The optimum ratio for design falls in the range of .9 – 1.05. A ratio of 1.05 would be slightly under designed and a ratio of 0.9 would mean slightly over designed. Most of the values fell in the range of .75-.9, which means the shelter design is conservative. Timber sizes of 8x12, 8x14 and a glulam size of 10.75x24 were chosen for constructability, cost effectiveness and the best strength ratio to expected loads. Each beam uses a Simpson Strong tie wood connection to hang rafters on both sides of the beam. The beams are affixed to 8x8 columns using Simpson Strong tie wood connection. Each connection meets expected load requirements.

Column design presented a unique challenge of transferring the axial loads and resisting buckling due to lateral wind pressures. Each column is a pressure treated 8x8 southern pine post that is embedded into reinforced concrete combination footing that utilizes the self-weight of the concrete and soil to resist the lateral wind pressures experienced above ground. This efficiently transfers the superstructure's loads into the foundation and into the soil.

Framing plan utilizes 2x8 southern pine framing to hide the existing columns in the walls. This aloud TCS consulting to provide an open feel to the non-enclosed part of the shelter while also giving needed support to the beams C and B. The framing is spaced to allow for maximum window coverage to utilize the natural lighting of the area. This natural lighting will help cut energy costs of lighting and cooling in the summer months.

6.4. Foundation Design Details

Typical live loads for a foyer, as well as the calculated dead loads, were applied to the floor slab of the information center and exterior slab. Analyzing the loads mentioned above, a ten-inch slab with #4 bars spaced twelve inches on center was sufficient; however, this design did not adequately address the issue of shrinkage and expansion. To address these issues #4 bars spaced nine inches on center running both directions was determined to be the best option.

In addition, there were three different footing types implemented in the design. The first of which were the continuous footings that are used around the interior building. There was only one spread footing necessary for the design, and it was used for the center most column. Combination footings were the last type used since they became more cost & structurally efficient to support the remaining columns instead of using multiple spread footings. All the footings were designed using chapter 18 of the IBC and checked for settlement, sliding, uplift, and the bearing capacity. The limiting factor in the design was the bearing capacity, and the dimensions of the footings were minimized to be acceptable for the check.

6.5. Hydrology Analysis

In order to check the required retention volume necessary after site development, a hydro analysis was performed. The boundary used for the hydrology analysis was eleven acres spanning west of Qf lane with the top border fifty yards north of the proposed building location. An analysis of the pre-site development was calculated using the rational method. The discharge of the pre-site development area was found to be 22.37 cfs. Then the first proposed option was calculated using the same process. Since there was small change to the overall area, the discharge remained unchanged (22.37 cfs). However, for the parking lot addition, a slight increase in the discharge was observed (22.8 cfs). Since there was an increase in the discharge, a water quality volume calculation had to be performed. From this calculation, the volume of water required to be stored for twenty-four hours is found. Using this volume, two small rain gardens to be placed in the parking were designed to meet this necessity.

6.6. Pavement Design

For the pavement design, we compared prices of the two most common surfaces: Portland concrete cement and hot mix asphalt. Since price was already a limiting factor for the parking lot, we went with asphalt since it is cheaper than concrete. The Asphalt Paving Association of Iowa has a recommended depth for both the base and surface based on the number of parking spots and subgrade class. Since the subgrade is clay, we used the “poor” classification which dictates that the base layer be 4.5” of hot mix asphalt and a surface layer of 1.5” hot mix asphalt. Making a total of 6” of hot mix asphalt for the surface and 8” of gravel for the sub base.

Section VII: Engineer’s Estimate

7.1. Preliminary Construction Cost Estimates

The following cost estimates for each site plan were calculated by using RSMeans Cost Handbook, Snyder & Associates Construction Costs for previous plan and IDOT Bid Tabs to gather unit cost for materials, equipment, labor, overhead and profit. Every item on the estimate has a DOT code and unit price comparable to those of similar recent projects.

Table 7.1.1 Construction Cost Estimate for Site Plan 1- Gravel Parking Lot

Boone County High Trestle Trail Information Shelter- Site Plan 1				1	
				Engineer's Estimate	
Item Number	Item Description	units	Quantity	Unit Price	Total
	General Provisions				
1	Mobilization	LS	1	$15,000.00	$15,000.00
2	Traffic Control	LS	1	$500.00	$500.00
				Sub Total	$15,500.00
	Site Devlopment				
3	6" HMA Pavement	TON	22.5	$75.00	$1,687.50
4	6" PCC Sidewalk	SY	63.6	$45.00	$2,864.00
5	4" PCC Sidewalk	SY	123.55	$30.00	$3,706.50
6	6" PCC Curb	LF	52.1	$9.00	$468.90
7	Pavement Markings, 4" yellow	LF	160	$0.15	$24.00
				Sub Total	$8,258.00
	Site Amenatites				
8	HVAC System	LS	1	$2,500.00	$2,500.00
9	Water Fountain	EA	1	$3,500.00	$3,500.00
10	Utility Connections	LS	1	$7,500.00	$7,500.00
11	Circule Galvanized Bike Racks	EA	20	$50.00	$1,000.00
12	Bike Repair Station	EA	1	$1,350.00	$1,350.00
13	Picnic Tables	EA	6	$250.00	$1,500.00
				Sub Total	$17,350.00
	Landscaping				
14	Sod	SY	15.0	$10.00	$150.00
15	Ornamental Bushes	EA	18	$150.00	$2,700.00
16	Ornamental Trees	EA	2	$250.00	$500.00
17	Erosion Control	LS	1	$2,000.00	$2,000.00
				Sub Total	$5,350.00
	Information Center				
18	10" PCC Reinfored Slab	CY	37.0	$108.00	$3,996.00
19	Footing Foundations	LS	1	$8,500.00	$8,500.00
20	2x8 Pressure Treated Southern Pine Framing	EA	45	$20.00	$900.00
21	2x8 Pressure Treated Southern Pine Roofing	EA	66	$20.00	$1,320.00
22	8x14 Pressure Treated Southern Pine Beams	EA	4	$400.00	$1,600.00
23	8x12 Pressure Treated Southern Pine Beams	EA	2	$300.00	$600.00
24	44ft 10.75x24 Glulam	LS	1	$2,500.00	$2,500.00
25	Flood Lights	EA	3	$45.00	$135.00
26	20' Ground Contact Pressure Treated Decking Board	EA	3	$35.00	$105.00
27	8x8 Pressure Treated Southern Pine Columns	EA	8	$13.00	$104.00
28	Standing Seam Steel Roof	SF	1364	$15.00	$20,460.00
29	48" W x 60" H Left Sliding Window	EA	4	$350.00	$1,400.00
30	60" W x 60" H Window	EA	2	$160.00	$320.00
31	48" W x 12" H Window	EA	4	$180.00	$720.00
32	36" W x 60" H Window	EA	1	$250.00	$250.00
33	Stone Siding	SF	329	$20.00	$6,580.00
34	Textured Fiber Cement Lap Siding 5/6" x 12" x 12'	EA	54	$20.00	$1,080.00
35	LSU 26 Galvanized Simpson	EA	176	$6.00	$1,056.00
36	CC66PC Galvanized Simpson	EA	9	$113.00	$1,017.00
37	HL55PC Galvanized Simpson	EA	2	$45.00	$90.00
38	LSTA24 Galvanized Tie Simpson	EA	22	$3.00	$66.00
39	7/8" x 24" SB Wall Anchor	EA	30	$20.00	$600.00
40	Wood Desk	EA	1	$300.00	$300.00
41	Indoor Bench	EA	3	$150.00	$450.00
				Sub Total	$54,149.00
		Total			**$101,099.90**
		Contingencies			10%
		Engineering and Administration			20%
		Total			**$131,429.87**

Table 7.1.2 Construction Cost Estimate for Site Plan 2 - Extended and Paved Parking Lot

Boone County High Trestle Trail Information Shelter - Site Plan 2				2	
				Engineer's Estimate	
Item No.	Item Description	Units	Quantity	Unit Price	Total
	General Provisions				
1	Mobilization	LS	1	$25,000.00	$25,000.00
2	Traffic Control	LS	1	$500.00	$500.00
				Sub Total	$25,500.00
	Site Devlopment				
3	6" HMA Pavement	TON	1163.0	$75.00	$87,225.00
4	8" Gravel Sub Base	TON	275	$50.00	$13,750.00
4	6" PCC Sidewalk	SY	63.6	$45.00	$2,864.00
5	4" PCC Sidewalk	SY	129.4	$30.00	$3,883.33
6	6" PCC Curb	LF	140.7	$9.00	$1,266.30
7	Pavement Markings, 4" white	LF	1500	$0.15	$225.00
8	Pavement Markings, 4' yellow	LF	1000	$0.15	$150.00
9	6' Parking Blocks	EA	46	$50.00	$2,300.00
				Sub Total	$111,663.63
	Site Amenatites				
10	HVAC System	LS	1	$2,500.00	$2,500.00
11	Water Fountain	EA	1	$3,500.00	$3,500.00
12	Utility Connections	LS	1	$7,500.00	$7,500.00
13	Circular Galvanized Bike Racks	EA	20	$50.00	$1,000.00
14	Bike Repair Station	EA	1	$1,350.00	$1,350.00
				Sub Total	$15,850.00
	Site Work & Landscaping				
15	Sod	SY	15.0	$10.00	$150.00
16	Ornamental Bushes	EA	18	$100.00	$1,800.00
17	Ornamental Trees	EA	5	$900.00	$4,500.00
18	Erosion Control	LS	1	$3,000.00	$3,000.00
				Sub Total	$9,450.00
	Information Center				
19	10" PCC Reinforced Slab	CY	37.0	$108.00	$3,996.00
20	Footing Foundations	LS	1	$8,500.00	$8,500.00
21	2x8 Pressure Treated Southern Pine Framing	EA	45	$20.00	$900.00
22	2x8 Pressure Treated Southern Pine Roofing	EA	66	$20.00	$1,320.00
23	8x14 Pressure Treated Southern Pine Beams (20' Sections)	EA	4	$400.00	$1,600.00
24	8x12 Pressure Treated Southern Pine Beams (20' Sections)	EA	2	$300.00	$600.00
25	44ft 10.75x24 Glulam	LS	1	$2,500.00	$2,500.00
26	Flood Lights	EA	3	$45.00	$135.00
27	20' Ground Contact Pressure Treated Decking Board	EA	3	$35.00	$105.00
28	8x8 Pressure Treated Southern Pine Columns	EA	8	$13.00	$104.00
29	Standing Seam Steel Roof	SF	1364	$15.00	$20,460.00
30	48" W x 60" H Left Sliding Window	EA	4	$350.00	$1,400.00
31	60" W x 60" H Window	EA	2	$160.00	$320.00
32	48" W x 12" H Window	EA	4	$180.00	$720.00
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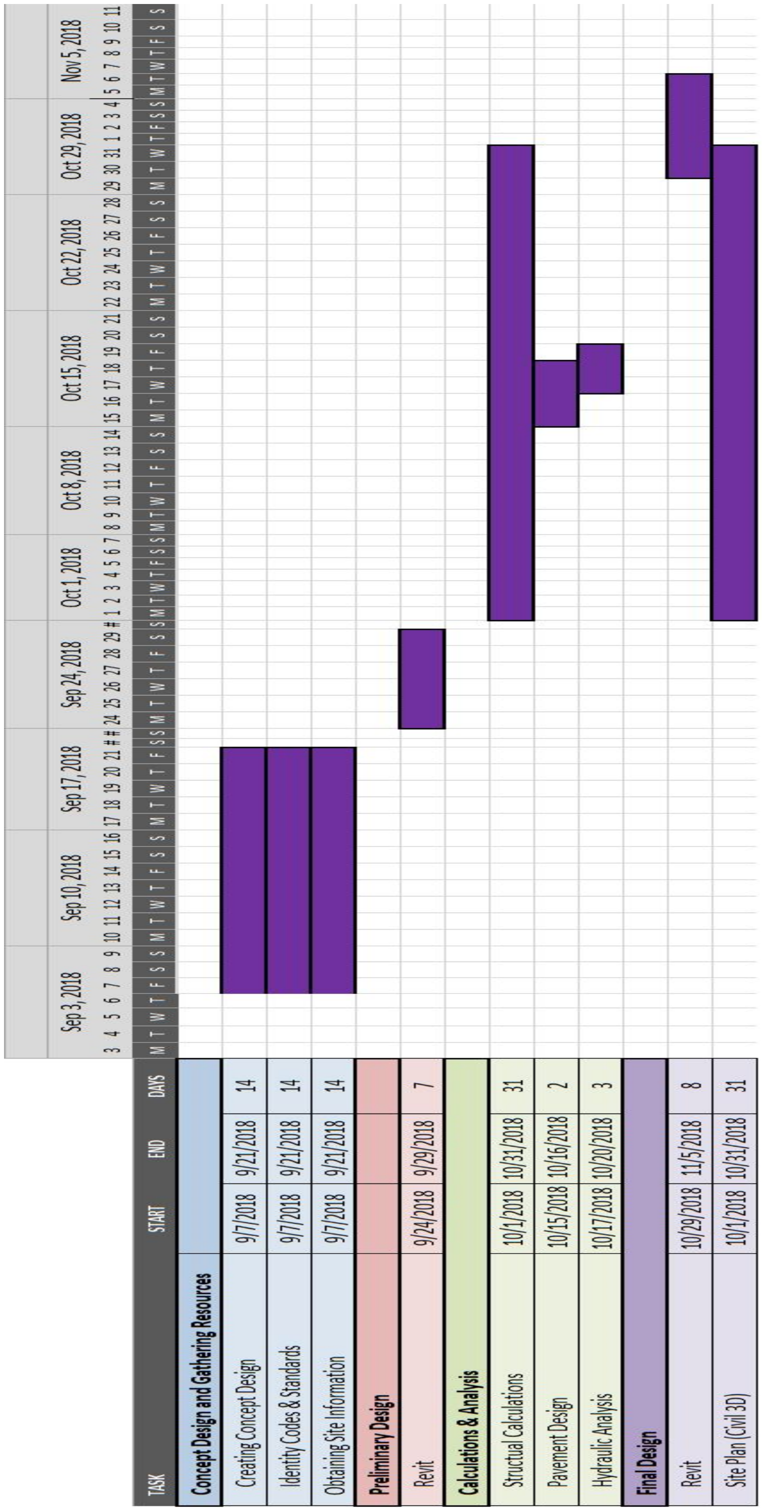
39	LSTA24 Galvanized Tie Simpson	EA	22	$3.00	$66.00
40	7/8" x 24" SB Wall Anchor	EA	30	$20.00	$600.00
41	Wood Desk	EA	1	$300.00	$300.00
42	Indoor Bench	EA	3	$150.00	$450.00
				Sub Total	$54,149.00
		Total			**$216,612.63**
		Contingencies			10%
		Engineering and Administration			20%
		Total			**$281,596.42**

Section VIII: Conclusion and Recommendations

8.1. Conclusions

TCS consulting recommends Boone County Conservation board to select site plan 1 configuration and design. This design plan includes the small unique partially enclosed park information center with amenities, ADA compliance access walks and handicap spots, and landscaping. Site plan 1 maximizes the design space while saving unnecessary expenses for future installation projects. By selecting the proposed design, Boone County is increasing the High Trestle Trails user friendliness and accentuating the true natural beauty of the surrounding forestry. From the railways and mines of the 19^{th} century comes the High Trestle Trail information center at Grant's Woods.

9.1. Gantt Chart


TASK
START
END
DAYS
Concept Design and Gathering Resources
Creating Concept Design
9/7/2018
9/21/2018
14
Identity Codes & Standards
9/7/2018
9/21/2018
14
Obtaining Site Information
9/7/2018
9/21/2018
14
Preliminary Design
Revit
9/24/2018
9/29/2018
7
Calculations & Analysis
Structural Calculations
10/1/2018
10/31/2018
31
Pavement Design
10/15/2018
10/16/2018
2
Hydraulic Analysis
10/17/2018
10/20/2018
3
Final Design
Revit
10/29/2018
11/5/2018
8
Site Plan (Civil 3D)
10/1/2018
10/31/2018
31
Sep 3, 2018
Sep 10, 2018
Sep 17, 2018
Sep 24, 2018
Oct 1, 2018
Oct 8, 2018
Oct 15, 2018
Oct 22, 2018
Oct 29, 2018
Nov 5, 2018

9.2. Design Sheets

HIGH TRESTLE TRAIL INFORMATION CENTER

SITE LOCATION:

TABLE OF CONTENTS:

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PHONE: 319.335.5647
FAX: 319.335.5660
EMAIL: civil-hawks@uiowa.edu

SHEET NO.
1

PROJECT: GRANT'S_WOODS_INFORMATION_CENTER
DATE : 11/9/18
DRAWN BY: SAMUEL-HERMANAS
REVISION:

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SHEET NAME
SITE-PLAN-1

SHEET NO.
2

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SHEET NAME
SITE_PLAN_OPTION_2

SHEET NO.
3

Notes:

1. ALL UTILITIES ARE APPROXIMATE AND MUST BE LOCATED. USE IOWA ONE CALL BEFORE CONSTRUCTION: 1(800)292-8989

LEGEND

TREE

BUSH

ASPHALT

PCC CURB

PROJECT: GRANT'S_WOODS_INFORMATION_CENTER

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SHEET NAME

SITE_1_ELEVATIONS

SHEET NO.

4

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SHEET NAME

SITE_OPTION_2_ELEVATIONS

SHEET NO.

5

Notes:

1. ALL UTILITIES ARE APPROXIMATE AND MUST BE LOCATED. USE IOWA ONE CALL BEFORE CONSTRUCTION: 1(800)292–8989

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GRANT'S_WOODS_TRAIL_SHELTER

SHEET NAME

PARKING_LOT_ELEVATION_SHEET

SHEET NO.

6

SHEET NO. 7	SHEET NAME Foundation Plan	**High Trestle Trail Information Center** 2335 Qf Lane Madrid, IA 50156	EDUCATIONAL - NOT FOR CONSTRUCTION	

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PROJECT:	CEE: 4850
DATE :	12/07/2018
DRAWN BY:	Thomas Fales
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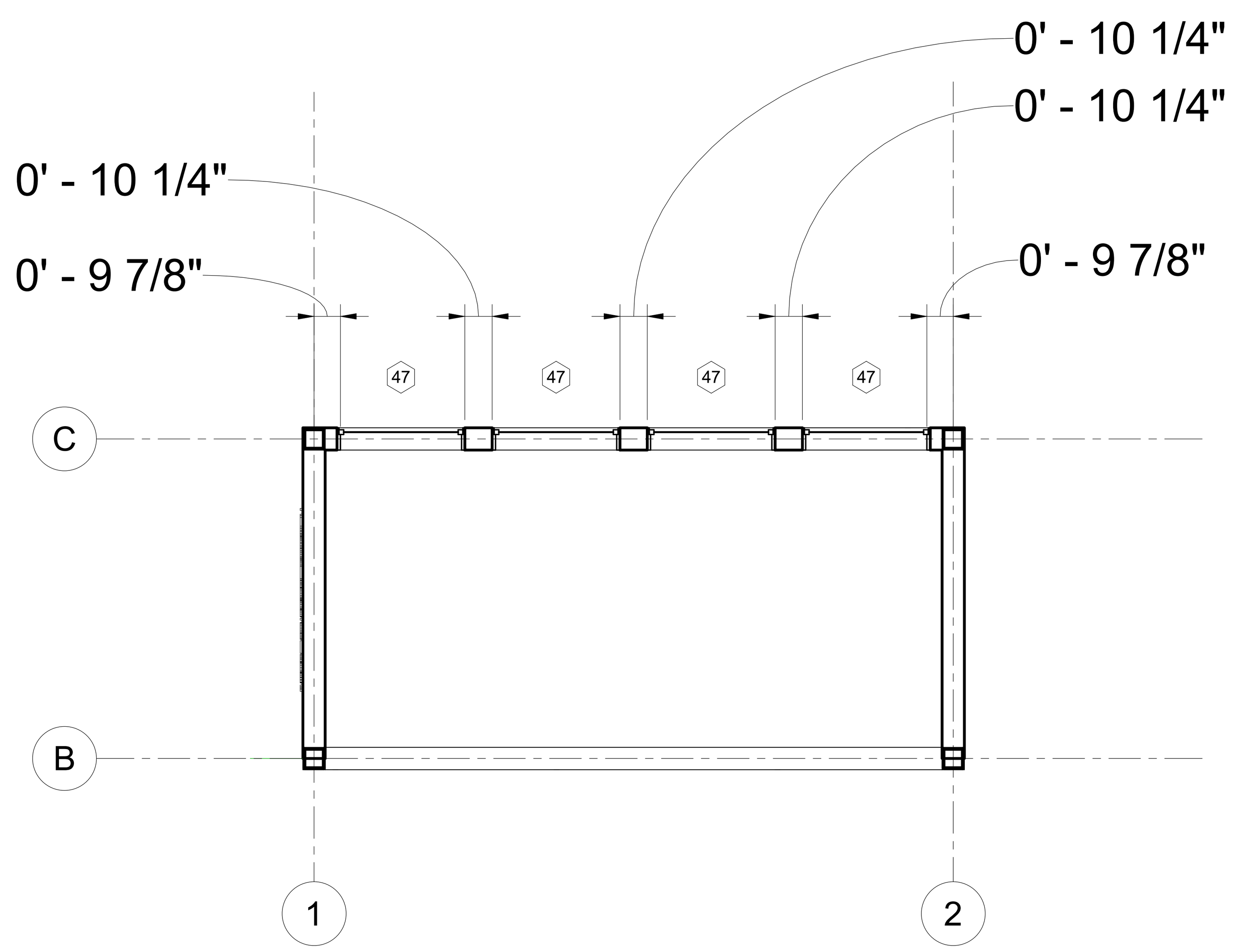
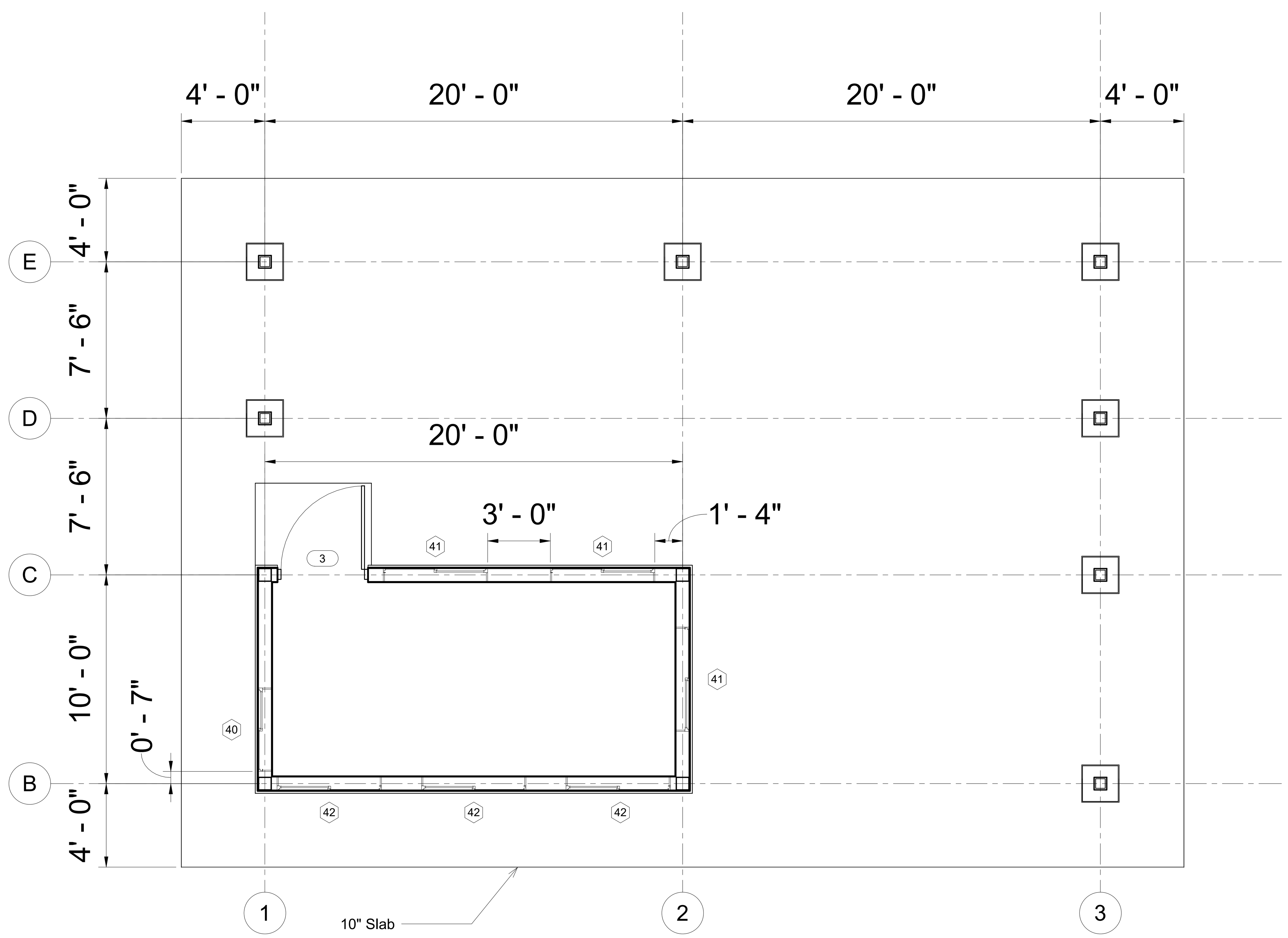


2 Top of Wall C
1/4" = 1'-0"



1 Finish Floor
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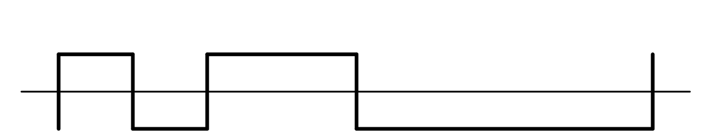

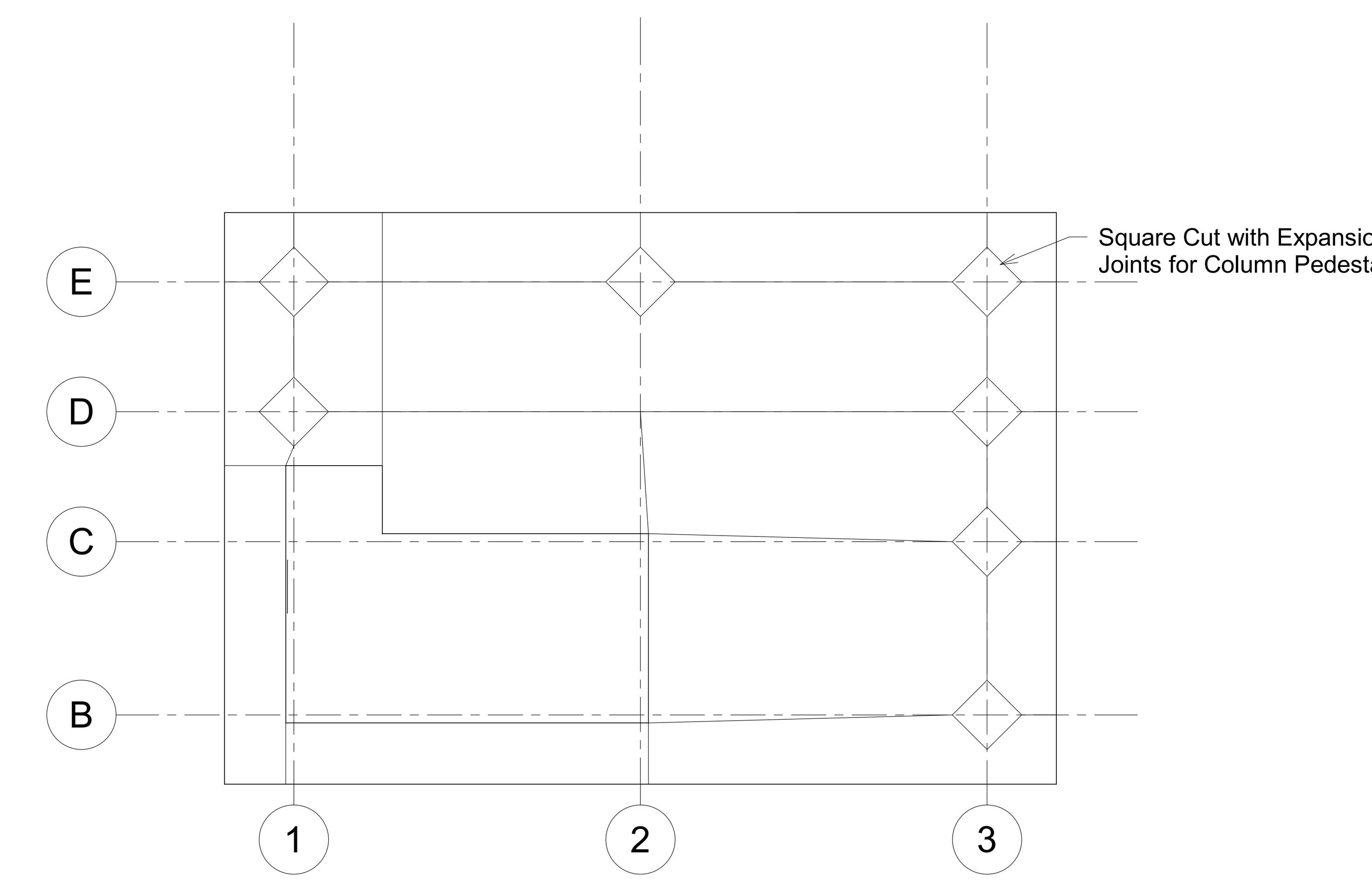

3 Slab Saw Cuts
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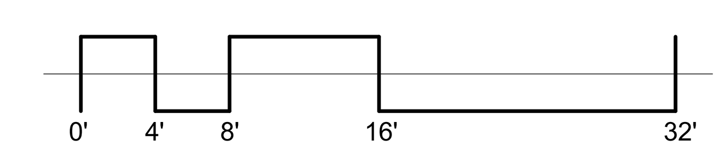

Window Schedule

Type Mark	Type	Sill Height	Description
47	12"x48"	8' - 6"	Hy-Lite Rectangle
47	12"x48"	8' - 6"	Hy-Lite Rectangle
47	12"x48"	8' - 6"	Hy-Lite Rectangle
40	48"x60"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
41	60"x60"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
41	60"x60"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
41	60"x60"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
42	60"x48"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
42	60"x48"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
42	60"x48"	2' - 6"	Builders Vinyl Sliding, 2-Panel, XO Left Hand
47	12"x48"	8' - 6"	Hy-Lite Rectangle

Door Schedule

Type	Type Comments	Type Mark
48" x 84"	Master Craft Dark Oak Wood Grain	3

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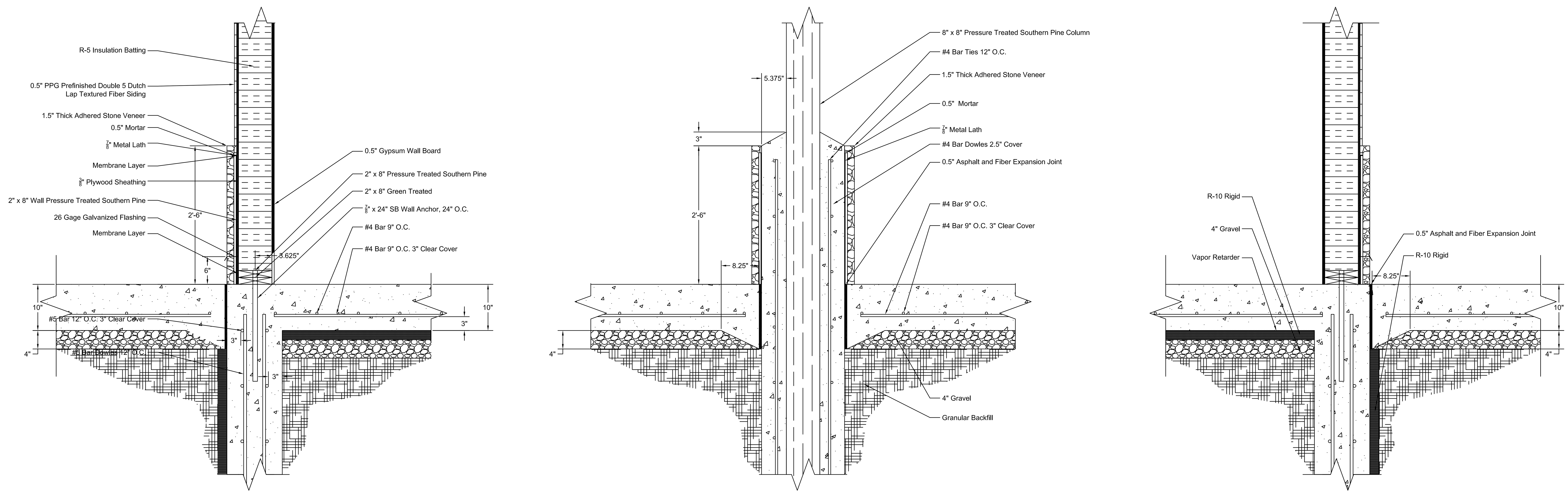
SHEET NAME
Floor Plan

SHEET NO.
8



Scale: 1" - 1'

0 1' 2'

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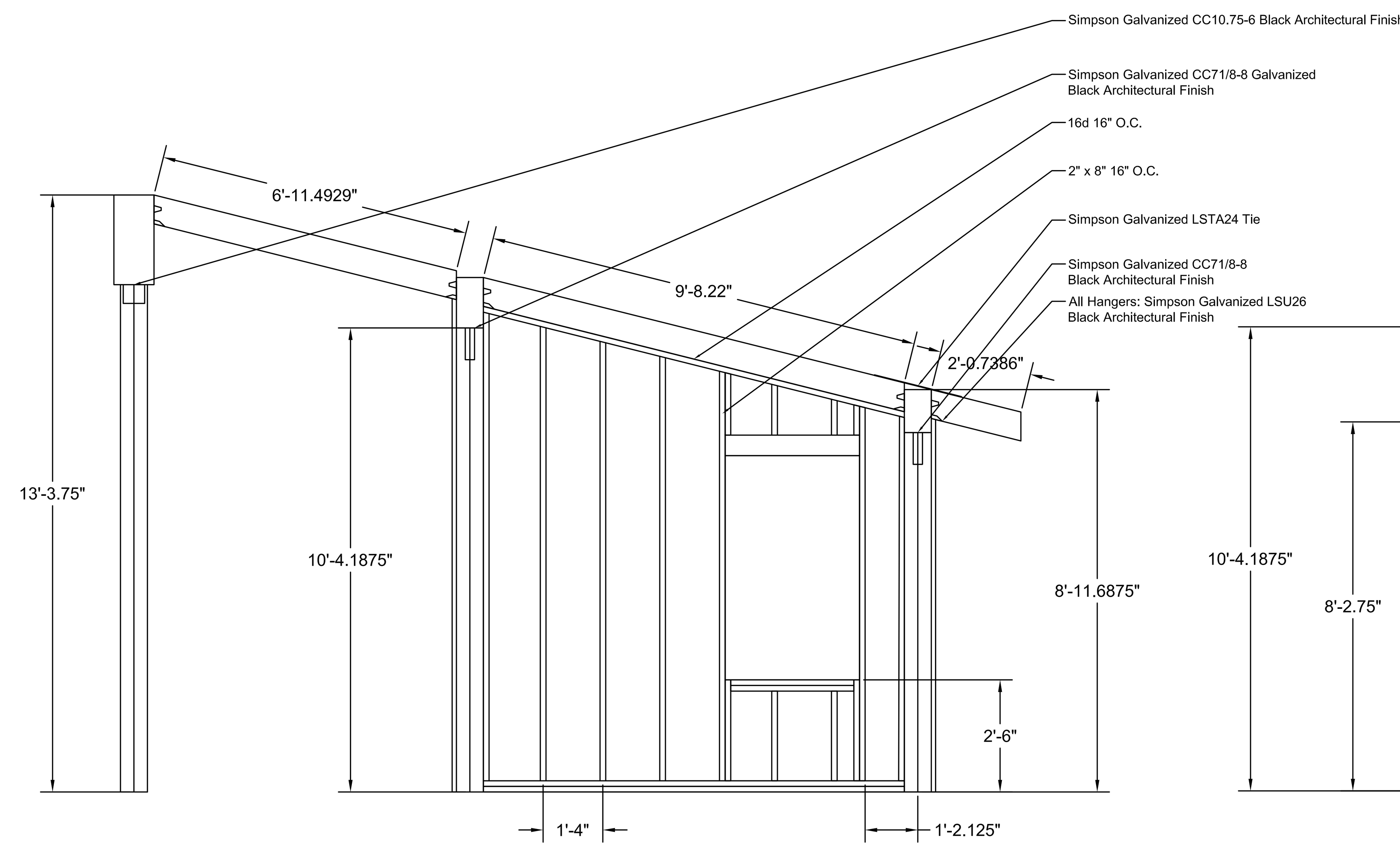
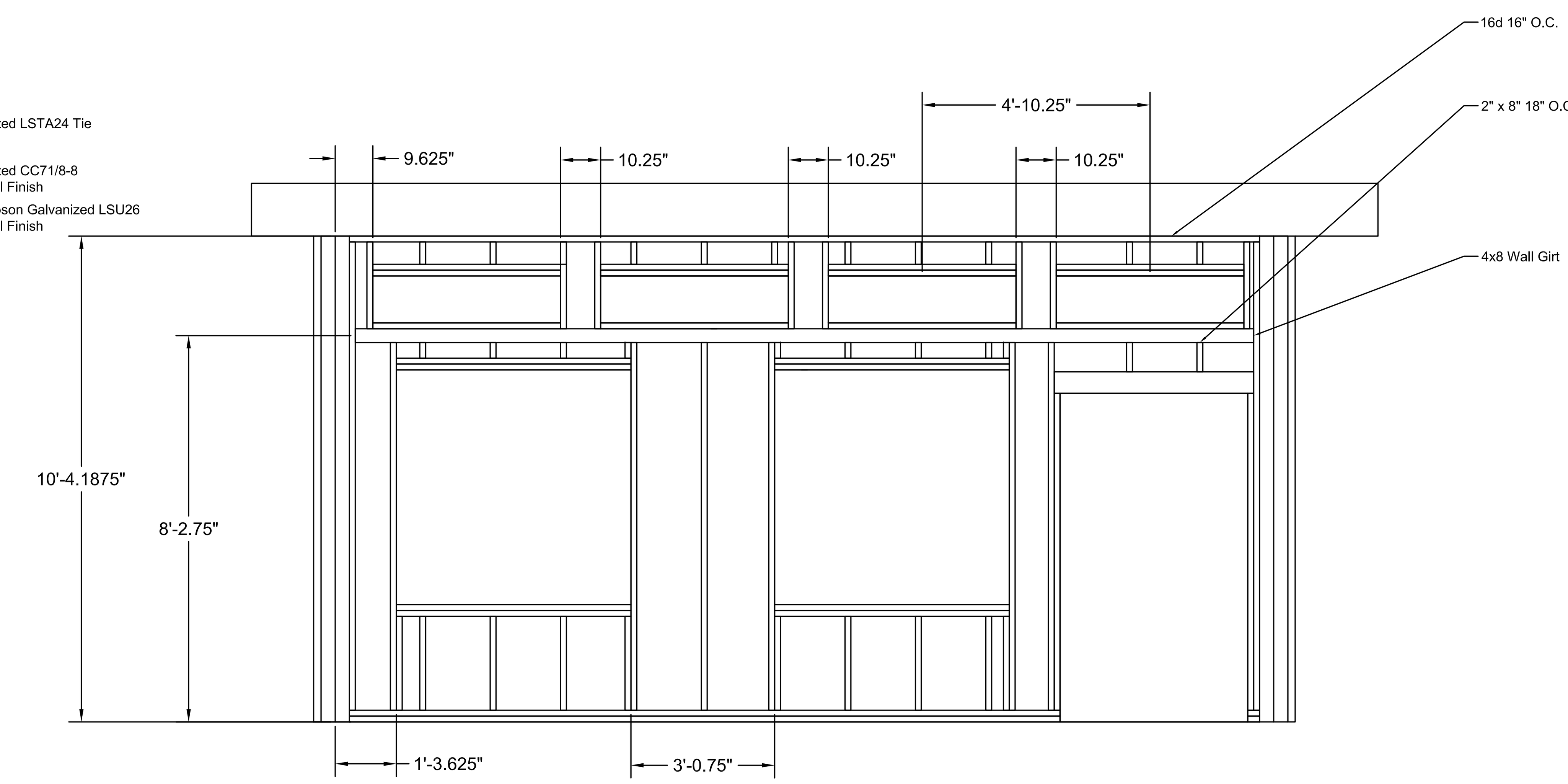
SHEET NAME
Wall Sections

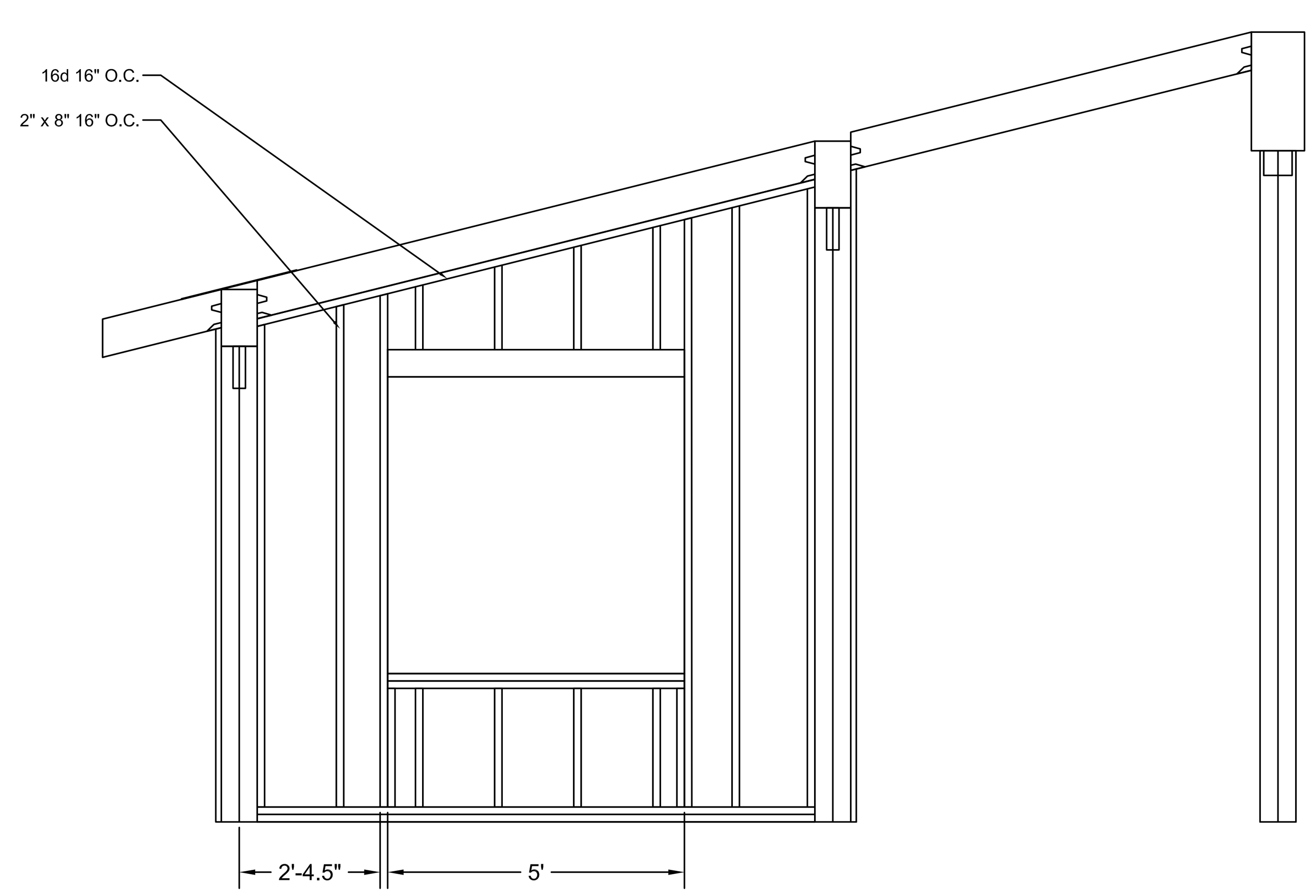
SHEET NO.
9



East



South



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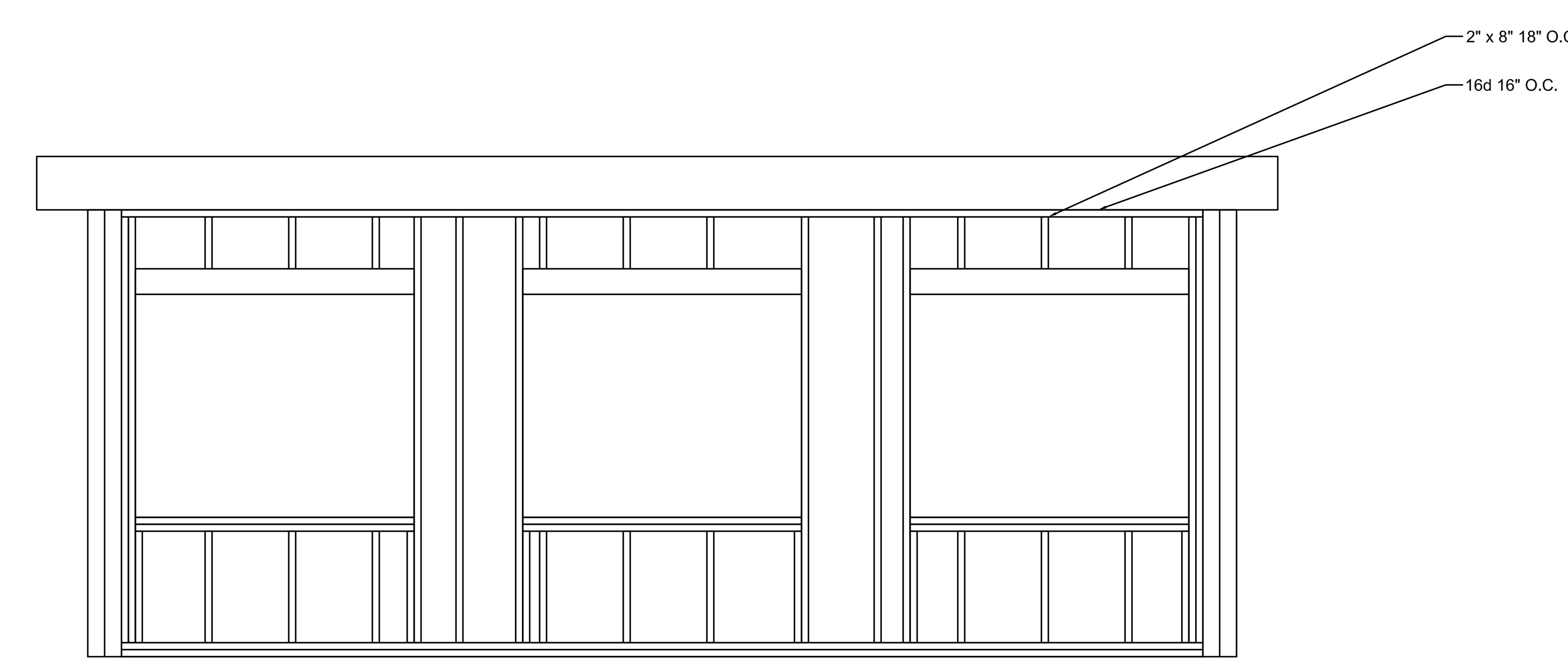

North

Scale: $\frac{3}{8}$" - 1'

0 1' 2'

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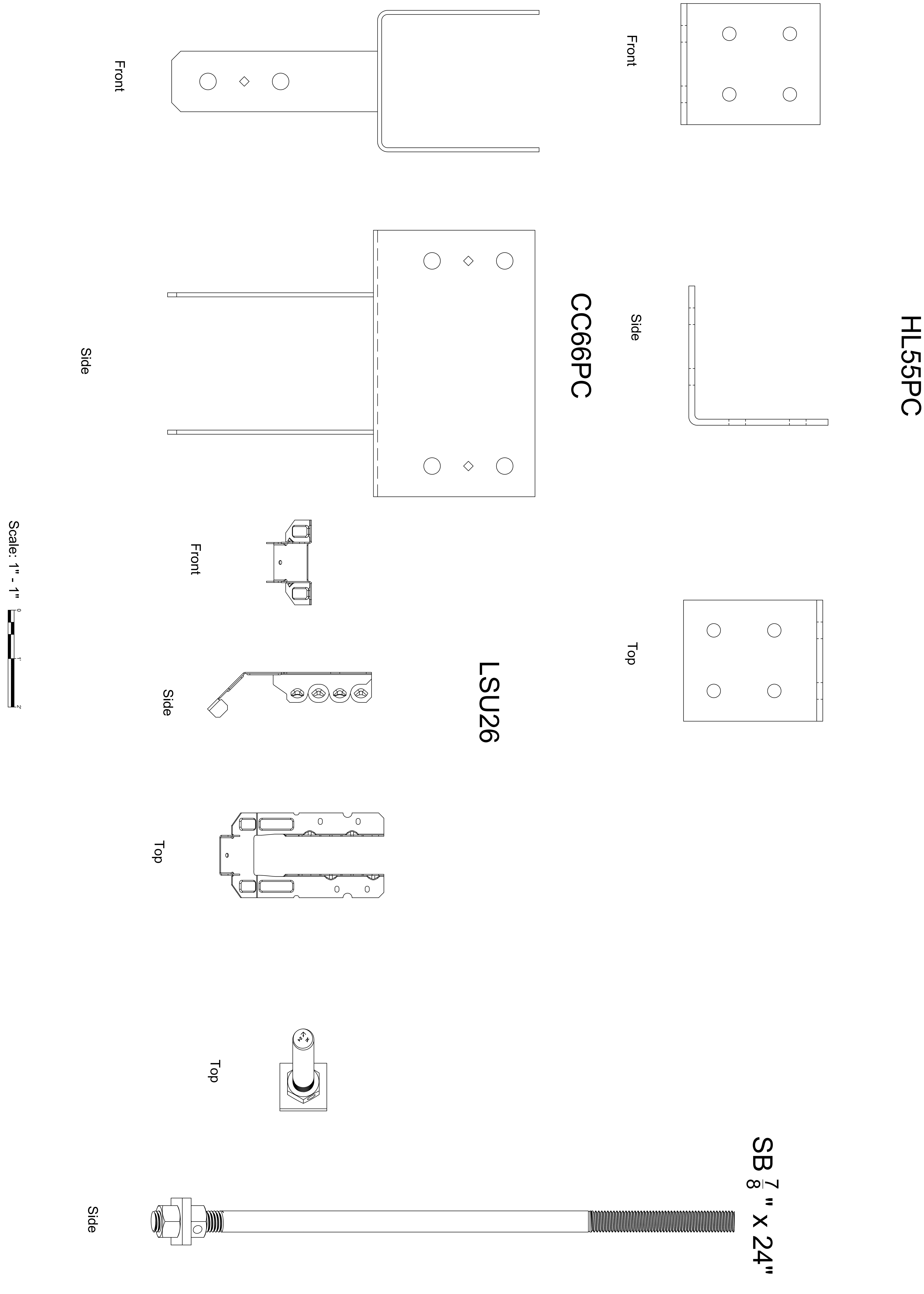
SHEET NAME

Frame Plan

SHEET NO.

10



SHEET NO.

11

SHEET NAME

Connections

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CEE logo BW - noText.tif

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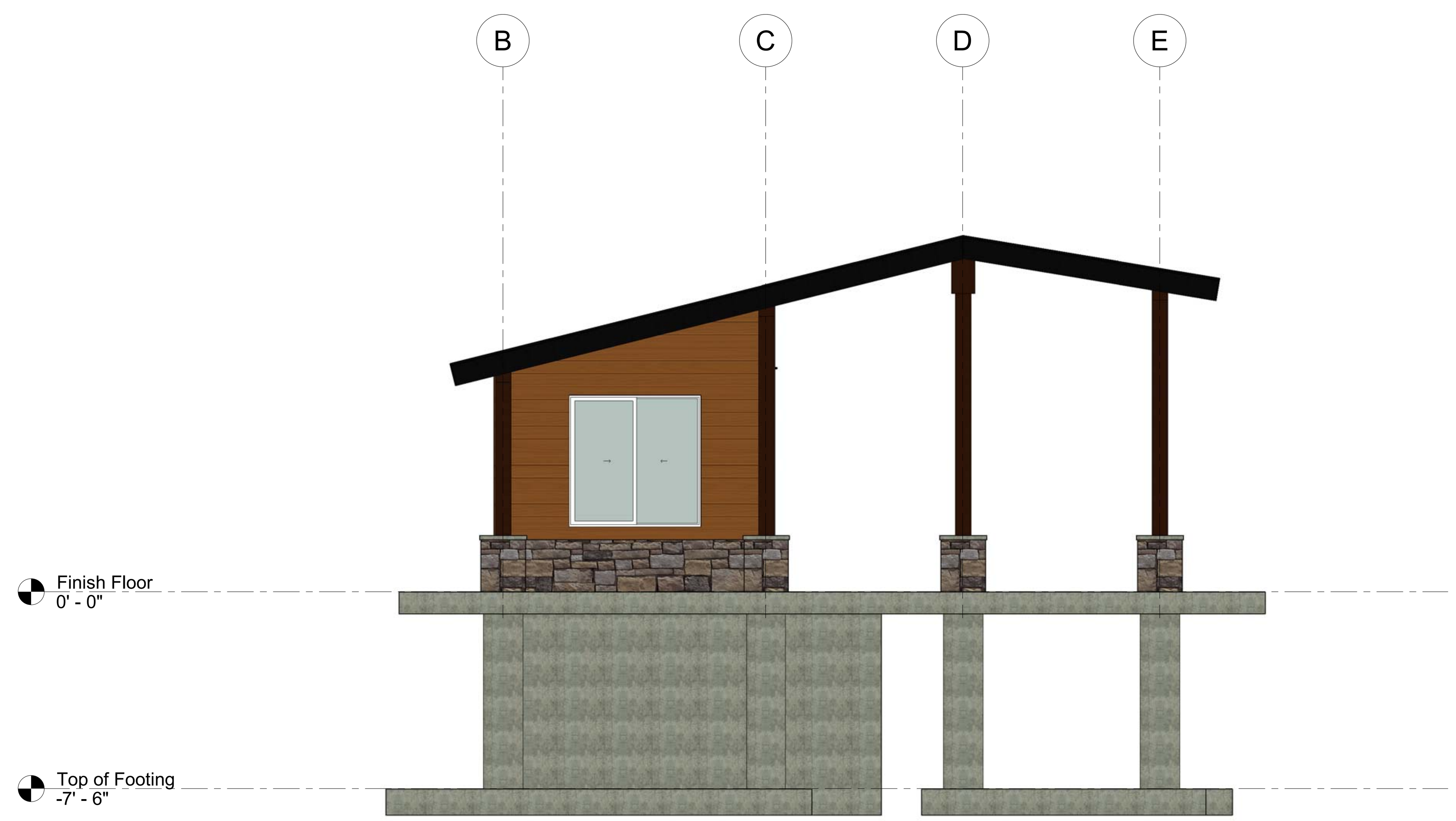

1 West
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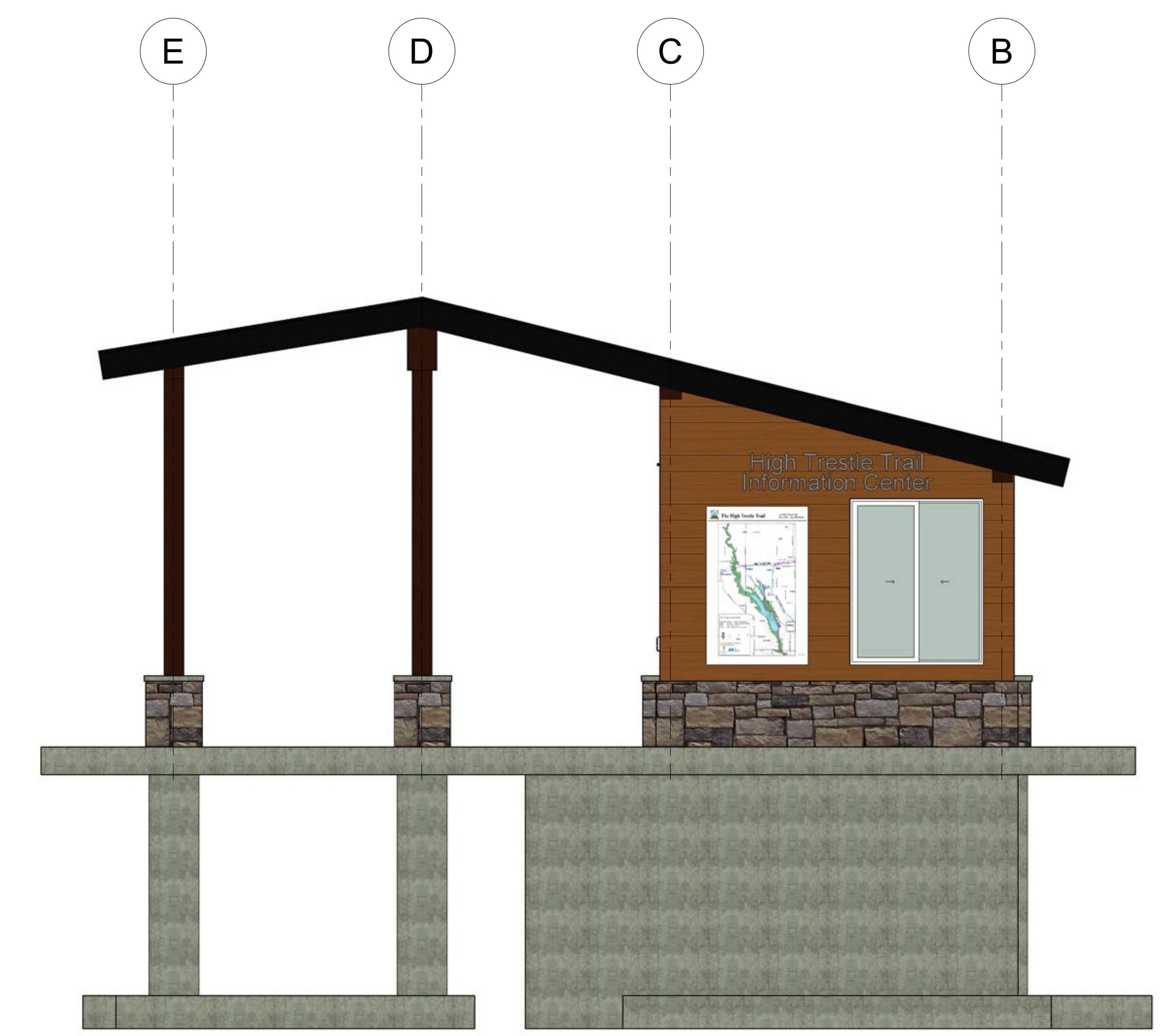
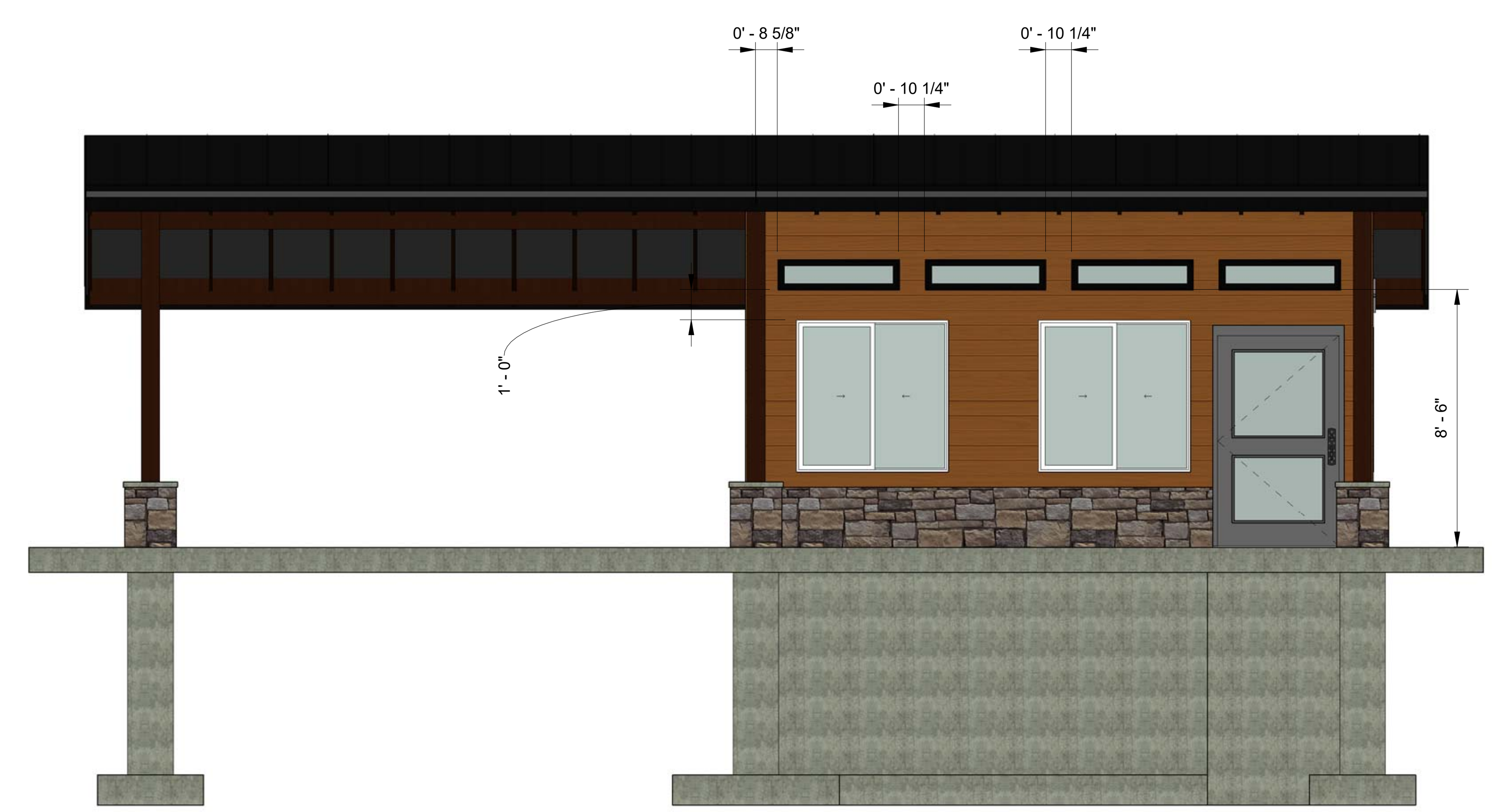
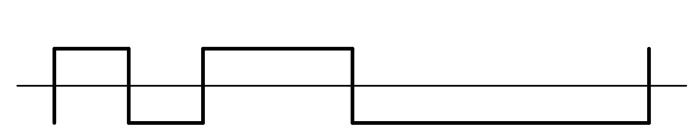


4 East
1/4" = 1'-0"

3 North
1/4" = 1'-0"



2 South
1/4" = 1'-0"



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SHEET NAME

Elevations

SHEET NO.

12

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DRAWN BY: SAMUEL_HERMANAS
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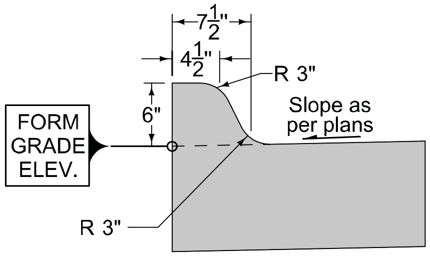
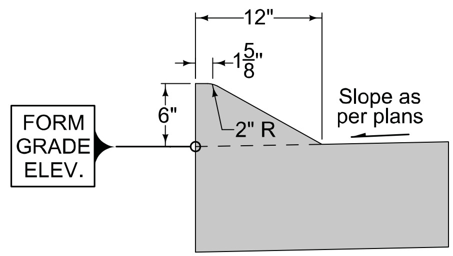
HIGH_TRESTLE_TRAIL_SHELTER

SHEET NAME
LANDSCAPE

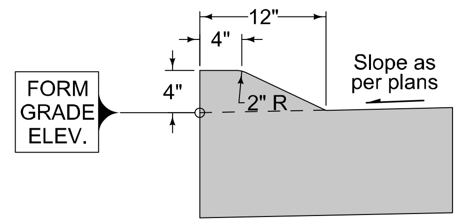
SHEET NO.
13



6" STANDARD CURB



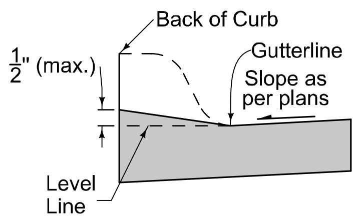
6" SLOPED CURB



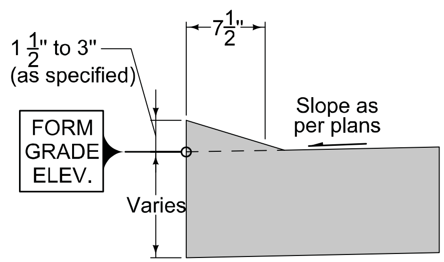
4" SLOPED CURB

For joint details, see PV-101.

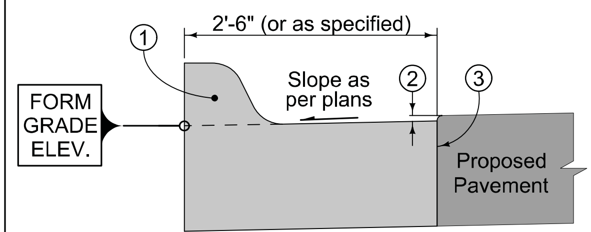
1. 6" Standard Curb, 6" Sloped Curb, or 4" Sloped Curb as specified.
2. $\frac{1}{8}$" if Proposed Pavement is HMA. No elevation difference if Proposed Pavement is PCC.
3. 'BT' , 'KT', or 'L' joint if Proposed Pavement is PCC. 'B' joint if Proposed Pavement is HMA.



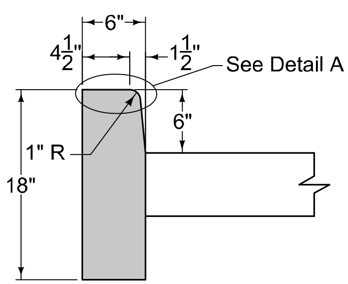
DROP CURB AT SIDEWALK



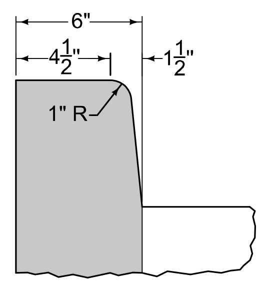
DRIVEWAY DROP CURB



CURB AND GUTTER UNIT



BEAM CURB*
*For short replacement sections, match existing curb profile



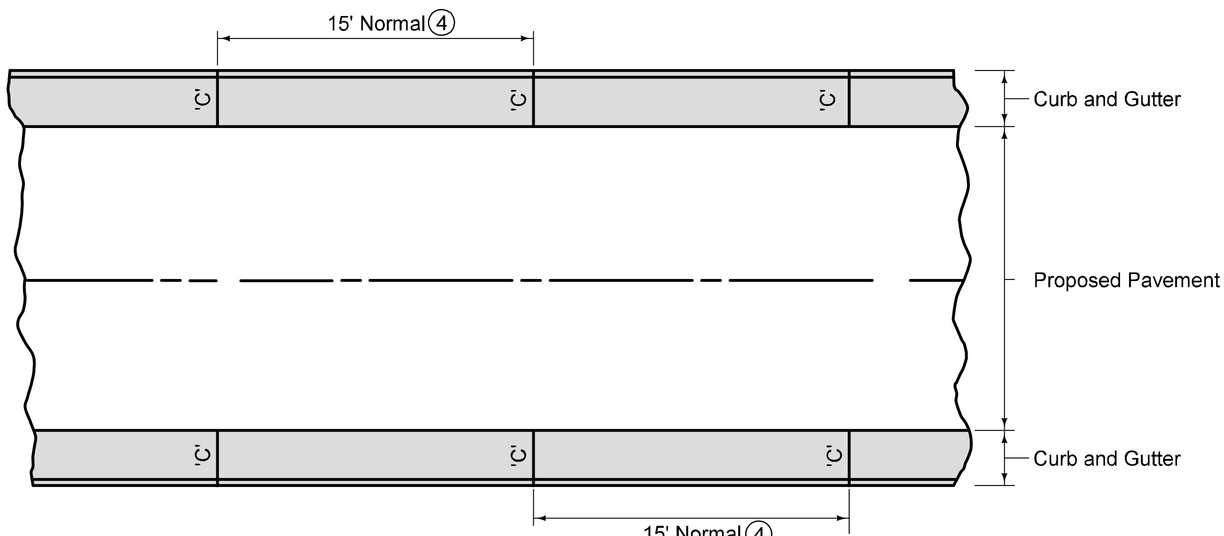
DETAIL A

SUDAS	IOWADOT	REVISION 4 — 10-18-16
FIGURE 7010.102	STANDARD ROAD PLAN	PV-102 SHEET 1 of 2

REVISIONS: Added note, 'Slope as per plans' on Drop Curb views on page 1. Updated DOT logo to new version.

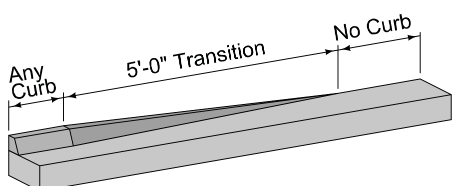
Paul D. Wiegand — SUDAS DIRECTOR
Brian Smith — DESIGN METHODS ENGINEER

PCC CURB DETAILS

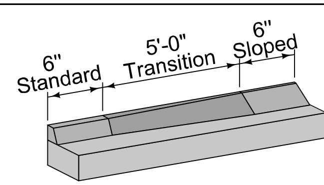


JOINTING DIAGRAM FOR CURB AND GUTTER UNIT

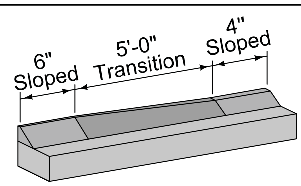
④ If proposed pavement is PCC, match joint spacing for proposed pavement. Place 'E' joints in curb and gutter section where expansion joints are to be placed in proposed pavement.



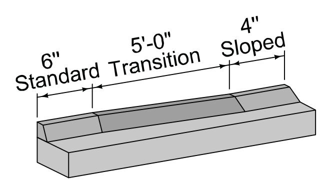
CURB RUNOUT FOR ALL CURBS



CURB TRANSITION FROM 6" STANDARD TO 6" SLOPED



CURB TRANSITION FROM 6" SLOPED TO 4" SLOPED



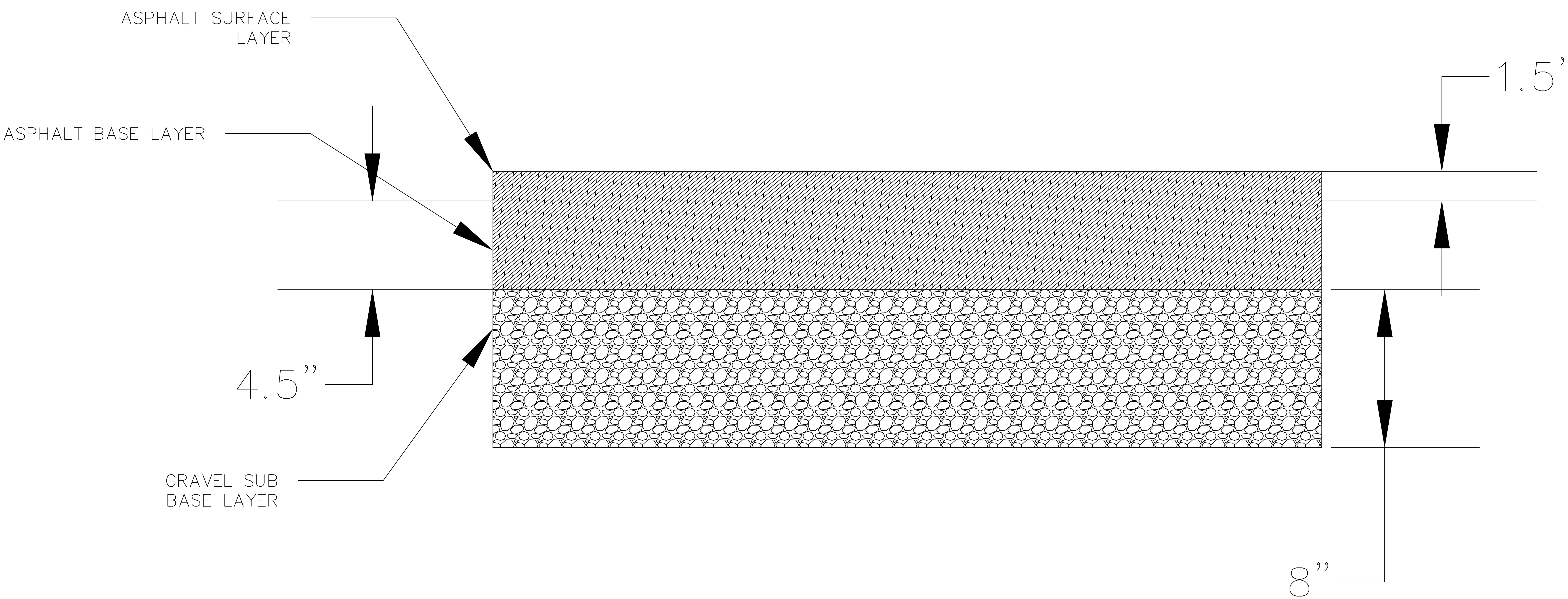
CURB TRANSITION FROM 6" STANDARD TO 4" SLOPED

SUDAS	IOWADOT	REVISION 4	10-18-16
FIGURE 7010.102	STANDARD ROAD PLAN	PV-102 SHEET 2 of 2	

REVISIONS: Added note, 'Slope as per plans' on Drop Curb views on page 1. Updated DOT logo to new version.

SUDAS DIRECTOR — DESIGN METHODS ENGINEER

PCC CURB DETAILS



PROJECT: INFORMATION_CENTER
DATE : 12/7/18
DRAWN BY: SAM_HERMANAS
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HIGH_TRESTLE_TRAIL_INFORMATION_CENTER

SHEET NAME
PAVEMENT_DESIGN

SHEET NO.
15

9.3. Hydraulic Analysis

Note: Q and Volume were calculated using Rational Method on Civil 3D using 10 year frequency

Hydro Analysis: Parking Lot Addition

Area of Site:

$A := 500931.2337\ ft^2 = 11.5\ acre$

Longest Run off length:

$L := 1150\ ft$

Start elevation

$E_{start} := 978\ ft$

End Elevation

$E_{end} := 942\ ft$

Slope:

$slope := \frac{E_{start} - E_{end}}{L} = 0.031$

Mannings Coefficients:

$n_{pave} := 0.014$

$n_{meadow} := 0.15$

Runoff Coefficients by Material

$C_{pave} := 0.9$

$C_{land} := 0.5$

Area by Material:

$A_{pave} := (27589.65 + 8600 + 3397.43 + 2068.9 + 240.5 + 311.36 + 2109)\ ft^2 = 1.017\ acre$

$A_{land} := A - A_{pave} = 10.482\ acre$

Weight Run off Coefficient

$C_{bar} := \frac{C_{pave} \cdot A_{pave} + C_{land} \cdot A_{land}}{A} = 0.535$

Rainfall Intensity (T=10 years & 24 hr duration):

$i := 0.18$ $D := 4.46\ in$

Sheet Flow Calculation

$S := \frac{978 - 971.73}{300} = 0.021$

$T_{osf} := \left(\frac{0.93 \cdot \left((300)^{0.6} \cdot n_{pave}{}^{0.6}\right)}{i^{0.4} \cdot S^{0.3}}\right) min = 13.941\ min$

Shallow Concentrated Calculation

$L := 268\ ft$ $S := 0.074$ $V := 1.25\ \frac{ft}{s}$

$T_{scf} := \frac{L}{V \cdot 60} = 0.06\ min$

Open Flow Calculation

Assuming Trapezoidal Shape

$L := 595.5\ ft$ $\quad S := 0.02$ $\quad n_{meadow} := 0.15$

$$R := \frac{5\ ft \cdot D + 2 \cdot 15\ ft \cdot D}{5\ ft + 2 \cdot 15\ ft} = 0.372\ ft \qquad R := 0.372$$

$$V := \left(\left(\frac{1.486}{n_{meadow}}\right) \cdot R^{\frac{2}{3}} \cdot S^{0.5}\right) \frac{ft}{s} = 0.725\ \frac{ft}{s}$$

$$T_{ocf} := \frac{L}{V} = 13.696\ min$$

T critical Calculation

$T_c := T_{ocf} + T_{scf} + T_{osf} = 28\ min$ **USE 30 min**

$Q_1 := 23.3\ \frac{ft^3}{s}$ $\qquad V_1 := 41813\ ft^3$

Hydro Analysis: Only Site Development

Area of Site:

$A := 500931.2337\ ft^2 = 11.5\ acre$

Longest Run off length:

$L := 1150\ ft$

Start elevation

$E_{start} := 978\ ft$

End Elevation

$E_{end} := 942\ ft$

Slope:

$$slope := \frac{E_{start} - E_{end}}{L} = 0.031$$

Mannings Coefficients:

$n_{pave} := 0.014$

$n_{meadow} := 0.15$

Runoff Coefficients by Material

$C_{pave} := 0.9$ $\quad C_{gravel} := 0.85$ $\quad C_{land} := 0.5$

Area by Material:

$A_{pave} := (240.5 + 2109 + 311.37)\ ft^2 = 0.061\ acre$

$A_{gravel} := 25000\ ft^2 = 0.574\ acre$

$A_{land} := A - A_{pave} - A_{gravel} = 10.865\ acre$

Weight Run off Coefficient

$$C_{bar} := \frac{C_{pave} \cdot A_{pave} + C_{land} \cdot A_{land} + C_{gravel} \cdot A_{gravel}}{A} = 0.52$$

Rainfall Intensity (T=10 years & 24 hr duration):

$i := 0.18$ $\qquad D := 4.46\ in$

Sheet Flow Calculation

$$S := \frac{978 - 971.73}{300} = 0.021$$

$$T_{osf} := \left(\frac{0.93 \cdot \left((300)^{0.6} \cdot n_{pave}{}^{0.6} \right)}{i^{0.4} \cdot S^{0.3}} \right) min = 13.941\ min$$

Shallow Concentrated Calculation

$L := 268\ ft$ $\qquad S := 0.074$ $\qquad V := 1.25\ \frac{ft}{s}$

$$T_{scf} := \frac{L}{V \cdot 60} = 0.06\ min$$

Open Flow Calculation

Assuming Trapezoidal Shape

$L := 595.5\ ft$ $\qquad S := 0.02$ $\qquad n_{meadow} := 0.15$

$$R := \frac{5\ ft \cdot D + 2 \cdot 15\ ft \cdot D}{5\ ft + 2 \cdot 15\ ft} = 0.372\ ft \qquad R := 0.372$$

$$V := \left(\left(\frac{1.486}{n_{meadow}} \right) \cdot R^{\frac{2}{3}} \cdot S^{0.5} \right) \frac{ft}{s} = 0.725\ \frac{ft}{s}$$

$$T_{ocf} := \frac{L}{V} = 13.696\ min$$

T critical Calculation

$T_c := T_{ocf} + T_{scf} + T_{osf} = 28\ min$ $\qquad$ **USE 30 min**

$Q_2 := 22.37\ \frac{ft^3}{s}$ $\qquad V_2 := 40265\ ft^3$

Hydro Analysis: No Site Development

Area of Site:

$A := 500931.2337\ ft^2 = 11.5\ acre$

Longest Run off length:

$L := 1150\ ft$

Start elevation

$E_{start} := 978\ ft$

End Elevation

$E_{end} := 942\ ft$

Slope:

$slope := \frac{E_{start} - E_{end}}{L} = 0.031$

Mannings Coefficients:

$n_{pave} := 0.014$

$n_{meadow} := 0.15$

Runoff Coefficients by Material

$C_{gravel} := 0.85$ $\quad C_{land} := 0.5$

Area by Material:

$A_{gravel} := 25000\ ft^2 = 0.574\ acre$

$A_{land} := A - A_{gravel} = 10.926\ acre$

Weight Run off Coefficient

$$C_{bar} := \frac{C_{pave} \cdot A_{pave} + C_{land} \cdot A_{land} + C_{gravel} \cdot A_{gravel}}{A} = 0.522$$

Rainfall Intensity (T=10 years & 24 hr duration):

$i := 0.18$ $\quad D := 4.46\ in$

Sheet Flow Calculation

$$S := \frac{978 - 971.73}{300} = 0.021$$

$$T_{osf} := \left(\frac{0.93 \cdot \left((300)^{0.6} \cdot n_{pave}^{\ 0.6} \right)}{i^{0.4} \cdot S^{0.3}} \right) min = 13.941\ min$$

Shallow Concentrated Calculation

$L := 268\ ft$ $\quad S := 0.074$ $\quad V := 1.25\ \frac{ft}{s}$

$$T_{scf} := \frac{L}{V \cdot 60} = 0.06\ min$$

Open Flow Calculation

Assuming Trapezoidal Shape

$L := 595.5\ ft \qquad S := 0.02 \qquad n_{meadow} := 0.15$

$$R := \frac{5\ ft \cdot D + 2 \cdot 15\ ft \cdot D}{5\ ft + 2 \cdot 15\ ft} = 0.372\ ft \qquad R := 0.372$$

$$V := \left(\left(\frac{1.486}{n_{meadow}} \right) \cdot R^{\frac{2}{3}} \cdot S^{0.5} \right) \frac{ft}{s} = 0.725\ \frac{ft}{s}$$

$$T_{ocf} := \frac{L}{V} = 13.696\ min$$

T critical Calculation

$T_c := T_{ocf} + T_{scf} + T_{osf} = 28\ min$ **USE 30 min**

$Q_0 := 22.37\ \frac{ft^3}{s} \qquad V_0 := 40265\ ft^3$

Design Summary:

Intial	$Q_0 = 22.37\ \frac{ft^3}{s}$	$V_0 = 40265\ ft^3$
Building & Parking Lot Changes	$Q_1 = 23.3\ \frac{ft^3}{s}$	$V_1 = 41813\ ft^3$
Building only (no parking lot changes)	$Q_2 = 22.37\ \frac{ft^3}{s}$	$V_2 = 40265\ ft^3$

Note: The building only option does not have a significant enough impact on the area to require a detention basin to be included; however, if the parking lot were to be expanded and paved then a detention basin will be required.

9.4. Structural Calculations

Load Analysis

Wind Loads ASCE 7-10 Chapters 26-27

Wind Load Parameters

$V := 115\ mph$

Table 1.5-1

Risk Category II

Figure 26.5-1A

$Kd := 0.85$

Table 26.6-1

Surface Roughness B

26.7.2

Exposure C

26.7.3

$Kzt := 1$

26.8.2

$G := 0.85$

26.9.1 - Assume Rigid

$Kz := 0.85$

Table 27.3-1

Table 27.2-1 Steps to Determine MWFRS Wind Loads for Enclosed, Partially Enclosed, and Open Buildings of All Heights

Step 1: Determine risk category of building or other structure, see Table 1.5-1

Step 2: Determine the basic wind speed, V, for the applicable risk category, see Figure 26.5-1A, B, or C

Step 3: Determine wind load parameters:
- Wind directionality factor, K_d, see Section 26.6 and Table 26.6-1
- Exposure category, see Section 26.7
- Topographic factor, K_{zt}, see Section 26.8 and Figure 26.8-1
- Gust-effect factor, G, see Section 26.9
- Enclosure classification, see Section 26.10
- Internal pressure coefficient, (GC_{pi}), see Section 26.11 and Table 26.11-1

Step 4: Determine velocity pressure exposure coefficient, K_z or K_h, see Table 27.3-1

Step 5: Determine velocity pressure q_z or q_h, see Eq. 27.3-1

Step 6: Determine external pressure coefficient, C_p or C_N:
- Fig. 27.4-1 for walls and flat, gable, hip, monoslope, or mansard roofs
- Fig. 27.4-2 for domed roofs
- Fig. 27.4-3 for arched roofs
- Fig. 27.4-4 for monoslope roof, open building
- Fig. 27.4-5 for pitched roof, open building
- Fig. 27.4-6 for troughed roof, open building
- Fig. 27.4-7 for along-ridge/valley wind load case for monoslope, pitched or troughed roof, open building

Step 7: Calculate wind pressure, p, on each building surface:
- Eq. 27.4-1 for rigid buildings
- Eq. 27.4-2 for flexible buildings
- Eq. 27.4-3 for open buildings

Partition Walls

Table 26.11-1 - Partially Enclosed

$GCpip := 0.55$

$GCpin := -0.55$

Determine Mean Roof Height:

$A1 := 19.5\ ft \cdot 40\ ft$ $\quad$ $A2 := 9.5\ ft \cdot 40\ ft$

$h1av := (8\ ft + 12\ ft + 4\ in) \cdot 0.5$ $\quad$ $h2av := (11\ ft + 12\ ft + 4\ in) \cdot 0.5$

$hr := (A1 \cdot h1av + A2 \cdot h2av) \div (A1 + A2) = 10.658\ ft$

5) Determine Velocity Pressure

$qz := 0.00256 \cdot Kz \cdot Kzt \cdot Kd \cdot 115^2 = 24.461$

$qz := qz \cdot psf = 24.461\ psf$

6) Determine External Pressure Coefficient

Note 1: Line B taken as windward wall.

Note 2:

First letter:	Second letter:	Third letter:
p = pressure	w = windward	w = wall
	l = leeward	r = roof
	s = side	

Figure 27.4-7-1 (cont.)

Wall Pressure Coefficients

Windward Wall

$Cpww := 0.8$

Leeward Wall L/B = 0.5

$Cplw := -0.5$

Side Wall

$Cpsw := -0.7$

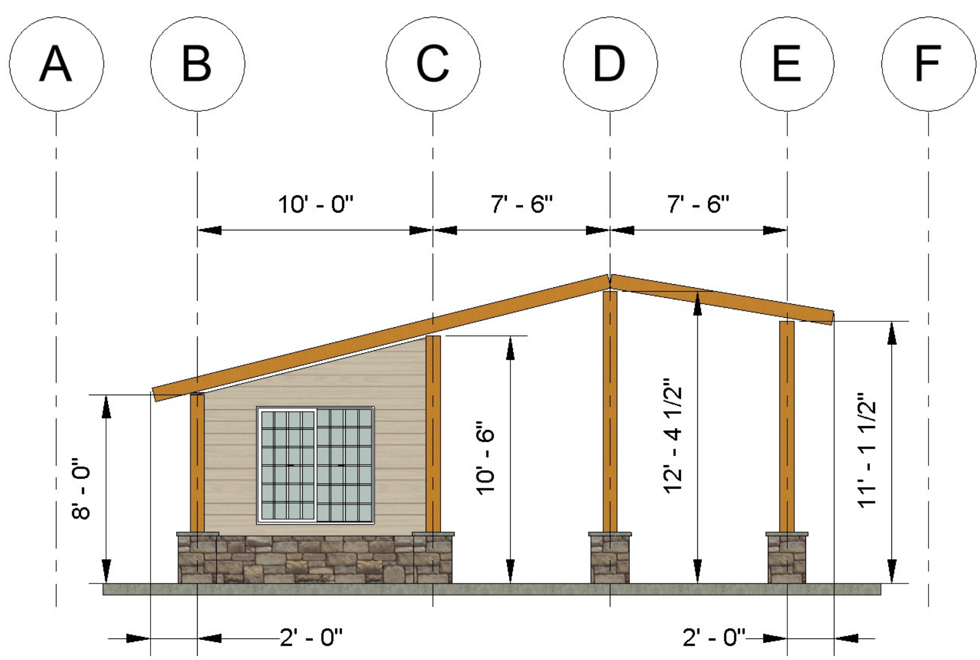
Roof Pressure Coefficients

Windward Roof h/L = 0.5

$Cpwr := -0.9$

Leeward Roof

$Cplr := -0.5$



27.4.1 Enclosed and Partially Enclosed Rigid Buildings. Design wind pressures for the MWFRS of buildings of all heights shall be determined by the following equation:

$$p = qGC_p - q_i(GC_{pi}) \text{ (lb/ft}^2\text{) (N/m}^2\text{)} \qquad (27.4\text{-}1)$$

Note 3:
Table 26.11-1 Note 3.
Case (i) postive GCpi applied to all internal surfaces
Case (ii) Negative GCpi applied to all internal surfaces

7) Determine net pressure:

Case (i)

Windward Wall

$pww := qz \cdot G \cdot Cpww - qz \cdot GCpip = 3.18\ psf$

Leeward Wall

$plw := qz \cdot G \cdot Cplw - qz \cdot GCpip = -23.849\ psf$

Side Wall

$psw := qz \cdot G \cdot Cpsw - qz \cdot GCpip = -28.008\ psf$

Windward Roof

$pwr := qz \cdot G \cdot Cpwr - qz \cdot GCpip = -32.166\ psf$

Leeward Roof

$plr := qz \cdot G \cdot Cplr - qz \cdot GCpip = -23.849\ psf$

Case (ii)

Windward Wall

$pww := qz \cdot G \cdot Cpww - qz \cdot GCpin = 30.087\ psf$

Leeward Wall

$plw := qz \cdot G \cdot Cplw - qz \cdot GCpin = 3.058\ psf$

Side Wall

$psw := qz \cdot G \cdot Cpsw - qz \cdot GCpin = -1.101\ psf$

Windward Roof

$pwr := qz \cdot G \cdot Cpwr - qz \cdot GCpin = -5.259\ psf$

Leeward Roof

$plr := qz \cdot G \cdot Cplr - qz \cdot GCpin = 3.058\ psf$

Critical net pressures:

$pww := 30.087\ psf$

$plw := -23.849\ psf$

$psw := -28\ psf$

$pwr := -32.166\ psf$

$plr := -23.849\ psf$

Snow Loads

Snow Load Factors

$Ce := 0.9$

Table 7-2, Terrain Category B

$Ct := 1.2$

Table 7-3

$Cs := 1$

Fig. 7-2c

$Is := 1$

Table 1.5-2

$pg := 25 \ psf$

Figure 7-1

Determine sloped roof snow loads:

$ps := 0.7 \cdot Ce \cdot Ct \cdot Is \cdot pg \cdot Cs = 18.9 \ psf$ $\quad psmin := 20 \ psf$ $\quad ps := psmin$

Partial Loading 7.5

Case 1

$psac := ps = 20 \ psf$ $\quad pscf := 0.5 \cdot ps = 10 \ psf$

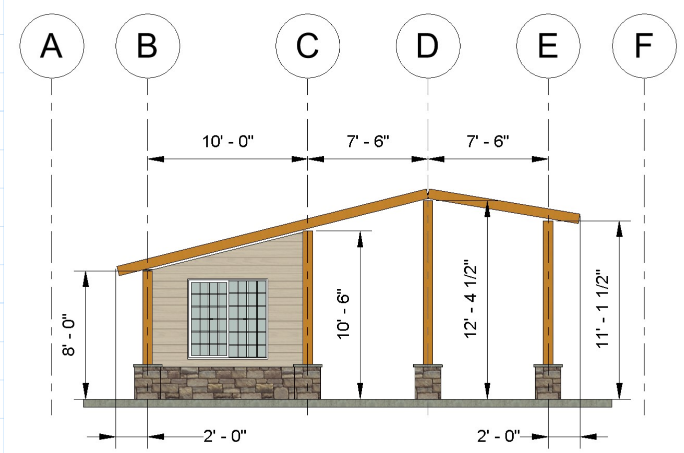
Case 2

$psac := 0.5 \cdot ps = 10 \ psf$ $\quad pscf := ps = 20 \ psf$

Case 3

$psad := ps = 20 \ psf$ $\quad psdf := 0.5 \cdot ps = 10 \ psf$

Note 4: Last two letters signify span of roof e.g. psdf means snow load on roof from line D to line F



Roof Live and Dead Load

Design Values for Wood Framing

NDS Table 4B No.1 Southern Pine

$\gamma w := 62.4\ pcf$ $\quad Gs := 0.55$ $\quad \gamma wood := Gs \cdot \gamma w = 34.32\ pcf$

NDS Table 1B

1x6

$W16 := 1.003\ \frac{lbf}{ft}$ $\quad t_{16} := 0.75\ in$ $\quad h_{16} := 5.5\ in$

2x6

$W26 := 2.005\ \frac{lbf}{ft}$ $\quad t_{26} := 1.5\ in$ $\quad h_{26} := 5.5\ in$

2x8

$W28 := 2.643\ \frac{lbf}{ft}$ $\quad t_{28} := 1.5\ in$ $\quad h_{28} := 7.25\ in$

6x6

$W66 := 7.352\ \frac{lbf}{ft}$ $\quad t_{66} := 5.5\ in$

8x8

$W88 := 13.67\ \frac{lbf}{ft}$ $\quad t_{44} := 3.5\ in$

Dead Load

$\sigma decking := \gamma wood \cdot t_{16} = 2.145\ psf$

$\sigma metalroof := 1\ psf$

$\sigma insulation := 3\ psf$ Extruded Polystyrene Insulation t = 2" R-10

Framing

2x8 @ 24" O.C.

$$\sigma frame := \frac{W28}{24\ in} = 1.322\ psf$$

$$D := \sigma decking + \sigma metalroof + \sigma insulation + \sigma frame = 7.467\ psf$$

Live Roof Load

$Lr := 20\ psf$

Table 4-1

Live Floor Load

$L := 100\ psf$

Table 4-1

$S := ps$

2.4 COMBINING NOMINAL LOADS USING ALLOWABLE STRESS DESIGN

2.4.1 Basic Combinations. Loads listed herein shall be considered to act in the following combinations; whichever produces the most unfavorable effect in the building, foundation, or structural member shall be considered. Effects of one or more loads not acting shall be considered.

1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W \text{ or } 0.7E)$

6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$

6b. $D + 0.75L + 0.75(0.7E) + 0.75S$

7. $0.6D + 0.6W$
8. $0.6D + 0.7E$

Summary

Note 5: This dead load only includes the wieght of the upper roof structure.

$D = 7.467\ psf$

$Lr = 20\ psf$

$L = 100\ psf$

$S = 20\ psf$

Wind

Note 6: See wind load reaction section below.

$pww = 30.087\ psf$

$plw = -23.849\ psf$

$psw = -28\ psf$

$pwr = -32.166\ psf$

$plr = -23.849\ psf$

Wind Load Reactions from Roof

Note 7: Wall B 1-3 taken as windward wall.
Note 8: Negative sign denotes away from roof.
Note 9: l denotes lateral force, v denotes vertical force

$\theta 1 := \operatorname{atan}\left(\frac{3}{12}\right)$ $\theta 2 := \operatorname{atan}\left(\frac{2}{12}\right)$

B1

$Ab1 := \left(\frac{7}{\cos(\theta 1)} \cdot 12\right) ft^2$

$Rb1 := Ab1 \cdot pwr = -2.785\ kip$
$Rb1l := Rb1 \cdot \sin(\theta 1) = -0.675\ kip$
$Rb1v := Rb1 \cdot \cos(\theta 1) = -2.702\ kip$

B2

$Ab2 := \left(\frac{7}{\cos(\theta 1)} \cdot 20\right) ft^2$

$Rb2 := Ab2 \cdot pwr = -4.642\ kip$
$Rb2l := Rb2 \cdot \sin(\theta 1) = -1.126\ kip$
$Rb2v := Rb2 \cdot \cos(\theta 1) = -4.503\ kip$

B3

$Ab3 := \left(\frac{7}{\cos(\theta 1)} \cdot 12\right) ft^2$

$Rb3 := Ab3 \cdot pwr = -2.785\ kip$
$Rb3l := Rb3 \cdot \sin(\theta 1) = -0.675\ kip$
$Rb3v := Rb3 \cdot \cos(\theta 1) = -2.702\ kip$

C1

$Ac1 := \left(\frac{10}{\cos(\theta 1)} \cdot 12\right) ft^2$

$Rc1 := Ac1 \cdot pwr = -3.979\ kip$
$Rc1l := Rc1 \cdot \sin(\theta 1) = -0.965\ kip$
$Rc1v := Rc1 \cdot \cos(\theta 1) = -3.86\ kip$

C2

$Ac2 := \left(\frac{10}{\cos(\theta 1)} \cdot 20\right) ft^2$

$Rc2 := Ac2 \cdot pwr = -6.631\ kip$
$Rc2l := Rc2 \cdot \sin(\theta 1) = -1.608\ kip$
$Rc2v := Rc2 \cdot \cos(\theta 1) = -6.433\ kip$

C3

$Ac3 := \left(\frac{10}{\cos(\theta 1)} \cdot 12\right) ft^2$

$Rc3 := Ac3 \cdot pwr = -3.979\ kip$
$Rc3l := Rc3 \cdot \sin(\theta 1) = -0.965\ kip$
$Rc3v := Rc3 \cdot \cos(\theta 1) = -3.86\ kip$

D1, D3

$Ad1 := \left(\left(\frac{7.5}{\cos(\theta 1)}\right) \cdot 12\right) ft^2$ $Ad2 := \left(\frac{7.5}{\cos(\theta 2)} \cdot 12\right) \cdot ft^2$

$Rd1 := Ad1 \cdot pwr = -2.984\ kip$ $Rd2 := Ad2 \cdot plr = -2.176\ kip$

$Rdl := Rd1 \cdot \sin(\theta 1) + Rd2 \cdot \sin(\theta 2) = -1.081\ kip$
$Rdv := Rd1 \cdot \cos(\theta 1) + Rd2 \cdot \cos(\theta 2) = -5.041\ kip$

E1, E3

$Ae1 := \left(\frac{9.5}{\cos(\theta 2)} \cdot 12\right) ft^2$

$Re1 := Ae1 \cdot plr = -2.756\ kip$

$Rel := Re1 \cdot \sin(\theta 2) = -0.453\ kip$

$Rev := Re1 \cdot \cos(\theta 2) = -2.719\ kip$

E2

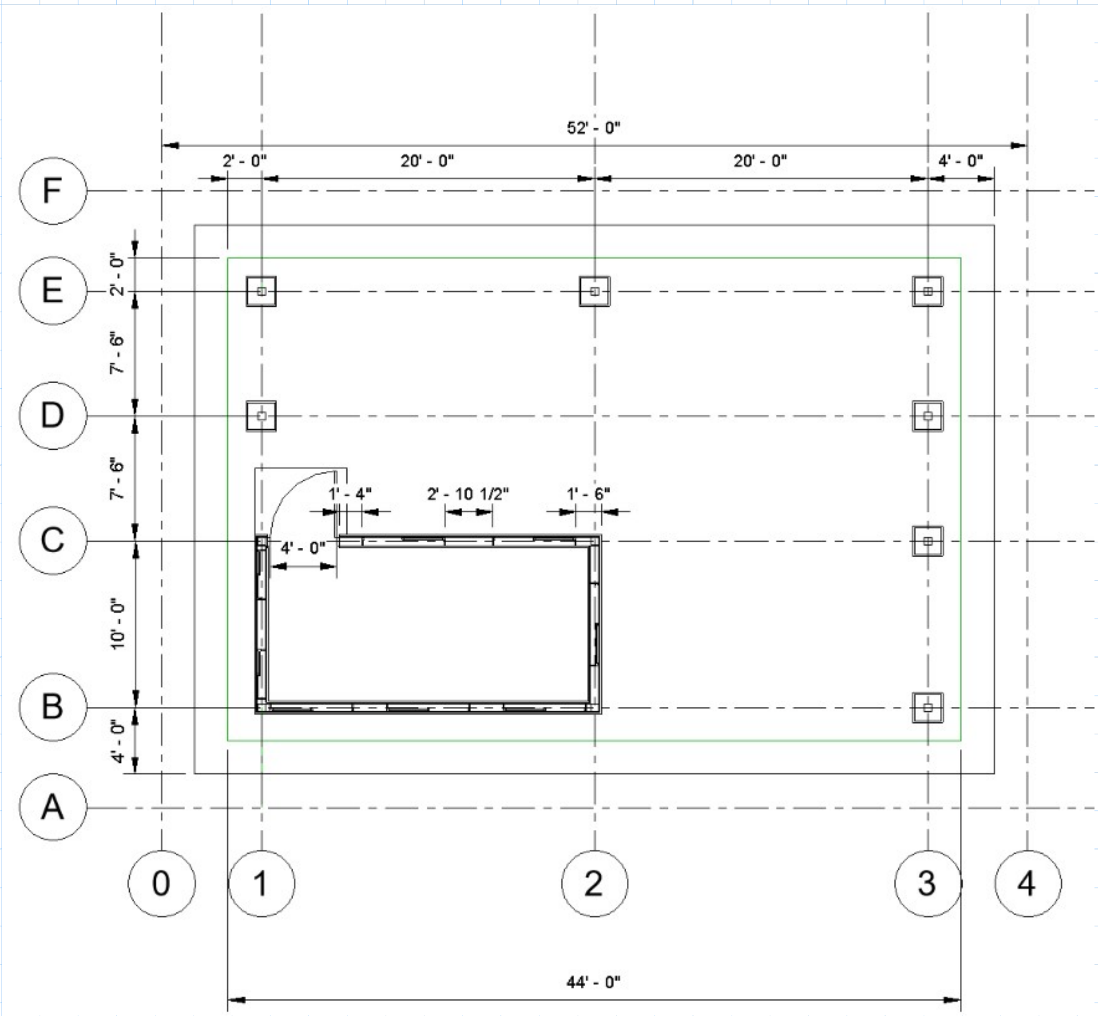
$Ae2 := \left(\frac{9.5}{\cos(\theta 2)} \cdot 20\right) ft^2$

$Re2 := Ae2 \cdot plr = -4.594\ kip$

$Re2l := Re2 \cdot \sin(\theta 2) = -0.755\ kip$

$Re2v := Re2 \cdot \cos(\theta 2) = -4.531\ kip$

Wall Dimensions



$hB := 8\ ft$ $hC := 10.5\ ft$ $L_{12} := 20\ ft$ $L_{BC} := 10\ ft$

2 x 8 Studs, 24 O.C.

Wind Load Reactions from Walls

Note 10: B 1-2 means wall spanning from line 1 to 2 along line B.
BC1 means wall spanning from B to C along line 1.

B 1-2

$pww = 30.087\ psf$

Tributary Height and Length:

$h := hB \cdot 0.5$ $\quad l := L_{12} = 20\ ft$

$w := pww \cdot h = 120.348\ plf$

$R := \frac{(w \cdot l)}{2} = 1.203\ kip$

$M := \frac{(w \cdot l^2)}{8} = 6.017\ ft \cdot kip$

Unit Shear:

$vb_{12} := \frac{R}{10\ ft} = 120.348\ plf$

$Rb_{12} := R = 1.203\ kip$

Direction: C to B
Columns: B1 B2
Anchors: Wall B 1-2

BC1 & BC2

$psw = -28\ psf$

Tributary Height and Length:

$h := \left(\frac{hB + hC}{2}\right) \cdot 0.5$ $\quad l := L_{BC} = 10\ ft$

$w := psw \cdot h = -129.5\ plf$

$R := \frac{(w \cdot l)}{2} = -0.648\ kip$

$M := \frac{(w \cdot l^2)}{8} = -1.619\ ft \cdot kip$

Unit Shear:

$vbc := \frac{R}{20\ ft} = -32.375\ plf$

$Rbc := R = -0.648\ kip$

Direction: Towards interior of enclosed structure
Columns: B1 C1 B2 C2
Anchors: Walls BC1 & BC2

C 1-2

$plw = -23.849\ psf$

Tributary Height and Length:

$h := hC \cdot 0.5$ $\quad l := L_{12} = 20\ ft$

$w := plw \cdot h = -125.207\ plf$

$R := \frac{(w \cdot l)}{2} = -1.252\ kip$

$M := \frac{(w \cdot l^2)}{8} = -6.26\ ft \cdot kip$

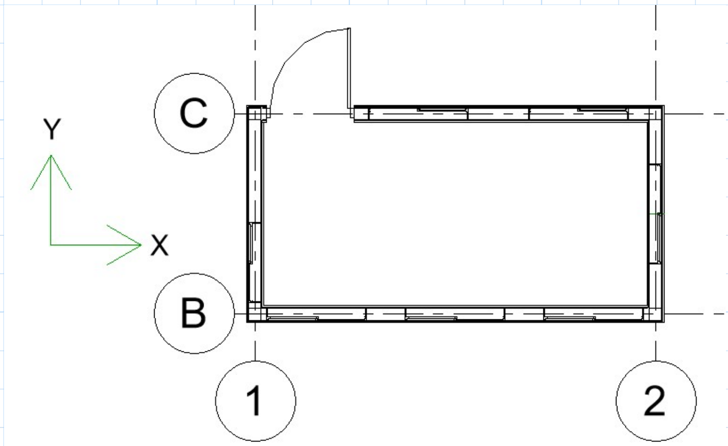
Unit Shear:

$vc_{12} := \frac{R}{10\ ft} = -64.75\ plf$

$Rc_{12} := R = -1.252\ kip$

Direction: C to B
Columns: C1 C2
Anchors: Wall C 1-2

Forces on Columns:



Forces act at top of column and follow sign convention of XY above

B1

$Ry_{B1} := -Rb_{12} = -1.203\ kip$

$Rx_{B1} := |Rbc| = 0.648\ kip$

B2

$Ry_{B2} := -Rb_{12} = -1.203\ kip$

$Rx_{B2} := |Rbc| = 0.648\ kip$

C1

$Ry_{C1} := -Rc_{12} = 1.252\ kip$

$Rx_{C1} := |Rbc| = 0.648\ kip$

C2

$Ry_{C2} := -Rc_{12} = 1.252\ kip$

$Rx_{C2} := |Rbc| = 0.648\ kip$

Unit Shears normal to outwards face of wall:

Wall BC

$vbc = -32.375\ plf$

Wall B 1-2

$vb_{12} = 120.348\ plf$

Wall C 1-2

$vc_{12} = -64.75\ plf$

Wall Dead Load ASCE 7-10 C3-1

$Dw := (2 + 3 \cdot 0.4 + 16)\ psf = 19.2\ psf$

Total Lateral forces (XY axis notation above) on Columns B/C 1-2

B1

$RlB1 := Ry_{B1} + Rb1l = -1.879\ \mathbf{kip}$

B2

$RlB2 := Ry_{B2} + Rb2l = -2.329\ \mathbf{kip}$

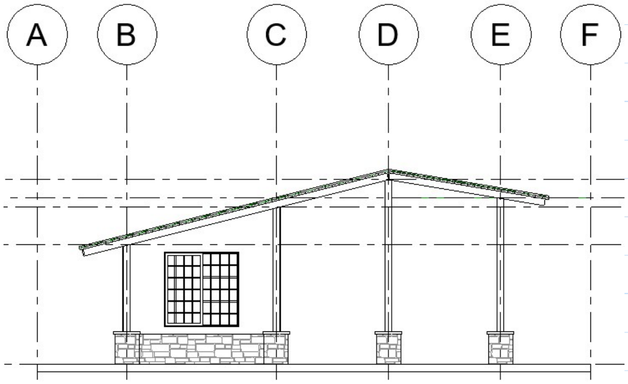
C1

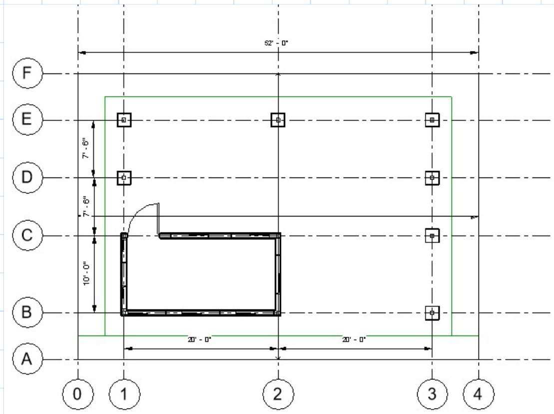
$RlC1 := Ry_{C1} + Rc1l = 0.287\ \mathbf{kip}$

C2

$RlC2 := Ry_{C2} + Rc2l = -0.356\ \mathbf{kip}$

Roof Member Analysis





2 ft. Over hang
BC horizontal distance = 10 ft.
DE horizontal distance = 7.5 ft.
CD horizontal distance = 7.5 ft.
Height of Column @ B = 8 ft.
Height of Column @ C = 10 ft. 6 in.
Height of Column @ D = 12 ft. 4.5 in.
Height of Column @ E = 11 ft. 1.5 in.

$\theta1 := \operatorname{atan}(3 \div 12) = 14.036\ deg$

$\theta2 := \operatorname{atan}(2 \div 12) = 9.462\ deg$

Spans

$bc := 10\ ft \cdot \cos(\theta1)^{-1} = 10.308\ ft$

$cd := 7.5\ ft \cdot \cos(\theta1)^{-1} = 7.731\ ft$

$de := 7.5\ ft \cdot \cos(\theta2)^{-1} = 7.603\ ft$

$bh := 2\ ft \cdot \cos(\theta1)^{-1} = 2.062\ ft$

$eh := 2\ ft \cdot \cos(\theta2)^{-1} = 2.028\ ft$

Treated Rosboro X-beam

$\gamma glu := 35\ pcf$

$Abr := 10.75\ in \cdot 21\ in$

Pressure Treated Southern Pine Columns

$Fb_c := 1350\ psi$ $\quad Ac := 7.25^2\ in^2$

$Ft_c := 900\ psi$

$Fv_c := 165\ psi$

$Fcp_c := 375\ psi$

$Fc_c := 825\ psi$

$E_c := 1500000\ psi$

$E_{cmin} := 500000\ psi$

$\gamma wood := 34.32\ pcf$

Live Load Element Factors IBC 1607.10.1

Column C2

$KllC2 := 4$

Columns B1, E1, B3, E3

$Kllcc := 2$

All Other Columns

$KllC := 3$

Interior Beams

$Kllb := 2$

Pressure Treated Southern Pine Rafters

$Fbs := 1500\ psi$

$Fts := 1000\ psi$

$Fvs := 175\ psi$

$Fcs := 1650\ psi$

$E := 1600\ ksi$

$Emin := 580\ ksi$

$I := \frac{1}{12} \cdot 1.5 \cdot 7.25^3\ in^4$

$Sx_r := 13.14\ in^3$

Axial Loading

ASD Load Case 3

$D := 7.467\ psf \qquad Lr := 20\ psf$

$width := 2\ ft$

Rafters Spanning B - C: $\quad Ar := 2 \cdot 8\ in^2 \qquad l := bc = 123.693\ in$

$w := width \cdot D + width \cdot Kllb \cdot Lr = 94.934\ plf \qquad wd := width \cdot D = 14.934\ plf$

$R := w \cdot \dfrac{l}{2} = 489.279\ lbf \qquad Mmax := \dfrac{w \cdot l^2}{8} = 1.261\ kip \cdot ft$

$f_b := \dfrac{Mmax}{Sx_r} = 1151.454\ psi \qquad f_{bmax} := f_b \qquad Vmax := R$

$\Delta maxst := 5 \cdot w \cdot \dfrac{l^4}{384 \cdot E \cdot I} = 0.316\ in \qquad \Delta maxlt := 5 \cdot wd \cdot \dfrac{l^4}{384 \cdot E \cdot I} = 0.05\ in$

$\Delta max := \Delta maxst + \Delta maxlt \cdot 2$

$\Delta max \le \dfrac{124\ in}{240} = 1$

Rafters Spanning C - D:

$w := width \cdot D + width \cdot Kllb \cdot Lr = 94.934\ plf \qquad l := cd$

$R := w \cdot \dfrac{l}{2} = 366.959\ lbf \qquad Mmax := \dfrac{w \cdot l^2}{8} = 0.709\ kip \cdot ft$

$f_b := \dfrac{Mmax}{Sx_r} = 647.693\ psi \qquad f_b < f_{bmax} = 1$

Rafters Spanning D - E:

$w := width \cdot D + width \cdot Kllb \cdot Lr = 94.934\ plf \qquad l := de$

$R := w \cdot \dfrac{l}{2} = 360.913\ lbf \qquad Mmax := \dfrac{w \cdot l^2}{8} = 0.686\ kip \cdot ft$

$f_b := \dfrac{Mmax}{Sx_r} = 626.526\ psi \qquad f_b < f_{bmax} = 1$

Rafter Overhang:

$w := width \cdot D + width \cdot Kllb \cdot Lr = 94.934\ plf \qquad l := bh$

$R := w \cdot l = 195.711\ lbf$

$Mmax := w \cdot \dfrac{l^2}{2} = 0.202\ kip \cdot ft$

$f_b := \dfrac{Mmax}{Sx_r} = 184.233\ psi \qquad f_b < f_{bmax} = 1$

Columns E1, E3:

$D = 7.467\ psf \qquad Dbeam := \gamma wood \cdot (8\ in \cdot 14\ in) \cdot (2\ ft + 10\ ft) = 0.32\ kip$

$Atl := (2\ ft + 10\ ft) \cdot (de \cdot 0.5 + eh) \cdot Kllcc = 139.904\ ft^2$

$Atd := (2\ ft + 10\ ft) \cdot (de \cdot 0.5 + eh) = 69.952\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 3.641\ kip$

Columns B1, B3:

$D = 7.467\ psf \qquad Dbeam := \gamma wood \cdot (8\ in \cdot 12\ in) \cdot (2\ ft + 10\ ft) = 0.275\ kip$

$Atl := (2\ ft + 10\ ft) \cdot (.5 \cdot bc + bh) \cdot Kllcc = 173.17\ ft^2$

$Atd := (2\ ft + 10\ ft) \cdot (.5 \cdot bc + bh) = 86.585\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 4.385\ kip$

Columns E2:

$D = 7.467\ psf \qquad Dbeam := \gamma wood \cdot (8\ in \cdot 14\ in) \cdot (20\ ft) = 0.534\ kip$

$Atl := (20\ ft) \cdot (de + eh) \cdot KllC = 577.862\ ft^2$

$Atd := (20\ ft) \cdot (de + eh) = 192.621\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 13.529\ kip$

Columns B2:

$D = 7.467\ psf \qquad Dbeam := \gamma wood \cdot (8\ in \cdot 12\ in) \cdot (20\ ft) = 0.458\ kip$

$Atl := (20\ ft) \cdot (bh + .5 \cdot bc) \cdot KllC = 432.926\ ft^2$

$Atd := (20\ ft) \cdot (bh + .5 \cdot bc) = 144.309\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 10.194\ kip$

Columns D1, D3: max unbraced height

$D = 7.467\ psf \qquad Dbeam := \gamma glu \cdot Abr \cdot 22\ ft = 1.207\ kip$

$Atl := (22\ ft) \cdot (cd \cdot 0.5 + de \cdot 0.5) \cdot KllC = 506.031\ ft^2$

$Atd := (22\ ft) \cdot (cd \cdot 0.5 + de \cdot 0.5) = 168.677\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 12.587\ kip$

$K_e := 1 \quad d_x := 7.25\ in \quad L := 12\ ft + 4.5\ in \qquad l_e := K_e \cdot L$

$s := \frac{l_e}{d_x} \qquad s \le 50 = 1$

Columns C1, C3:

$D = 7.467\ psf$ $\qquad Dbeam := \gamma wood \cdot (8\ in \cdot 14\ in) \cdot 12\ ft = 0.32\ kip$

$Atl := (12\ ft) \cdot (0.5 \cdot cd + 0.5 \cdot bc) \cdot KllC = 324.695\ ft^2$

$Atd := (12\ ft) \cdot (0.5 \cdot cd + 0.5 \cdot bc) = 108.232\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 7.622\ kip$

Columns C2:

$D = 7.467\ psf$ $\qquad Dbeam := \gamma wood \cdot (8\ in \cdot 14\ in) \cdot (20\ ft) = 0.534\ kip$

$Atl := (20\ ft) \cdot (cd + 0.5 \cdot bc) \cdot KllC2 = \left(1.031 \cdot 10^3\right)\ ft^2$

$Atd := (20\ ft) \cdot (cd + 0.5 \cdot bc) = 257.694\ ft^2$

$P := Atl \cdot Lr + Atd \cdot D + Dbeam = 23.074\ kip$

$$f_c := \frac{P}{7.25\ in \cdot 7.25\ in} = 438.974\ psi$$

Columns: Southern Pine, No. 1, Pressure treated

Check 8"x8", Column C2 = Controlling Load
Adjustment Factors:

$C_M := 1$ $C_T := .9$ $E_{cmin} = \left(5 \cdot 10^5\right)\ psi$ $E_c = \left(1.5 \cdot 10^6\right)\ psi$

$K_e := 1.0$ $L := 10.5\ ft$ $c := .8$

$C_F := 1.0$ $C_D := 1.0$ $F_c := 1300\ psi$ $C_i := 1.0$

Design Calculations: $Fc_c = 825\ psi$

$Area_C := 7.25\ in \cdot 7.25\ in = 52.563\ in^2$

$d_x := 7.25\ in$ $l_e := K_e \cdot L = 10.5\ ft$ $\frac{l_e}{d_x} = 17.379$

$E_{min'} := E_{cmin} \cdot C_M \cdot C_T \cdot C_i = 450000\ psi$

$$F_{ce} := \frac{.822 \cdot E_{min'}}{\left(\frac{l_e}{d_x}\right)^2} = 1224.67\ psi$$

$$F_{cStar} := Fc_c \cdot C_F \cdot C_D \cdot C_M \cdot C_T \cdot C_i$$

$$C_p := \frac{1 + \frac{F_{ce}}{F_{cStar}}}{2 \cdot c} - \sqrt[2]{\left(\frac{1 + \left(\frac{F_{ce}}{F_{cStar}}\right)}{2 \cdot c}\right)^2 - \frac{\frac{F_{ce}}{F_{cStar}}}{c}} = 0.831$$

$F_{c'} := F_{cStar} \cdot C_p = 617.127\ psi$

$F_{c'final} := F_{c'} = 617.127\ psi$

$$\Omega := \frac{f_c}{F_{c'final}} = 0.711$$

Rafters: Southern Pine, No. #1, Pressure treated

Check 2"x8", Rafter B-C = Controlling Load

Adjustment Factors:

$C_m := .85 \quad C_t := 1 \quad C_i := .80 \quad C_F := 1.3 \quad C_D := .9 \quad C_r := 1.15$

$E := 1600000\ psi \qquad E_{min} := 580000\ psi$

Design Calculations:

$$Area := 1.5\ in \cdot 5.5\ in = 8.25\ in^2$$

$$F_b := 1350\ psi$$

$$F_{b'} := F_b \cdot C_D \cdot C_m \cdot C_t \cdot C_F \cdot C_i \cdot C_r = 1235.169\ psi$$

$$F_v := 175\ psi$$

$$F_{v'} := F_v \cdot C_D \cdot C_m \cdot C_t \cdot C_i = 107.1\ psi$$

$$\Omega := \frac{f_{bmax}}{F_{b'}} = 0.932$$

$$\Omega := \frac{Vmax}{F_{v'} \cdot (Ar)} = 0.286$$

$$DCR := \frac{f_{bmax}}{F_{b'}} = 0.932$$

Vertical Loads on Columns for Uplift Check

$D := 7.467\ psf$ $ABb := 8\ in \cdot 12\ in$ $ABc := 8\ in \cdot 14\ in$

$\gamma wood := 34.32\ pcf$ $ABd := 8.75\ in \cdot 19\ in$ $ABe := 8\ in \cdot 14\ in$

$\gamma glu := 35\ pcf$

$\theta 1 := \operatorname{atan}\left(\frac{3}{12}\right) = 14.036\ deg$ $\theta 2 := \operatorname{atan}\left(\frac{2}{12}\right) = 9.462\ deg$

Spans

$bc := 10\ ft \cdot \cos(\theta 1)^{-1} = 10.308\ ft$

$cd := 7.5\ ft \cdot \cos(\theta 1)^{-1} = 7.731\ ft$

$de := 7.5\ ft \cdot \cos(\theta 2)^{-1} = 7.603\ ft$

$bh := 2\ ft \cdot \cos(\theta 1)^{-1} = 2.062\ ft$

$eh := 2\ ft \cdot \cos(\theta 2)^{-1} = 2.028\ ft$

Vertical loads from wind (see Loads file):

$BW1 := 2.7\ kip$ $DW1 := 5\ kip$

$BW2 := 4.5\ kip$ $DW3 := 5\ kip$

$BW3 := 2.7\ kip$ $EW1 := 2.72\ kip$

$CW1 := 3.86\ kip$ $EW2 := 4.53\ kip$

$CW2 := 6.433\ kip$ $EW3 := 2.72\ kip$

$CW3 := 3.86\ kip$

Columns E1, E3:

$D = 7.467\ psf$ $Dbeam := \gamma wood \cdot ABd \cdot (2\ ft + 10\ ft) = 0.475\ kip$

$Atd := (2\ ft + 10\ ft) \cdot (de \cdot 0.5 + eh) = 69.952\ ft^2$

$P := Atd \cdot D + Dbeam = 0.998\ kip$ $UE13 := EW1 - P = 1.722\ kip$

Columns B1, B3:

$D = 7.467\ psf$ $Dbeam := \gamma wood \cdot ABb \cdot (2\ ft + 10\ ft) = 0.275\ kip$

$Atd := (2\ ft + 10\ ft) \cdot (.5 \cdot bc + bh) = 86.585\ ft^2$

$P := Atd \cdot D + Dbeam = 0.921\ kip$ $UB13 := BW1 - P = 1.779\ kip$

Columns E2:

$D = 7.467\ psf$ $Dbeam := \gamma wood \cdot ABe \cdot (20\ ft) = 0.534\ kip$

$Atd := (20\ ft) \cdot (de + eh) = 192.621\ ft^2$

$P := Atd \cdot D + Dbeam = 1.972\ kip$ $UE2 := EW2 - P = 2.558\ kip$

Columns B2:

$D = 7.467\ psf$ $Dbeam := \gamma wood \cdot ABb \cdot (20\ ft) = 0.458\ kip$

$Atd := (20\ ft) \cdot (bh + .5 \cdot bc) = 144.309\ ft^2$

$P := Atd \cdot D + Dbeam = 1.535\ kip$ $UB2 := BW2 - P = 2.965\ kip$

Columns D1, D3:

$D = 7.467\ psf$ $Dbeam := \gamma glu \cdot ABd \cdot 22\ ft = 0.889\ kip$

$Atd := (22\ ft) \cdot (cd \cdot 0.5 + de \cdot 0.5) = 168.677\ ft^2$

$P := Atd \cdot D + Dbeam = 2.148\ kip$ $UD13 := DW1 - P = 2.852\ kip$

Columns C1, C3:

$D = 7.467\ psf$ $\qquad$ $Dbeam := \gamma wood \cdot ABc \cdot 12\ ft = 0.32\ kip$

$Atd := (12\ ft) \cdot (0.5 \cdot cd + 0.5 \cdot bc) = 108.232\ ft^2$

$P := Atd \cdot D + Dbeam = 1.128\ kip$ $\qquad$ $UC13 := CW1 - P = 2.732\ kip$

Columns C2:

$D = 7.467\ psf$ $\qquad$ $Dbeam := \gamma wood \cdot ABc \cdot (20\ ft) = 0.534\ kip$

$Atd := (20\ ft) \cdot (cd + 0.5 \cdot bc) = 257.694\ ft^2$

$P := Atd \cdot D + Dbeam = 2.458\ kip$ $\qquad$ $UC2 := CW2 - P = 3.975\ kip$

Summary

$UB13 = 1.779\ kip$

$UB2 = 2.965\ kip$

$UC13 = 2.732\ kip$

$UC2 = 3.975\ kip$

$UD13 = 2.852\ kip$

$UE13 = 1.722\ kip$

$UE2 = 2.558\ kip$

Foundation

Table 1806.2 IBC

$q_z := 1500\ psf$ Bearing Capacity (IBC)

$q_h := 100\ \frac{psf}{ft}$ Lateral Bearing Pressure (IBC)

$c := 130\ psf$ Cohesion (IBC)

$q_z := 1.33 \cdot q_z = 1995\ psf$ IBC 1806.1

$q_h := 1.33 \cdot q_h = 133\ \frac{psf}{ft}$ IBC 1806.1

When using alternative Load Comboination from 1605.3.2
D+L+0.6 ω W....Equation 16-18
where $\omega = 1.3$ because wind loads were calculated with ASCE Chapter 27

Table 5-2 NFBA

$E_s := 3920\ psi$
$\mu_s := 0.5$
$\gamma_{soil} := 125\ pcf$

$P_a := 30\ \frac{psf}{ft}$

$\gamma_b := 110\ pcf$

Web Soil Survey
Soil is CL

$t_{slab} := 10\ in$

$P_p := 60\ \frac{psf}{ft}$ Table 1610.1 IBC

$\phi' := 38°$ Backfill Infromation

Uplift Forces at Columns

$UB13 := 1.779\ kip$
$UB2 := 2.965\ kip$
$UC13 := 2.372\ kip$
$UC2 := 3.975\ kip$
$UD13 := 2.852\ kip$
$UE13 := 1.722\ kip$
$UE2 := 2.558\ kip$

$\gamma_c := 150\ pcf$ Normal Weight of Concrete

Roof Dead Load: $D_{roof} := 7.467\ psf$

Post Properties: $t_{post} := 7.25\ in$

Diagonal Length of Beam: $b := t_{post} \cdot \sqrt{2} = 10.253\ in$

$H1_{post} := 10.5\ ft$
$M_{g1} := 0.5 \cdot 2.08\ kip \cdot H1_{post} = 14.806\ kN \cdot m$

$H2_{post} := 12.375\ ft$
$M_{g2} := 0.5 \cdot 2.08\ kip \cdot H2_{post} = 17.449\ kN \cdot m$

Solve Block (Guess Values / Constraints / Solver):

$d1 := 1\ m$

$d1 = \sqrt{\frac{4.25 \cdot M_{g1}}{q_h \cdot d1 \cdot b}}$

$d1 := \text{find}(d1) = 7.419\ ft$

Solve Block (Guess Values / Constraints / Solver):

$d2 := 1\ m$

$d2 = \sqrt{\frac{4.25 \cdot M_{g2}}{q_h \cdot d2 \cdot b}}$

$d2 := \text{find}(d2) = 7.837\ ft$

Depths: $d1 := 7.5\ ft$ $d2 := 8\ ft$

Footing Type 1 Analysis: Building Footing (20' section)

Footing Type 1 Properties:

$B_1 := 3\ ft$ $\quad L_1 := 22\ ft$ $\quad t_f := 1\ ft$

$A_{f1} := B_1 \cdot L_1 = 66\ ft^2$

$I_1 := \frac{1}{12} L_1 \cdot B_1^{\ 3}$ $\quad W_{f1} := B_1 \cdot L_1 \cdot t_f \cdot \gamma_c$

Applied Loads:

$P := 23.067\ kip$ $\quad M_{g1} = 10.92\ kip \cdot ft$

Analyze Bearing Capactiy:

$$q := \frac{P}{A_{f1}} + \gamma_c \cdot t_f + d1 \cdot \gamma_b + \frac{\left(M_{g1} \cdot \left(\frac{B_1}{2}\right)\right)}{I_1} + t_{slab} \cdot \gamma_c = 1780.409\ psf$$

$FS_q := \frac{q_z}{q} = 1.121$ $\quad FS_q > 1$

Analyze Slide:

$V_w := 2.4\ kip$

$V_{slide} := V_w + \left(0.5 \cdot q_h \cdot H1_{post}^{\ 2} \cdot t_{post}\right) = 6.83\ kip$

$$V_n := \left(P + W_{f1}\right) \cdot \tan\left(\phi'\right) + 0.5 \cdot \left(0.5 \cdot \tan\left(45° + \frac{\phi'}{2}\right)^2 \cdot \gamma_{soil} \cdot B_1 \cdot d1^2\right) = 47.925\ kip$$

$FS_v := \frac{V_n}{V_{slide}} = 7.017$ $\quad FS_v > 1.5$

Analyze Uplift:

$W_{dead} := 7.467\ psf \cdot 144.309\ ft^2 = 1.078\ kip$

$W_{column} := 34.32\ pcf \cdot H1_{post} \cdot t_{post}^{\ 2} = 0.132\ kip$

$F_R := W_{f1} + W_{dead} + \left(\gamma_b \cdot H1_{post} \cdot A_{f1}\right) + W_{column} = 87.339\ kip$

$F_o := UB2 + UB13 = 4.744\ kip$

$FS_o := \frac{F_R}{F_o} = 18.41$

Footing 1: Analyze Settlement

$$q'_{net} := \frac{(P)}{A_{f1}} + t_f \cdot \gamma_c + \gamma_b \cdot d1 - \gamma_{soil} \cdot d1 = 387\ psf \qquad \alpha := 4$$

$$B' := 0.5 \cdot B_1 = 1.5\ ft \qquad H := 5 \cdot B_1 = 15\ ft$$

$$m := \frac{L_1}{B_1} = 7.333 \qquad n := \frac{H}{B'} = 10 \qquad \mu_s = 0.5$$

Solve Block — Guess Values / Constraints / Solver:

$$I_j := 0.092$$

$$\frac{8-7}{0.091-0.099} = \frac{8-m}{0.091-I_j}$$

$$\mathrm{I_j} := \mathrm{find}\left(I_j\right) = 0.096$$

$$I_i := 0.770$$

$$I_s := I_i + \left(\frac{1-2 \cdot \mu_s}{1-\mu_s}\right) \cdot \mathrm{I_j} = 0.77$$

$$\frac{d1}{B_1} = 2.5 \qquad \frac{B_1}{L_1} = 0.136$$

Solve Block — Guess Values / Constraints / Solver:

$$I_f := 0.77$$

$$\frac{0.6-0.2}{0.71-0.78} = \frac{0.292-0.2}{I_f-0.78}$$

$$\mathrm{I_f} := \mathrm{find}\left(\mathrm{I_f}\right) = 0.764$$

Use: $I_f := 0.85$

$$\delta_{E1} := q'_{net} \cdot \alpha \cdot B' \cdot \left(\frac{1-{\mu_s}^2}{E_s}\right) \cdot I_s \cdot I_f = 0.024\ in$$

Footing Type 2 Analysis: Building Footing (10' Section)

Footing Type 2 Properties:

$B_2 := 3.5\ ft$ $\quad L_2 := 14\ ft$ $\quad t_f := 1\ ft$

$A_{f2} := B_2 \cdot L_2$

$I_2 := \frac{1}{12} \cdot L_2 \cdot B_2^{\ 3}$ $\quad W_{f2} := B_2 \cdot L_2 \cdot t_f \cdot \gamma_c$

Applied Loads:

$P := 23.067\ kip$ $\quad M_{g2} = 12.87\ kip \cdot ft$

Analyze Bearing Capactiy:

$$q := \frac{P}{A_{f2}} + \gamma_c \cdot t_f + \frac{\left(M_{g1} \cdot \left(\frac{B_2}{2}\right)\right)}{I_2} + d1 \cdot \gamma_b + \gamma_c \cdot t_{slab} = 1952.796\ psf$$

$FS_q := \frac{q_z}{q} = 1.022$ $\quad FS_q > 1$

Analyze Slide:

$V_w := 1.608\ kip$

$$V_{slide} := V_w + \left(0.5 \cdot q_h \cdot H2_{post}^{\ 2} \cdot t_{post}\right) = 7.761\ kip$$

$$V_n := \left(P + W_{f2}\right) \cdot \tan\left(\phi'\right) + 0.5 \cdot \left(0.5 \cdot \tan\left(45° + \frac{\phi'}{2}\right)^2 \cdot \gamma_{soil} \cdot B_2 \cdot d1^2\right) = 49.627\ kip$$

$FS_v := \frac{V_n}{V_{slide}} = 6.395$ $\quad FS_v \geq 1.5$

Analyze Uplift:

$W_{dead} := 7.467\ psf \cdot 144.309\ ft^2 = 1.078\ kip$

$W_{column} := 34.32\ pcf \cdot H1_{post} \cdot t_{post}^{\ 2} = 0.132\ kip$

$F_R := W_{f2} + W_{dead} + \left(\gamma_b \cdot H1_{post} \cdot A_{f2}\right) + W_{column} = 65.154\ kip$

$F_o := UB2 + UC2 = 6.94\ kip$

$FS_o := \frac{F_R}{F_o} = 9.388$

Footing 2: Analyze Settlement

$$q'_{net} := \frac{(P)}{A_{f2}} + t_f \cdot \gamma_c + \gamma_b \cdot d1 - \gamma_{soil} \cdot d1 = 508.255\ psf \qquad \alpha := 4$$

$$B' := 0.5 \cdot B_2 = 1.75\ ft \qquad H := 5 \cdot B_2 = 17.5\ ft$$

$$m := \frac{L_2}{B_2} = 4 \qquad n := \frac{H}{B'} = 10 \qquad \mu_s = 0.5$$

$$I_i := 0.74 \qquad I_j := 0.059$$

$$I_s := I_i + \left(\frac{1 - 2 \cdot \mu_s}{1 - \mu_s}\right) \cdot I_j = 0.74$$

$$\frac{d2}{B_2} = 2.286 \qquad \frac{B_2}{L_2} = 0.25$$

Solver — Guess Values — Constraints

$$I_f := 0.77$$

$$\frac{0.5 - 0.2}{0.79 - 0.78} = \frac{0.5 - \frac{B_2}{L_2}}{0.79 - I_f}$$

$$\mathrm{I_f} := \mathrm{find}\left(\mathrm{I_f}\right) = 0.782$$

$$\delta_{E2} := q'_{net} \cdot \alpha \cdot B' \cdot \left(\frac{1 - {\mu_s}^2}{E_s}\right) \cdot I_s \cdot \mathrm{I_f} = 0.033\ in$$

Foundation Type 3: Spread Footings

Footing Type 2 Properties:

$B_3 := 5.5\ ft$ $L_3 := 5.5\ ft$ $t_f := 1\ ft$

$A_{f3} := B_3 \cdot L_3$

$W_{f3} := B_3 \cdot L_3 \cdot t_f \cdot \gamma_c$ $I_3 := \frac{1}{12} \cdot L_3 \cdot B_3^{\ 3}$

Applied Loads:

$P := 13.481\ kip$ $M_{g2} = 12.87\ kip \cdot ft$

Analyze Bearing Capactiy:

$$q := \frac{P}{A_{f3}} + \gamma_c \cdot t_f + \frac{\left(M_{g2} \cdot \left(\frac{B_3}{2}\right)\right)}{I_3} + d2 \cdot \gamma_b = 1939.785\ psf$$

$Fs_q := \frac{q_z}{q} = 1.028$ $FS_q > 1$

Analyze Slide:

$V_w := 0.755\ kip$

$$V_{slide} := V_w + \left(0.5 \cdot q_h \cdot H2_{post}^{\ 2} \cdot t_{post}\right) = 6.908\ kip$$

$$V_n := \left(P + W_{f3}\right) \cdot \tan\left(\phi'\right) + 0.5 \cdot \left(0.5 \cdot \tan\left(45° + \frac{\phi'}{2}\right)^2 \cdot \gamma_{soil} \cdot B_3 \cdot d2^2\right) = 60.319\ kip$$

$FS_v := \frac{V_n}{V_{slide}} = 8.732$ $FS_v \geq 1.5$

Analyze Uplift:

$W_{dead} := 7.467\ psf \cdot 192.621\ ft^2 = 1.438\ kip$

$W_{column} := 34.32\ pcf \cdot H2_{post} \cdot t_{post}^{\ 2} = 0.155\ kip$

$$F_R := W_{f3} + W_{dead} + \left(\gamma_b \cdot H2_{post} \cdot A_{f3}\right) + W_{column} = 47.309\ kip$$

$F_o := UE2 = 2.558\ kip$

$FS_o := \frac{F_R}{F_o} = 18.494$

Footing 3: Settlement Analysis

$$q'_{net} := \frac{(P)}{A_{f3}} + t_f \cdot \gamma_c + \gamma_b \cdot d2 - \gamma_{soil} \cdot d2 = 475.653 \ psf \qquad \alpha := 4$$

$$B' := 0.5 \cdot B_3 = 2.75 \ ft \qquad H := 5 \cdot B_3 = 27.5 \ ft$$

$$m := \frac{L_3}{B_3} = 1 \qquad n := \frac{H}{B'} = 10 \qquad \mu_s = 0.5$$

$$I_i := 0.498 \qquad I_j := 0.016$$

$$I_s := I_i + \left(\frac{1 - 2 \cdot \mu_s}{1 - \mu_s}\right) \cdot I_j = 0.498$$

$$\frac{d2}{B_3} = 1.455 \qquad \frac{B_3}{L_3} = 1$$

$$I_f := 0.72$$

$$\delta_{E3} := q'_{net} \cdot \alpha \cdot B' \cdot \left(\frac{1 - {\mu_s}^2}{E_s}\right) \cdot I_s \cdot I_f = 0.03 \ in$$

Foundation Type 4: Combination Footings (10' span)

Applied Loads:

$P_1 := 4.382\ kip$ $P_2 := 7.588\ kip$ $l_3 := 10\ ft$ $l_2 := 1\ ft$ $t_f := 1\ ft$

Solver: Guess Values / Constraints

$L := 12\ ft$

$$\frac{P_1 \cdot (L - (l_2)) + P_2 \cdot (L - (l_3 + l_2))}{P_1 + P_2} = 0.5 \cdot L$$

$\mathrm{L} := \mathrm{find}(\mathrm{L}) = 14.678\ ft$

$L_4 := 14.75\ ft$

$l_1 := L_4 - l_3 - l_2 = 3.75\ ft$

Solver: Guess Values / Constraints

$e_L := 0.05\ ft$

$$P_1 \cdot (L - l_2) + P_2 \cdot (L - l_3 - l_2) - (P_1 + P_2) \cdot \left(\frac{L}{2} - e_L\right) = 0$$

$\mathrm{e_L} := \mathrm{find}(e_L) = (1.379 \cdot 10^{-8})\ ft$

Footing Type 4 Properties:

$B_4 := 3\ ft$

$A_{f4} := B_4 \cdot L_4$

$W_{f4} := B_4 \cdot L_4 \cdot t_f \cdot \gamma_c$ $I_4 := \frac{1}{12} \cdot L_4 \cdot B_4^{\,3}$

Analyze Bearing Capactiy:

$$q := \frac{P_1 + P_2}{A_{f4}} + \gamma_c \cdot t_f + \frac{\left(M_{g1} \cdot \left(\frac{B_4}{2}\right)\right)}{I_4} + d1 \cdot \gamma_b = 1739.068\ psf$$

$Fs_q := \frac{q_z}{q} = 1.147$ $FS_q > 1$

Analyze Slide:

$V_w := 0.675\ kip + 0.965\ kip = 1.64\ kip$

$$V_{slide} := V_w + \left(0.5 \cdot q_h \cdot H1_{post}^{\,2} \cdot t_{post}\right) = 6.07\ kip$$

$$V_n := (P + W_{f4}) \cdot \tan(\phi') + 0.5 \cdot \left(0.5 \cdot \tan\left(45° + \frac{\phi'}{2}\right)^2 \cdot \gamma_{soil} \cdot B_4 \cdot d1^2\right) = 37.886\ kip$$

$FS_v := \frac{V_n}{V_{slide}} = 6.242$ $FS_v \ge 1.5$

Analyze Uplift:

$W_{dead} := 7.467\ psf \cdot 86.585\ ft^2 = 0.647\ kip$

$W_{column} := 34.32\ pcf \cdot H2_{post} \cdot t_{post}^{\ 2} = 0.155\ kip$

$F_R := W_{f4} + W_{dead} + \left(\gamma_b \cdot H1_{post} \cdot A_{f4}\right) + W_{column} = 58.548\ kip$

$F_o := UB13 + UC13 = 4.151\ kip$

$FS_o := \dfrac{F_R}{F_o} = 14.105$

Footing 4: Settlement Analysis

$q'_{net} := \dfrac{(P)}{A_{f4}} + t_f \cdot \gamma_c + \gamma_b \cdot d1 - \gamma_{soil} \cdot d1 = 342.155\ psf$ $\qquad \alpha := 4$

$B' := 0.5 \cdot B_4 = 1.5\ ft$ $\qquad H := 5 \cdot B_4 = 15\ ft$

$m := \dfrac{L_4}{B_4} = 4.917$ $\qquad n := \dfrac{H}{B'} = 10$ $\qquad \mu_s = 0.5$

Guess Values

$I_i := 0.736$

Constraints

$\dfrac{5-4}{0.758-0.740} = \dfrac{5-m}{0.78-I_i}$

Solver

$\mathrm{I_i} := \mathrm{find}\left(I_i\right) = 0.779$

Guess Values

$I_j := 0.044$

Constraints

$\dfrac{5-4}{0.758-0.740} = \dfrac{5-m}{0.758-I_j}$

Solver

$\mathrm{I_j} := \mathrm{find}\left(\mathrm{I_j}\right) = 0.757$

$$I_s := \mathrm{I_i} + \left(\frac{1-2 \cdot \mu_s}{1-\mu_s}\right) \cdot \mathrm{I_j} = 0.779$$

$\dfrac{d1}{B_3} = 1.364$ $\qquad \dfrac{B_3}{L_3} = 1$

$I_f := 0.72$

$$\delta_{E4} := q'_{net} \cdot \alpha \cdot B' \cdot \left(\frac{1-\mu_s^{\ 2}}{E_s}\right) \cdot I_s \cdot I_f = 0.018\ in$$

Foundation Type 5: Combination Footings (7.5' span)

Applied Loads:

$P_1 := 3.805\ kip \quad P_2 := 3.582\ kip$

Footing Length Dimensions:

$l_3 := 7.5\ ft \quad l_2 := 1\ ft \quad t_f := 1\ ft$

Solver Constraints Guess Values

$L := 10\ ft$

$$\frac{P_1 \cdot (L - (l_2)) + P_2 \cdot (L - (l_3 + l_2))}{P_1 + P_2} = 0.5 \cdot L$$

$L := \text{find}(L) = 9.274\ ft$

$L_5 := 9.333\ ft$

$l_1 := L_5 - l_3 - l_2 = 0.833\ ft$

Solver Constraints Guess Values

$e_L := 0.05\ ft$

$$P_1 \cdot (L - l_2) + P_2 \cdot (L - l_3 - l_2) - (P_1 + P_2) \cdot \left(\frac{L}{2} - e_L\right) = 0$$

$e_L := \text{find}(e_L) = (2.823 \cdot 10^{-9})\ ft$

$L' := L_5 - 2 \cdot e_L = 9.333\ ft$

$B_5 := 3.5\ ft$

$W_{f5} := B_5 \cdot L_5 \cdot t_f \cdot \gamma_c \qquad I_5 := \frac{1}{12} \cdot L' \cdot B_5^{\ 3} \qquad A_{f5} := B_5 \cdot L'$

Analyze Bearing Capactiy:

$$q := \frac{(P_1 + P_2)}{A_{f5}} + \gamma_c \cdot t_f + \frac{\left(M_{g1} \cdot \left(\frac{B_5}{2}\right)\right)}{I_5} + d2 \cdot \gamma_b = 1829.222\ psf$$

$Fs_q := \frac{q_z}{q} = 1.091 \qquad FS_q > 1$

Analyze Slide:

$V_w := 1.081\ kip + 0.453\ kip = 1.534\ kip$

$$V_{slide} := V_w + \left(0.5 \cdot q_h \cdot H1_{post}^{\ 2} \cdot t_{post}\right) = 5.964\ kip$$

$$V_n := (P_1 + P_2 + W_{f5}) \cdot \tan(\phi') + 0.5 \cdot \left(0.5 \cdot \tan\left(45° + \frac{\phi'}{2}\right)^2 \cdot \gamma_{soil} \cdot B_5 \cdot d2^2\right) = 39.026\ kip$$

$FS_v := \frac{V_n}{V_{slide}} = 6.544 \qquad FS_v \geq 1.5$

Analyze Uplift:

$$W_{dead} := 7.467\ psf \cdot 192.621\ ft^2 = 1.438\ kip$$

$$W_{column} := 34.32\ pcf \cdot H2_{post} \cdot t_{post}{}^2 = 0.155\ kip$$

$$F_R := W_{f5} + W_{dead} + \left(\gamma_b \cdot H2_{post} \cdot A_{f5}\right) + W_{column} = 50.959\ kip$$

$$F_o := UD13 + UE13 = 4.574\ kip$$

$$FS_o := \frac{F_R}{F_o} = 11.141$$

Footing 5: Settlement Analysis

$$q'_{net} := \frac{(P)}{A_{f5}} + t_f \cdot \gamma_c + \gamma_b \cdot d2 - \gamma_{soil} \cdot d2 = 442.698\ psf \qquad \alpha := 4$$

$$B' := 0.5 \cdot B_5 = 1.75\ ft \qquad H := 5 \cdot B_5 = 17.5\ ft$$

$$m := \frac{L_3}{B_3} = 1 \qquad n := \frac{H}{B'} = 10 \qquad \mu_s = 0.5$$

$$I_i := 0.498 \qquad I_j := 0.016$$

$$I_s := I_i + \left(\frac{1 - 2 \cdot \mu_s}{1 - \mu_s}\right) \cdot I_j = 0.498$$

$$\frac{d2}{B_5} = 2.286 \qquad \frac{B_5}{L_5} = 0.375$$

Solver Constraints Guess Values

$$I_f := 0.77$$

$$\frac{0.5 - 0.2}{0.85 - 0.79} = \frac{0.5 - \frac{B_5}{L_5}}{0.85 - I_f}$$

$$\mathrm{I_f} := \mathrm{find}\left(I_f\right) = 0.825$$

$$\delta_{E5} := q'_{net} \cdot \alpha \cdot B' \cdot \left(\frac{1 - \mu_s{}^2}{E_s}\right) \cdot I_s \cdot \mathrm{I_f} = 0.02\ in$$

Differential Settlement Check:

$\delta_{E1} - \delta_{E2} = -0.009\ in$ $\quad \delta_{E2} - \delta_{E4} = 0.014\ in$ $\quad \delta_{E4} - \delta_{E5} = -0.002\ in$

$\delta_{E5} - \delta_{E3} = -0.01\ in$ $\quad \delta_{E3} - \delta_{E5} = 0.01\ in$ $\quad \delta_{E5} - \delta_{E2} = -0.013\ in$

No differential Settlement exceeds 0.25 in

Dimension Summary:

ALL FOOTINGS ARE: $t_f = 1\ ft$

Continuous Footing for 20 ft span of building:

$B_1 = 3\ ft$

$L_1 = 22\ ft$

Continuous Footing for 10 ft span of building:

$B_2 = 3.5\ ft$

$L_2 = 14\ ft$

Spread Footing:

$B_3 = 5.5\ ft$

$L_3 = 5.5\ ft$

Combined Footings 10ft:

$B_4 = 3\ ft$

$L_4 = 14.75\ ft$

$l_3 := 10\ ft$ $\quad l_2 := 1\ ft$

$l_1 := L_4 - l_3 - l_2 = 3.75\ ft$

Combined Footings 7.5ft:

$B_5 = 3.5\ ft$

$l_3 := 7.5\ ft$ $\quad l_2 := 1\ ft$ $\quad t_f := 1\ ft$

$L_5 := 9.333\ ft$

$l_1 := L_5 - l_3 - l_2 = 0.833\ ft$

Floor Slab

$L1 := 20\ ft$ $L2 := 10\ ft$ $wc := 150\ pcf$ $Es := 29000\ ksi$ $f'c := 4000\ psi$ $\phi := 0.9$

$\frac{L1}{L2} = 2$ One-way action $Ec := 33 \cdot 150^{1.5} \cdot \sqrt{4000}\ psi$ $n := \frac{Es}{Ec} = 7.563$ $\beta := 0.85$

$tw := 10\ in$ tw = Stud Wall Thickness $fy := 60\ ksi$
$tf := 12\ in$ tf = thickness of foundation wall

Minimum slab height Table 7.3.1.1

$\frac{20}{28}\ ft = 8.571\ in$

All References are from ACI 318-14, unless noted otherwise

Minimum cover Table 20.6.1.3.1
$cc := 3\ in$

Guess hs, height of slab
$hs := 10\ in$

$ws := wc \cdot hs = 125\ psf$
$ll := 100\ psf$
$wu := 1.2 \cdot ws + 1.6 \cdot ll = 310\ psf$ $wu := wu \cdot 1\ ft = 310\ plf$

Effective Flange of L beam:
$bw := tf$

$beff := bw + min\left(\frac{20}{8}\ ft, 8 \cdot hs, 0.5 \cdot (L2)\right) = 3.5\ ft$

$ln := L2 - tw = 110\ in$ clear span

Moment at center:

$mupos := \frac{1}{14}\ wu \cdot ln^2 = 1.861\ kip \cdot ft$

Moment at face of support:

$muneg := \frac{-1}{24}\ wu \cdot ln^2 = -1.085\ kip \cdot ft$

Shear at face of support:

$Vs := 1.15 \cdot wu \cdot ln \cdot 0.5 = 1.634\ kip$

Shear at middle using live load on half of slab:

$Vmid := 100\ plf \cdot 1.6 \cdot \frac{ln}{8} = 0.183\ kip$ $x2 := \frac{ln}{2} = 4.583\ ft$

Assume #6 main bar, and #4 stirrups:

$d6 := 0.75\ in \qquad a6 := \pi \cdot 0.25 \cdot d6^2 = 0.442\ in^2$

$d4 := 0.5\ in \qquad a4 := \pi \cdot 0.25 \cdot d4^2 = 0.196\ in^2$

$cc = 3\ in$

$co := cc + d4 + 0.5 \cdot d6 = 3.875\ in$

$d := hs - co = 6.125\ in$

Find Critical Shear when x = d using linear interoplation:

$Vx := Vmid - (x2 - d) \cdot (Vmid - Vs) \cdot (x2)^{-1} = 1.472\ kip$

Try 1 #4 bars

Check Area Ratio:

$As := 1 \cdot a4 = 0.196\ in^2$

$\rho := \dfrac{As}{bw \cdot d} = 0.003$

$\rho min := \max\left(\dfrac{200\ psi}{fy}, 3 \cdot \dfrac{\sqrt{4000}}{60000}\right) = 0.003$

Check Flexural Capactiy:

$a := 1.282\ in$

$c := \dfrac{a}{\beta} = 1.508\ in$

$ecu := 0.003 \qquad eo := -ecu \cdot \dfrac{(hs - c)}{c} = -0.017$

$es := \dfrac{(hs - co)}{hs} \cdot eo + \dfrac{co}{hs} \cdot ecu = -0.009$

$$es := \begin{cases} \text{if } |es| > \dfrac{Es}{fy} & \dfrac{Es}{fy} \\ \text{else} & es \end{cases} = -0.009$$

$Fs := es \cdot Es \cdot As = -52.29\ kip$

$Fc := \beta \cdot f'c \cdot 1\ ft \cdot a = 52.306\ kip \qquad \dfrac{(Fs + Fc)}{Fc} = 3.002 \cdot 10^{-4}$

$$Mn := Fc \cdot \left(hs - \frac{a}{2}\right) + Fs \cdot co = 23.909\ kip \cdot ft$$

$\phi \cdot Mn = 21.518\ kip \cdot ft$

$mupos = 1.861\ kip \cdot ft$ Design is adequate

#4 bar spaced at 12'

Shear

$Vc := 2\ psi \cdot \sqrt{4000} \cdot 1\ ft \cdot d = 9.297\ kip$

$.5 \cdot \phi \cdot Vc = 4.184\ kip$

$Vx = 1.472\ kip$

No need for Shear Reinforcement

Deflection Check

$$Ig := \frac{1}{12}\, hs^3 \cdot 1\ ft$$

$$fr := 7.5\ psi \cdot \sqrt{4000} = 474.342\ psi$$

$$Mcr := fr \cdot \frac{Ig}{\left(\frac{hs}{2}\right)} = 7.906\ kip \cdot ft$$

$$c := 1\ in \qquad Atr := (1\ ft) \cdot c + n \cdot As$$

$$Atr \cdot c = 1\ ft \cdot \frac{c^2}{2} + n \cdot As \cdot d$$

$$\mathrm{c} := \mathrm{find}(c) = 1.124\ in$$

$$Icr := (1\ ft) \cdot \frac{\mathrm{c}^3}{12} + 1\ ft \cdot \mathrm{c} \cdot \left(\frac{\mathrm{c}}{2}\right)^2 + n \cdot As \cdot (d - \mathrm{c})^2 = 42.822\ in^4$$

$$Ie := Icr + \left(\frac{Mcr}{mupos}\right)^3 \cdot (Ig - Icr) = \left(7.347 \cdot 10^4\right)\ in^4$$

$$\Delta := wu \cdot \frac{ln^4}{Ec \cdot Ie} = 0.013\ in \qquad deflimit := \frac{20\ ft}{360} = 0.667\ in$$

Temperature and Shrinkage

$$s := min(5 \cdot hs, 18\ in) = 18\ in$$
$$\rho min := 0.002$$
$$Ast := \rho min \cdot hs \cdot 1\ ft = 0.24\ in^2$$

$$s := 12\ in \cdot \frac{a4}{Ast} = 9.817\ in$$

Space #4 bar 9 in. <= closest spacing of bar, controls design

Top Reinforcement

$$muneg = -1.085\ kip \cdot ft$$
$$mupos = 1.861\ kip \cdot ft$$
$$Mn = 23.909\ kip \cdot ft$$

#4 bar spaced at 9 in. will be sufficient

Development Lengths:

$$l := 60000 \cdot \frac{d4}{24 \cdot \sqrt{4000}} = 19.764\ in$$

90 deg hook

$$lhook := \max\left(6\ in, 8 \cdot d4, 60000 \cdot \frac{d4}{50 \cdot \sqrt{4000}}\right) = 9.487\ in$$

Asphalt Paving Association of Iowa

Table 5-4. Thickness Chart: Parking Lots with More Than 50 Spaces

A. For Asphalt Concrete Base Pavements					
Design Criteria*			**Thickness in Inches Hot Mix Asphalt**		
Traffic Class (Spaces)	**Subgrade Class**	**CBR**	**Base**	**Surface**	**Total**
II (50-500 spaces)	Good	9	3.0	1.0	4.0
	Moderate	6	3.5	1.5	5.0
	Poor	3	4.5	1.5	6.0

Our Subgrade is CL so well have to use Class: Poor

Base = 4.5 inches
Surface = 1.5 inches
Total = 6 inches

9.5. Design Renderings and Models


High Trestle Trail
Information Center