The University of Iowa | Office of Outreach and Engagement

FINAL DELIVERABLE

Title	Don Williams Recreation Area Forney's Point Overlook Pavilion
Completed By	Cristian Treto, John Hill, Tyler Conkling
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UI Department	Civil and Environmental Engineering
Course Name	CEE:4850:0001 Senior Design
Instructor	Paul Hanley
Community Partners	Boone County Conservation

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Open Shelter at "Forney's Point" at Don Williams Recreation Area

Submitted on: December 7, 2018

Submitted by: JTC Engineering

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Section I: Executive Summary

JTC Engineering is a design engineering project team whose team members include; Cristian Treto, John Hill, and Tyler Conkling. Together, this team designed the Open Shelter at Forney's Point, which will service the Don Williams Recreational Area. Cristian Treto served as the project manager, John Hill worked as the technical services member, and Tyler Conkling served as the project editor. This design project is part of the senior design course required for the civil engineering program at the University of Iowa.

The purpose of this project is to provide a design and layout for a new overlook pavilion that will be located at Forney's Point in the Don Williams Recreation Area. The proposed design will add a unique and exclusive area intended for social gatherings to an otherwise underutilized area in the park. In addition to the overlook pavilion, a new roadway and parking lot was designed in order to increase accessibility and functionality to the site. The purpose of these two design components is to increase the accessibility of Forney's Point as well as increase the project's functionality. Forney's Point will also feature a bathroom that will be exclusive to this area. The four main design components being the overlook pavilion, upgraded roadway, new parking area, and bathroom.

The overlook pavilion will be located on the far north point of Forney's Point. Given that Forney's Point is an elevated area, this presents a great opportunity for this overlook pavilion to capture a scenic view of Don Williams Lake. It is recommended that selective removal of the existing north tree line, be conducted to ensure that the new pavilion's view overlook stands unobstructed. The new overlook pavilion will be 1400 square feet which will accommodate approximately 40-50 people. Additionally, the client requested to incorporate the existing Osprey breeding nest in the pavilion design. After researching Osprey, it was determined that Osprey flourish in isolation and avoid contact with other animals. Attempting to encourage breeding, the existing osprey stand will be relocated away from Forney's point as guest traffic is expected to increase with installation of the proposed design. The Breeding nest will be relocated to the north side of the existing road in view of the proposed pavilion. Coinciding with the design criteria, the overlook pavilion would also serve as an Osprey viewing area due to the relocated nest. Some additional amenities for the shelter to further attract guests to the area would include a fire place and grilling area for the shelter. The shelter's size and amenities make this an ideal secluded location for private social gathering.

The overlook pavilion will also feature a walkway, which leads into a parking area exclusive to the area. This 3,280 square foot parking lot will be located on the south end of Forney's Point. The parking lot will feature 6 parking stalls with 1 being an accessible stall. In order to reduce cost while maintaining compliance with ADA the walkway would be constructed form PCC pavement and the proposed parking lot will be constructed with asphalt pavement. This sidewalk and parking lot will serve to increase the accessibility of Forney's Point.

Connected to the parking lot, will be a prefabricated self-composting single use restroom. A self-composting bathroom is ideal so that no additional utilities will be needed in order to supply a functional bathroom to Forney's point. This bathroom will be exclusive to Forney's Point so that visitors do not have to travel longer distances to use the bathroom. The Clivus Multrum M54 Trail Head Series single stall unit is recommended to accommodate the project site.

Another design component to achieve the objective of increasing accessibility is an upgrade to the existing roadway to a two lane asphalt paved driveway. In order to minimize tree removal, the proposed roadway will be located in the same position as the gravel road. By constructing the road out of asphalt both price and maintenance will be reduced compared to a concrete roadway. Since the park's main road is also asphalt, this road's required maintenance can be done along with the rest of park's existing roads. Since the roadway acts as both the inlet and outlet for Forney's Point, the new roadway must consist of two lanes to increase accessibility.

The additions of the roadway, parking lot, and overlook pavilion will affect the area's existing drainage conditions. To accommodate these new developments, a new drainage plan is constructed to manage storm water runoff. Two new sod lined open channels are proposed as drainage management measures. The first channel is located along the eastern side of the roadway. The second channel will be connected to the first open channel will run from the intersection of the existing road and the proposed road along the bottom of the hill to the east. These channels allow for storm water to run off of Forney's Point into one central drainage area. The second channel also acts as a bio infiltration swale that will remove pollutants in the water before ultimately reaching the central drainage area. It is recommended that 6 inch riprap be placed along the second channel as well as at the central drainage point. The riprap will act as a counter measure to any potential erosion that can occur from storm water runoff.

The main idea of this proposed project is to attract more guests to Forney's Point. With the construction of a new shelter area, visitors will be able to obtain a new unique perspective of Don Williams Lake while learning about the parks Osprey rehabilitation efforts. The view of the lake will be the focal point to make the area a more desired of the park. The shelter, along with the additional amenities will promote gatherings like family parties, reunions, company outings, large picnics, wedding receptions, and summer camps. The shelter will leave a lasting impact on the community of Ogden and increase local tourism to the Don Williams Recreation Area.

The proposed design consisting of 4 main design components along with the required site development is estimated to be a grand total $146,275. The 4 main design components consist of the new overlook pavilion, upgraded roadway, parking area, and bathroom. The proposed design for the overlook pavilion will cost $81,000. The upgrade asphalt roadway is estimated to be $21,000. The cost for the new parking lot is $16,000. The cost for a prefabricated bath is priced at $24,000. Finally, the cost for the required site development is estimated at $4,275.00. A table with the cost breakdown of the major design elements can be seen in Table 1 below.

Table 1: Total Estimated Project Cost

Total Estimated Project Cost	
Overlook Pavilion	$81,000
Roadway	$21,000.00
Parking Lot	$16,000.00
Restroom	$24,000.00
Site Work	$4,275.00
Total	**$146,275.00**

Section II: Organization Qualifications and Experience

JTC Engineering

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JTC Engineering is a student design team at the University of Iowa participating in a senior capstone design class. The design team consists of:

> **Cristian Treto**, project manager, civil practice focus, lead for environmental and schematic design work. Cristian also lead the production for report development.
>
> **Tyler Conkling**, structures focus, led for structural schematics and lead for architectural design. Tyler led the structural design for the pavilion structure.
>
> **John Hill**, transportation focus, lead for transportation and hydraulics related design. John led the schematic design of the road and parking lot.

Section III: Design Services

1. Project Scope: A unique and innovative open-air pavilion was designed on Forney's Point to provide the park with an area for social gatherings. The shelter provides an exclusive restroom facility, a clear view of the lake, inclusion of an osprey breeding nest, and the proper capacity to adequately accommodate forty to fifty guests. Additionally, full reconstruction of the existing entrance road and an additional parking area was added to make the overlook pavilion more accessible. As part of our design process, a new drainage plan was developed. This new drainage plan includes the design for two new open channels to properly manage storm water runoff. As part of the drainage plan, measures for erosion mitigation are implemented.

2. Work Plan:
   Implementation of design tasks throughout the contract period is represented by the Gantt chart found in Figure 7 in Appendix B. Each team member's initials are in parenthesis next to the task that they managed. Each member was tasked to oversee certain parts of the project based on their previous work experience and expertise. As the project manager, Cristian oversaw the completion of the tasks on time and to completion as well handling the majority of client relations. Tyler led the design of the pavilion. This role included the modeling and completion of structural calculations required to design the pavilion to safe standards. John led the design for both the roadway leading up to the site and the parking area located on the project site. Initial research for design regulations was conducted by the whole team. Cristian and John worked together to develop the drainage plan for the project. Cristian and Tyler collaborated in the design of the shelter and the structural modeling.

Section IV: Constraints, Challenges and Impacts

1. Constraints: When designing this project some constraints were taken into consideration. The first constraint was budgeting, the project was not given any specific information in regards to a proposed budget. In turn, our design accommodates for the most efficient concepts and materials. Next, the project location presented some constraints. Forney's Point is an elevated area with fairly steep drop offs on three of the four sides of the proposed site. Given this unique topography, the location of the design components was confined to realistic constructible locations. Another constraint was to accommodate the clients request for minimal tree removal. Forney's Point is currently completely surrounded by trees, the goal was to keep as much of the natural forestry as possible. This was accomplished by placing the proposed road in the same location as the existing road, and limiting the size and location of the other major design components to a space with no existing forestry.

2. Challenges: The proposed project consisted of two main challenges. First, being the incorporation of an Osprey breeding nest, and second the water flow mitigation needed as a result of the additional impervious surfaces included in the design. The Iowa DNR in assistance with Don Williams Recreation Area is in the process of rehabilitating the native Osprey back into Iowa as they have seen a drop in population over the past few years. Osprey are generally very protective solitary animals that avoid any contact with other animals. This presented the challenge to encourage the nesting of a typically

solitary animal in a location with an expected increase in guest activity. In order to accommodate for both the osprey and the park guest the osprey breeding nest was relocated to an area away from guest activity but still within the view of the guest utilizing the pavilion. In addition this gives the opportunity for Don Williams to educate their park guests on their rehabilitation efforts while allowing the guests to view the nest in person. Next, the additions of the shelter, parking lot area, and the roadway present more impervious surfaces to Forney's Point. The resulting increase in water flow during storm events increases likely hood of flooding and erosion. In order to mitigate drainage issues two grass lined open channels were designed along the roadway and in front of the hill to redirect water flow. Additionally, to mitigate the potential erosion the design recommends implementation of rip rap in the open channel at the intersection of the proposed road and the existing road as well as at the location of the central drainage point.

3. <u>Societal Impacts:</u> The implementation of the proposed design will ultimately have a positive impact on park guests, Boone County, and Don Williams Recreational Area. Don Williams Recreational Area is located in Ogden IA, and is owned by Boone County. It currently acts as a source of economic income for Boone County being a vacation destination for camping, boating, fishing, golfing, and much more. With the implementation of the proposed design Boone County will be able to advertise a new attraction for a unique private location to host social gatherings. These social gathering could include things such as family parties, reunions, company outings, wedding receptions, and summer camps. With these large functions occurring at Forney's point it will increase park traffic and ultimately increasing park attendance. This increase in overall park attendance and would increase revenue for Boone County and stimulate the local economy. Also the proposed site was designed to minimalize overall required maintenance, so little operation cost would be required. Additionally the park could assign a cost to reserve the proposed pavilion at Forney's point, in which would increase the opportunity for an increase in revenue. As for the regular users of the park they will be able to obtain a new unique perspective of Don Williams Lake when utilizing all the new features incorporated in the design. Lastly, with the implementation of the proposed design minimal environmental impacts will occur. This is because minimization of tree removal was prioritized during design as well as majority of water leaving the site during storm events will be filtrated. This infiltration takes place in the proposed bio-infiltration swale located next to the existing road and at the bottom of the hill.

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

When considering alternative designs, three design options for the overlook pavilion were presented to the client. The first example incorporated an open gable with a shed style roofing. Advantages to this style is it allows the sense of separation if more than one party was using the pavilion at a time. Additionally, it can be modified to allow for a communal center piece of a grill or fire pit in the center or along the back wall of shelter. This particular concept encompasses a scenic view, a principle that was incorporated into the selected design by locating the overlook pavilion at the northern tip of Forney's Point. The concept can be seen in figure 1.

Figure 1: 1st Shelter Design Concept

The second alternative is an open gable roofing style with the potential to provide shelter for a larger area to accommodate more guests than the other examples. Having a larger area to work with will allow for larger social gatherings. This concept's featured a more elongated shelter design. Also, this concept featured a unique brick fireplace. The idea of adding a fire place to the overall design of the pavilion was requested by the client. The second concept design can be seen in figure 2.

Figure 2: 2nd Shelter Design Concept

The third open shelter has a “T-shaped” layout with an open gable roofing style. This concept features veneer style footings, this is a particular design component that interested the client. The third shelter concepts also features wood columns as well incorporating one central back wall. This central back wall incorporates a stone fire place built into its design. Ultimately, this design concept was chosen per the client’s preference.

Figure 3: Third Shelter Design Concept

Other alternatives considered were the material used for the roadway and parking lot construction. The alternatives considered were concrete, asphalt or gravel. Ultimately, asphalt was selected for several reasons. Overall, asphalt presents a middle ground between the the three options in the way of cost. Asphalt is the less expensive alternative versus constructing a concrete road. While a gravel road would be the least expensive of all the options, Forney’s Point has an existing gravel road in place currently. Providing a gravel road is not a sufficient upgrade to the project accessibility. An asphalt road provides an upgrade to the site accessibility as well as providing a more aesthetic option than gravel for this unique design. The asphalt road is more durable than a gravel road, with a gravel road, the shear force from storm water can shift the gravel down the road over time. The asphalt is also easier to maintain and being that all of the other roads in the park are asphalt.

Section VI: Final Design Details

Overlook Pavilion

The overlook pavilion is the focal point of this overall design project. The overlook pavilion sits at of the hill at Forney’s Point, specifically the northern tip of the site. The structure can be seen on design sheets E.1-7 in Appendix A**.** The pavilion stands at 1400 sq. feet and features a 12 foot high roof. This is in part to capture the scenic view presented by the Don Williams Lake. The pavilion features one back wall but incorporates a more open design style. The pavilion can serve parties of up to 50 people, and will provide amenities like a grill and wood burning fireplace. The pavilion is constructed using select structural Douglas Fir Larch Wood. The pavilion was designed to meet all ADA and IBC criteria and was further designed using design specifications from the *American Wood Council*. Loading for the structure was determined using Allowable Strength Design and specific members were designed to meet ASD criteria. The design for all structural member sizes was engineered to carry the calculated ASD loading on column, girder, foundation footings, truss, and wall can be found in Appendix D**.** The team utilized the ASCE 7-16 design manual to determine minimum design loads for the structure. In design sheet E.4**,** you will also find cross section views for our prefabricated trusses as well as cross sectional views for structure. A rendering of the proposed overlook pavilion design can be seen below in Figure 4.

Figure 4: Overlook Pavilion

The pavilion will consist of a roof framed by wooden trusses that are supported by girder beams held by timber columns anchored into the ground by concrete footings. The roof is held up by a single a back wall and 10 columns designed as 8x8 pressure treated timber members and are enclosed at the base by a limestone veneer. Each column is continued into the foundation and is anchored into the spread footing using Simpson Strong-tie CB88 connectors. The roof is supported by 6x10 girder beams which are connected to the columns by CC68 column caps and mounted to CMU back wall using GFCMU hangers. Each truss is secured to the girder beams by HS26, which these straps are a great solution to prevent uplift on the pavilion. Roof trusses spaced at 24" o.c. and spanning 16 feet with a 2 foot overhang, are designed as 2x8 members. It is recommended that the Fink shaped trusses be sourced from a pre-fab supplier. The asphalt shingle finish is placed on ½" OSB plywood sheathing, designed for 24' span rating. A recommendation for a wood burning fireplace is provided in design sheet G.1. The pre-fabricated masonry fireplace shall be constructed at the center of the CMU back wall and cast into place. The back wall of the pavilion is finished with 2" thick limestone veneer on all sides but is structurally composed of 8" thick concrete masonry unit that extends down into to the continuous wall's foundation. The back wall's footing will be cast 7" off center for eccentric loading. Additionally, all foundation footings are recommended to be cast a foot below the frost line at a depth of 4.5 feet. All design sheets for the pavilion can be found in sheets E.1-7.

The pavilion has sidewalk entrance from the parking area leading to the east side of the pavilion. To design the appropriate sidewalks, our team followed the SUDAS section 12A-2 Accessible sidewalk requirements for our design criteria. Finally, the pavilion features a centerpiece fireplace located along the single back wall of the pavilion. The fire place is meant serve as an aesthetic component to the pavilion but also serve its functional purpose being able to provide heat to the pavilion area.

Bathroom

To provide amenities to Forney's Point, a recommendation for a pre-fabricated bathroom was given in the design. The design team has selected a Clicus Multrum M54 Trailhead prefabricated bathroom for the project site and can be seen our site plan located on design sheet B.1**.** The bathroom is located on the southernmost part of the project site, this is implemented purposefully to distance the bathroom ventilation away from the pavilion gathering area. A self-composting design was recommended for ease of maintenance and due to lack of utilities on the site. The prefabricated bathroom features a pine board/batten exterior, an asphalt shingled roof, and dry toilet. The recommended design is completely ADA accessible and placement at the south end of the parking lot will allow for a paved path up to the bathroom's entrance. The spec sheet for the prefabricated bathroom can be found in sheet F.1.

Parking Lot

To better accommodate the client's needs, a parking area was designed at the top of the site. This parking lot is designed for park users to have easy accessibility to the pavilion. The parking lot is located south of the pavilion and can be seen on design sheet B.1. To design the parking lot, the American Association of State Highway and Transportation Officials (AASHTO) was referenced in order to determine our design criteria. Specifically, Table 8C-1.02 from SUDAS was used to ensure the accommodation of the correct number of accessible spaces. The parking lot has 5 spots and 1 accessible spot. The total square footage of the parking lot 3,280 sq. feet. The parking lot is pitched with a 1.5% slope towards the opening between the parking rows on the east side of the parking lot. This slope this allows for water to be diverted off the parking lot and to the correct drainage area. Please view Appendix B Figure 8 to see the water droplet simulation of the proposed parking lot through AutoCAD Civil 3D. The parking lot is constructed of asphalt, the asphalt is designed to be six inches in depth and have twelve inches of prepared subgrade. This design criteria was determined using table 8B-1.03 from SUDAS, this table can also be seen in Table 3 of Appendix A**.** The specific elevations and dimensions of the parking lot along with a cross section can be seen on design sheet B.3.

Roadway

As part of our design scope, the design team has developed a full reconstruction design for the road leading up to Forney's Point. Due to the fact that this road acts as both the inlet and outlet to the project site, the proposed road consist of two ten foot wide lanes in order to increase accessibility. To see a cross sectional view of the proposed road one can view design sheet C.2. The new two-lane roadway stretches 232 feet from the existing main road all the way up to Forney's Point. One can view the plan profile design sheet for the new road on the design sheet C.1. The designed asphalt road allows for easy accessibility to Forney's Point and adds to the aesthetes of the project area. To design the road we followed the necessary steps located in the Iowa Statewide Urban Design and Specifications (SUDAS) Manuel. From SUDAS section 5D-1, designers determined the correct asphalt pavement mixture selection. The mixture design life is 20 years and the selected pavement thickness is based off a 50 year design life. The selected binder for the asphalt mix is PG Binder 58-28S. The tables used for mix size, binder content, and mix design criteria can be found in Table 4 in Appendix A**.** Using Table 5F-1.08 in SUDAS, design values were determined for the percentage of usage, base year AADT and EASLS, which were ultimately used in determining the correct pavement thickness. Due to the expected extremely low traffic volume the roadway was designed as a driveway and a pavement thickness of six inches was determined from table 8B-1.03 from SUDAS, this table can be seen in table 3 of Appendix A**.** Table 5C-1.02 was used to determine design speeds, level of service, and lane widths. This table can be seen in Appendix A Table 6. The selected roadway design speed is 15 mph, level of service is "D", and our lane widths are 10 feet wide. Reference values from Table 5C-2.09 located in Table 5 of Appendix A were used to design a curb return radii of 30 feet. The road way is crowned with a 2% in both directions to divert water off the road as part of the designed drainage plan. One can view design sheet C.2 for the cross section and volume reports for the proposed road.

Open Channels

Two grass lined open channels were designed and developed as a part of the drainage plan for Forney's Point. Theses open channels run along our designed roadway and allows for water to drain down the hill and move east along the base of the hill to the designated drainage area. The first channel starts at the top of the designed road and is located on the east side of the road way. The first channel feature a 5.28 foot width along the roadway. This designed channel has a 0.75 foot depth with 4:1 slope on the west side and 3:1 slope on the east side. The channel runs down the road at a length of 232 ft. The cross section of this channel can be seen in design sheet C.2 and the location of this channel can be seen in red in Figure 5. The channel then connects to a larger channel design along the bottom north side of the hill. The second channel features a 3 foot bottom width. It also has a 0.75 foot depth and has 3:1 slope on both sides. The front channel has a total length of 130 ft. This channels cross section can be found on design sheets D.2 and can be seen in Figure 5 in green. The first and second channel have max flow capacities of 2.8 CFS and 2.7 CFS respectively. The 2nd Channel also acts as a bio infiltration swale. With a combination of water flowing at rate less than 1 ft/s and the channel being sod lined, water flowing through the channel has pollutants removed before reaching the central drainage area.

A drainage report was conducted to determine the correct sizes required for our open channel. The drainage report required the calculation of the hydraulic runoff for Forney's Point both for the existing conditions and for the designed development. To conduct the drainage report, designers utilized the Hydra flow Express Extension from Autodesk Civil 3D. The rational method was used to determine peak flow and conduct the drainage report for the project.

To determine where water would flow, we used flow paths in Civil 3D along the project area. Flow paths can be seen in the drainage image seen in Figure 9 in Appendix B**.** To determine the peak flow for predevelopment, the project area was broken into three zones to determine three different peak flow values. For the post development, the whole project area was grouped into one large area, taking into account all of the impervious surfaces added to the project. This was possible because the southernmost peak flow was negligible because the new developments would not affect its existing drainage. The two northern zones were grouped together taking to account both impervious surfaces as well as existing conditions. The peak flow was then determined for the post developed project to be 2.57 CFS. Given that the max peak flow values are larger than the post development peak flow, the open channels are more than capable of properly draining storm water to the correct location. The calculations for the drainage can be seen in Appendix C**,** which includes three pre development peak flows, one post development peak flows, and the open channel calculations. The design for the open channel is based off a 10 year, 24 hour flood event and we used the Iowa D.O.T. Design Manuel chapter 4A-5 to select our design criteria.

When developing the drainage plan, erosion was considered. To determine where erosion can potential occur, a shear force analysis was conducted. In performing this shear force analysis, it is determined that erosion would occur at the curve of the 2nd channel and at the central drainage zone. As a counter measure to erosion, 6 inch riprap at 1 foot depth should be placed along the 2nd channel as well as covering the central drainage point. The shear force analysis calculations can be found in Appendix D.

Figure 5: Two sod lined open channels

Section VII: Engineer's Cost Estimate.

The grand total to the proposed design is $146,275. The total estimated costs for the main design components can be seen in Table 1. The rounded cost of the overlook pavilion includes the cost of the sidewalks as well. The cost of the open channel, sodding, and riprap are included in the site work. An exact breakdown for all the design components can be seen in Appendix E. These estimated costs include overhead and profit for the contractor. The cost, however, does not include any contingencies. These figures are the sum of the bare material cost plus 10% for profit, the bare labor cost plus total overhead and profit, and the bare equipment cost plus 10% profit.

Table 1: Total Estimated Project Cost

Total Estimated Project Cost	
Overlook Pavilion	$81,000
Roadway	$21,000.00
Parking Lot	$16,000.00
Restroom	$24,000.00
Site Work	$4,275.00
Total	**$146,275.00**

Appendix A: Reference Design Tables

Table 2: Minimum Accessible Parking Ratios

Table 8C-1.02: Minimum Accessible Parking Ratios

Total Number of Spaces Provided	Minimum Number of Accessible Spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1,000	2% of total
1,001 and over	20, plus 1 for each 100, or fraction thereof, over 1,000

Table 3: Pavement Thickness for Light Loads

Table 8B-1.03: Pavement Thickness for Light Loads
(Parking lots with 200 or less cars/day and/or 2 or less trucks/day or equivalent axle loads)

Subgrade CBR	Surface Material	On 12" of Prepared Subgrade		On 12" of Prepared Subgrade with 4" Granular Subbase	
		Minimum	*Desirable*	*Minimum*	*Desirable*
9	Rigid	5"	6"	4"	5"
	Flexible	5"	6"	4"	5"
6	Rigid	5"	6"	4"	5"
	Flexible	5"	6"	4"	5"
3	Rigid	5"	6"	4"	5"
	Flexible	6"	6"	5"	5"

Table 4: Mixture Selection Guide

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Table 5D-1.02: Mixture Selection Guide

Design $ESAL_{20}$ (Millions)	Layer Designation	Lift Thickness[3]			Mix Size[1]	Bid Item Designation	Binder Content[2]
		min	*rec*	*max*			
≤ 0.3	Surface	1.5	1.5	2.5	1/2"	Low Traffic (LT)	6.00
	Intermediate	1.5	1.5	3			
	Base	1.5	3	4.5			
0.3 to 1.0	Surface	1.5	1.5	2.5	1/2"	Standard Traffic (ST)	6.00
	Intermediate	1.5	1.5	3			
	Base	1.5	3	4.5			
1.0 to 10.0	Surface	1.5	2	2.5	1/2"	High Traffic (HT)	6.00
	Intermediate	2	2.5	3	3/4"		5.50
	Base	3	4	4.5	1"		5.25

[1] The Common mix size is shown. When other mix sizes are used, the minimum lift thickness also changes (see Section 5D-1, C, 6, b).
[2] These values are for estimating quantities only. The actual asphalt binder content is established in the approved job mix formula.
[3] Some lift thickness values in this guide may conflict with traffic control or allowable compaction criteria.

Table 5: Minimum Turn Radius

Table 5C-2.09: Curb Return Radii Based Upon Roadway Classification

Roadway Classification	Arterial	Collector	Local - Commercial/ Industrial	Local - Residential
Arterial	Special*	Special*	30'	30'
Collector	Special*	30'	30'	25'
Local - Commercial/Industrial	30'	30'	25'	25'
Local - Residential	30'	30'	25'	25'

*Special design required. Use turning templates.

Table 6: Roadway Elements

Table 5C-1.02: Acceptable Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	Res.	*C/I*	*Res.*	*C/I*	*Res.*	*C/I*
General						
Design Level-of-Service[1]	D	D	D/E	D/E	D/E	D/E
Lane width (single lane) (ft)[2]	10	11	11	11	11	11
Two-Way Left-Turn Lanes (TWLTL) (ft)	N/A	N/A	12	12	12	12
Width of new bridges, (ft)[3]	See Footnote 3					
Width of bridges to remain in place (ft)[4]	20	22	24	24	26	26
Vertical clearance (ft)[5]	14.5	14.5	14.5	14.5	14.5	14.5
Object setback (ft)[6]	1.5	1.5	1.5	1.5	1.5	1.5
Clear zone (ft)	Refer to Tables 5C-1.03, 5C-1.04, and 5C-1.05					
Urban						
Curb offset (ft)[7]	1.5[8]	1.5[8]	1.5[8]	1.5[8]	2	2
Parking lane width (ft)	7.5	7.5	7.5	9	10	10
Roadway width with parking[9, 11]	26/31[10]	31	31	34[11]	34	34
Roadway width without parking[11]	26[10]	26	26	26	26	26
Raised median with left-turn lane (ft)[12]	N/A	N/A	18	18	18.5	18.5
Cul-de-sac radius (ft)	45	45	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	2	2	2	2	8	8
ADT: 400 to 1,500	5	5	5	5	8	8
ADT: 1,500 to 2,000	6	6	6	6	8	8
ADT: over 2,000	8	8	8	8	8	8
Foreslope (H:V)[13]	3:1	3:1	3:1	3:1	4:1	4:1
Backslope (H:V)	3:1	3:1	3:1	3:1	3:1	3:1

Res. = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

Design Element	Design Speed, mph[14]															
	25		*30*		*35*		*40*		*45*		*50*		*55*		*60*	
Stopping sight distance (ft)	155		200		250		305		360		425		495		570	
Passing sight distance (ft)	900		1,090		1,280		1,470		1,625		1,835		1,985		2,135	
Min. horizontal curve radius (ft)[15]	198		333		510		762		1,039		833		1,060		1,330	
Min. vertical curve length (ft)	50		75		105		120		135		150		165		180	
Min. rate of vert. curve, Crest (K)[16]	12		19		29		44		61		84		114		151	
Min. rate of vert. curve, Sag (K)	26		37		49		64		79		96		115		136	
Min. rate of vert. curve, Sag (K) based on driver comfort/overhead lighting[17]	14		20		27		35		44		54		66		78	
Minimum gradient (percent)[18]	0.5		0.5		0.5		0.5		0.5		0.5		0.5		0.5	
Maximum gradient (percent)[19]	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I
Local	12	10	12	9	11	9	11	9	10	8	9	8	N/A	N/A	N/A	N/A
Collector	12	9	11	9	10	9	10	9	9	8	8	7	N/A	N/A	N/A	N/A
Arterial	N/A	N/A	9	9	8	8	8	8	N/A	7	N/A	7	N/A	6	N/A	6

R = Residential, C/I = Commercial/Industrial

Table 7: APA Performance Standards for Structural Sheathing

UNIFORM LOADS (PSF) ON APA RATED PLYWOOD SHEATHING.
MULTI-SPAN, NORMAL DURATION OF LOAD, DRY CONDITIONS, PANELS 24 INCHES OR WIDER

Span Rating[b]	Load Governed By[c]	Strength Axis[a]: Perpendicular to Supports, Span Center-to-Center of Supports (inches)										Parallel to Supports, Span Center-to-Center of Supports (inches)		
		12	16	19.2	24	30	32	36	40	48	60	12	16	24
24/0	L/360	287	108	59	29	14	11	10				16		
	L/240	431	162	89	43	21	17	15				23		
	L/180	574	216	118	57	28	23	20				31		
	Bending	208	117	81	52	33	29	19				45		
	Shear	295	214	175	138	109	102	86				524		
32/16	L/360	544	205	112	54	27	22	19	14			35	13	
	L/240	816	307	168	81	40	32	29	21			53	20	
	L/180	1,088	409	224	108	53	43	38	27			70	27	
	Bending	308	173	120	77	49	43	27	22			77	43	
	Shear	381	276	226	178	140	131	111	100			657	476	
40/20	L/360	1,088	409	224	108	53	43	38	27	18		78	29	10
	L/240	1,631	614	336	163	80	65	57	41	27		117	44	15
	L/180	2,175	818	448	217	106	87	76	55	36		157	59	20
	Bending	521	293	203	130	83	73	46	38	26		125	70	25
	Shear	467	338	277	218	172	161	136	122	106		819	593	367
48/24	L/360	1,914	720	394	191	94	76	67	48	31	15	283	106	36
	L/240	2,871	1,080	591	286	140	114	100	72	47	23	424	160	54
	L/180	3,828	1,440	788	382	187	152	134	96	63	31	566	213	72
	Bending	775	436	303	194	124	109	69	56	39	25	225	127	45
	Shear	571	414	339	267	211	197	167	150	129	102	1,381	1,000	619

(a) The strength axis is the long panel dimension unless otherwise identified.

(b) Nominal thickness may vary within Span Rating. For range of thicknesses, see Table 5 of APA's *Panel Design Specification*, Form D510.

(c) Tabulated values are based on the most conservative plywood construction, as shown in Table 6. Some capacities may be increased by application of formulas in *Panel Design Specification*, Form D510.

Appendix B: Reference Design Figures:

clivusmultrum incorporated

Model M54W
Specification Sheet

NSF Certification

The Clivus Model M54W is certified by the National Sanitation Foundation under Standard 41 (day-use, park).

Capacity

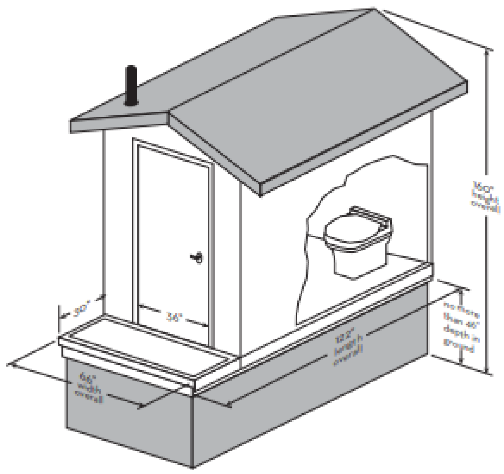
M54W Volume

Solids storage capacity: 81 cubic feet; 604 US gallons

Liquid storage capacity: 40 cubic feet; 300 US gallons

Daily capacity at average temp. >65°F: 60 visits

Annual capacity at average temp. >65°F: 22,000 visits



Specifications and Materials

Dimensions

Pre-fabricated Shipping Dimensions (2 pcs):

Base: Length: 118"; Width: 65"; Height: 48"

Building: Length: 122"; Width: 85.5"; Height: 114"

Kit Shipping Dimensions:

Length: 240" (20'); Width: 85.5"; Height: 72"

Pre-fabricated Shipping Weight:

Base: 1,000 lbs, Building: 1,400 lbs

Kit Shipping Weight: 2,400 lbs

Assembled Building Dimensions:

Outside Length: 122"; Width: 66"; Height: 114"

Building Enclosure (inside)

Inside Length: 82"; Inside Width: 61"

Composter Base

Length: 118"; Width: 65"; Height: 48"

Materials

Composter Base

Composter Base is rotationally molded high-density linear polyethylene resin that conforms with the following specifications:

- Density (ASTM TEST 4883): 0.942 g/cm3
- Tensile Strength at Yield (ASTM D638): 2,950 psi
- Dart Impact (-40°C, 250 mils thickness): 108 ft-lbs
- Envt. Stress Crack Resistance, 100% Igepal (D1693): 550 hrs

Building

Building walls are six structural insulated panels (SIP) with expanded polystyrene core with fiberglass reinforced plastic over OSB interior finish and OSB exterior surface finished with 1" rough-sawn pine board-and-batten (other exterior finishes optional). Door is 24 gauge cold rolled steel with zinc coating, factory painted medium gloss white, foamed-in-place polyurethane core; steel hinges; adjustable strike; frame milled from 5/4 kiln-dried pine; door opening: 36" x 80". Fixed window is 36" x 24" frosted lexan. Standard exterior is board and batten.

Roof is two structural insulated panels (SIP) of 4" virgin expanded polystyrene faced with white fiberglass reinforced panels inside and OSB plywood outside for application of asphalt shingles or other finish.

Floor is expanded polystyrene core with 7/16" plywood underside with painted .016 aluminum skin and 7/16" plywood top surface with .08" non-skid rubber coating surface.

Standard package ships pre-fabricated. Kit form is an option.

Ventilation

DC: 12V fan. Maximum free air is 100 cfm. Power input is 5 watts. CSA & UL approved. DC fan is powered by an optional photo-voltaic system customized for location and site requirements. Call for quotation. AC fan also available.

Toilet Options

Waterless Toilet

Constructed of impact resistant fiberglass with sanitary white finish. Seat and lid are made of plastic; the liner is rotationally molded polyethylene. The toilet must be located directly over the composter, which is situated in a space or room below. The toilet is connected with a 14" diameter straight chute.

Toilet Height: Standard: 14"; ADA Compliant: 18". Width: 18.5"; Length: 24.25".

Foam-flush Toilet

The Foam-flush toilet is constructed of vitreous ceramic. The seat and lid are made of plastic. The toilet connects to the composting unit with a 4" plastic pipe. The drain may slope up to 45 degrees from vertical. A water connection and a power connection (AC) are required.

Toilet height: Standard: 16"; ADA compliant: 17.5". Width: 15"; Length: 29".

ADA Compliant

The M54w Trailhead conforms to the requirements for universal access of the Americans with Disabilities Act .

Clivus Multrum, Inc., 15 Union Street, Lawrence, MA 01840 | 800.425.4887 | clivusmultrum.com   Rev. 8/12

Figure 6: Pre-fabricated Bathroom Spec sheet

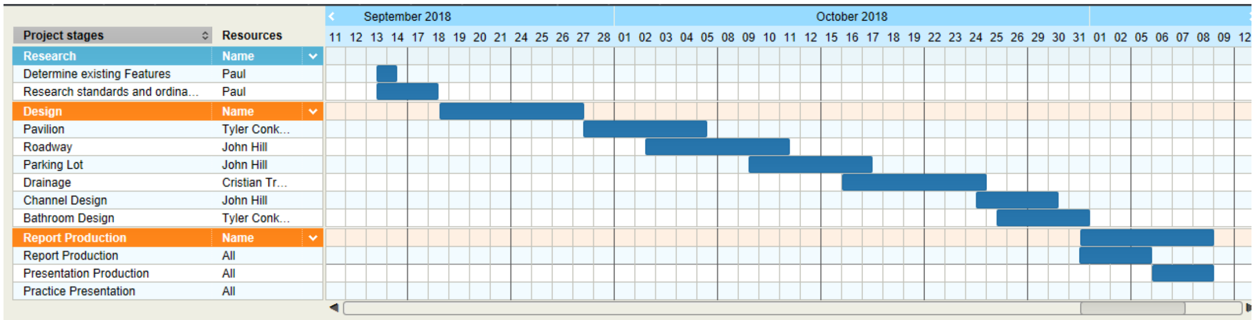


Figure 7: Gantt chart of Work Plan

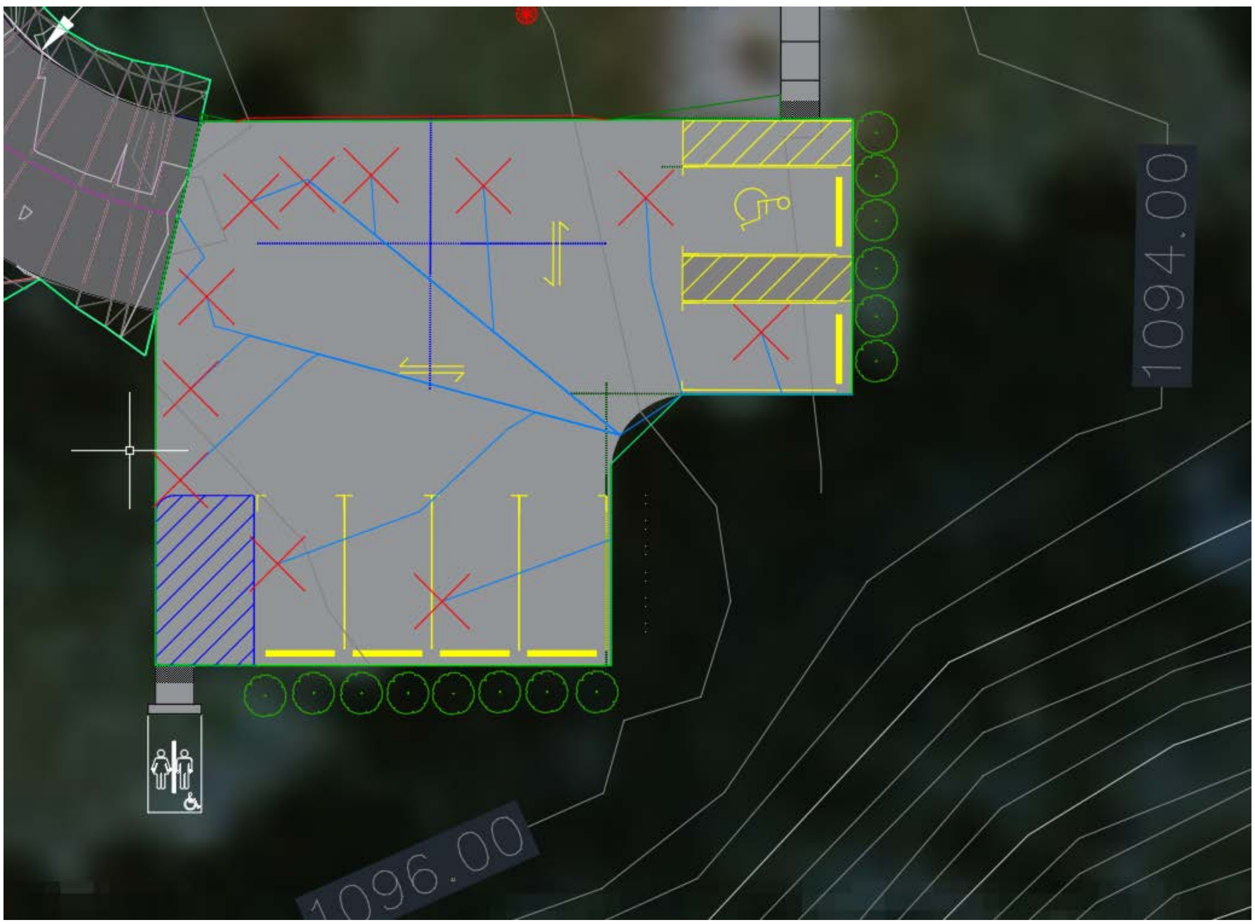


Figure 8: Water Droplet simulation of Parking Lot

Figure 9: Drainage pre development

Appendix C: Hydrology

Hydrology Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Nov 9 2018

<Name>

Hydrograph type	= Rational	Peak discharge (cfs)	= 0.955
Storm frequency (yrs)	= 10	Time interval (min)	= 1
Drainage area (ac)	= 0.440	Runoff coeff. (C)	= 0.3
Rainfall Inten (in/hr)	= 7.238	Tc by TR55 (min)	= 5
IDF Curve	= SampleExpress.IDF	Rec limb factor	= 1.00

Hydrograph Volume = 287 (cuft); 0.007 (acft)

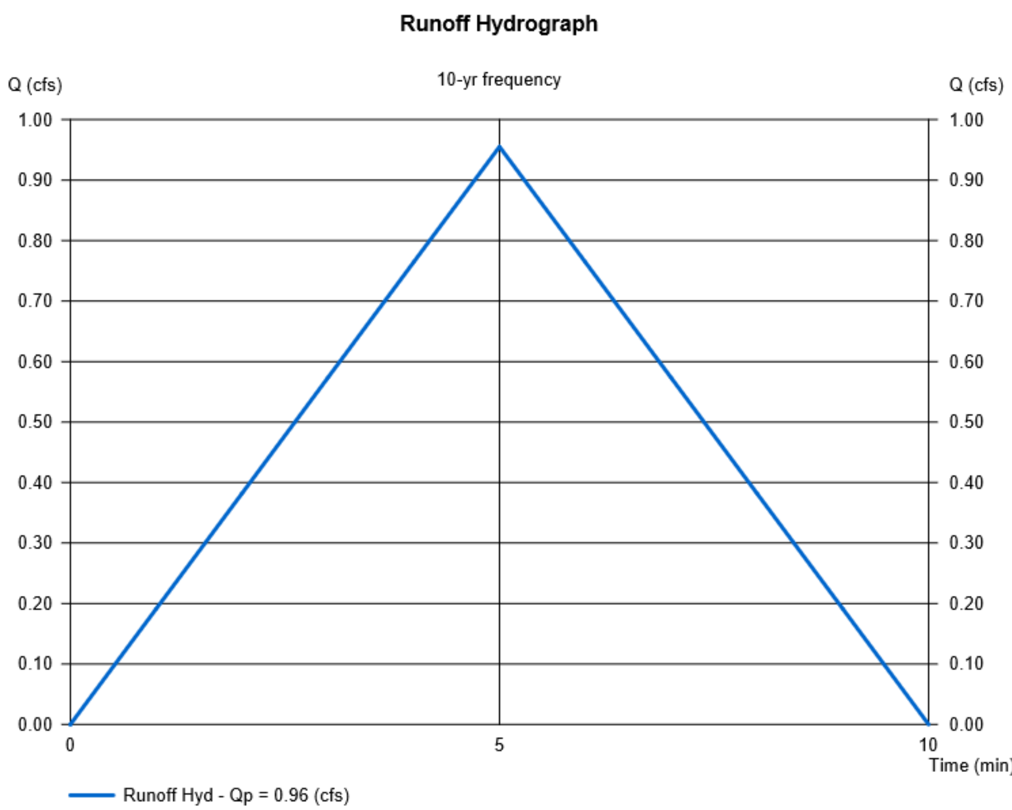


Figure 10: Quadrant 1, Pre-Development Hydrology Report

TR55 Tc Worksheet

Hydraflow Express by Intelisolve

Rational

<Name>

Description		A		B		C		Totals
Sheet Flow								
Manning's n-value	=	0.240		0.000		0.000		
Flow length (ft)	=	30.0		0.0		0.0		
Two-year 24-hr precip. ((in))	=	3.08		0.00		0.00		
Land slope (%)	=	4.00		0.00		0.00		
Travel Time (min)	**=**	**4.21**	**+**	**0.00**	**+**	**0.00**	**=**	**4.21**
Shallow Concentrated Flow								
Flow length (ft)	=	200.00		0.00		0.00		
Watercourse slope (%)	=	33.30		0.00		0.00		
Surface description	=	Unpaved		Paved		Paved		
Average velocity (ft/s)	=	9.31		0.00		0.00		
Travel Time (min)	**=**	**0.36**	**+**	**0.00**	**+**	**0.00**	**=**	**0.36**
Channel Flow								
X sectional flow area ((sqft))	=	0.00		0.00		0.00		
Wetted perimeter ((ft))	=	0.00		0.00		0.00		
Channel slope (%)	=	0.00		0.00		0.00		
Manning's n-value	=	0.000		0.000		0.000		
Velocity (ft/s)	=	0.00		0.00		0.00		
Flow length (ft)	=	0.0		0.0		0.0		
Travel Time (min)	**=**	**0**	**+**	**0**	**+**	**0**	**=**	**0.00**
Total Travel Time, Tc								**5.00 min**

Figure 11: Zone 1 Predevelopment Hydrology Report

Hydrology Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Nov 9 2018

<Name>

Hydrograph type	= Rational	Peak discharge (cfs)	= 1.262
Storm frequency (yrs)	= 10	Time interval (min)	= 1
Drainage area (ac)	= 0.510	Runoff coeff. (C)	= 0.3
Rainfall Inten (in/hr)	= 8.251	Tc by TR55 (min)	= 2
IDF Curve	= SampleExpress.IDF	Rec limb factor	= 1.00

Hydrograph Volume = 151 (cuft); 0.003 (acft)

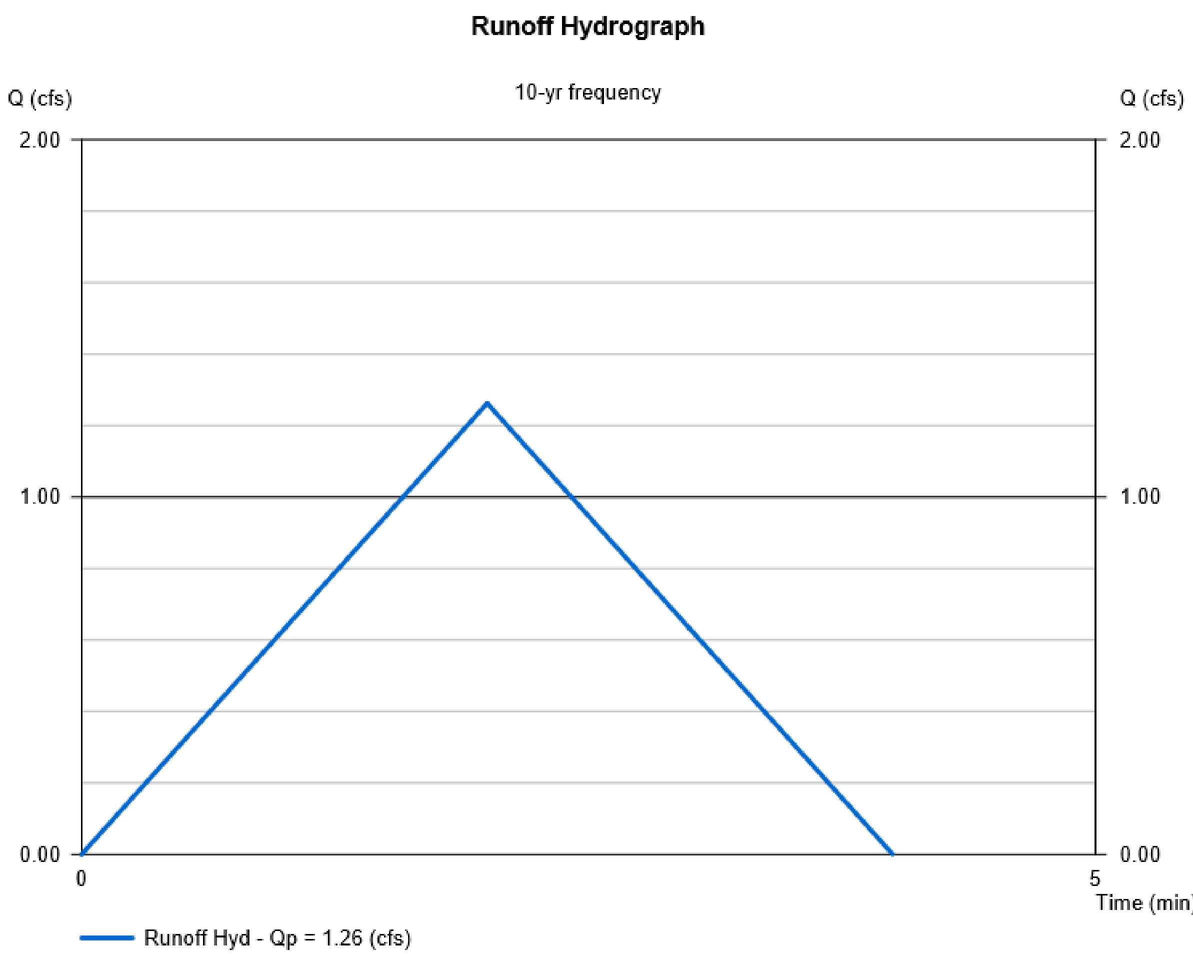


Figure 12: Zone 2, Pre-Development Hydrology Report

TR55 Tc Worksheet

Hydraflow Express by Intelisolve

Rational

<Name>

Description		A		B		C		Totals
Sheet Flow								
Manning's n-value	=	0.240		0.011		0.011		
Flow length (ft)	=	12.0		0.0		0.0		
Two-year 24-hr precip. ((in))	=	3.08		0.00		0.00		
Land slope (%)	=	4.00		0.00		0.00		
Travel Time (min)	**=**	**2.02**	**+**	**0.00**	**+**	**0.00**	**=**	**2.02**
Shallow Concentrated Flow								
Flow length (ft)	=	212.32		0.00		0.00		
Watercourse slope (%)	=	33.30		0.00		0.00		
Surface description	=	Unpaved		Paved		Paved		
Average velocity (ft/s)	=	9.31		0.00		0.00		
Travel Time (min)	**=**	**0.38**	**+**	**0.00**	**+**	**0.00**	**=**	**0.38**
Channel Flow								
X sectional flow area ((sqft))	=	0.00		0.00		0.00		
Wetted perimeter ((ft))	=	0.00		0.00		0.00		
Channel slope (%)	=	0.00		0.00		0.00		
Manning's n-value	=	0.015		0.015		0.015		
Velocity (ft/s)	=	0.00		0.00		0.00		
Flow length (ft)	=	0.0		0.0		0.0		
Travel Time (min)	**=**	**0**	**+**	**0**	**+**	**0**	**=**	**0.00**
Total Travel Time, Tc								**2.00 min**

Figure 13: Zone 2Predevelopment Drainage Report

Hydrology Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Nov 9 2018

<Name>

Hydrograph type	= Rational	Peak discharge (cfs)	= 1.303
Storm frequency (yrs)	= 10	Time interval (min)	= 1
Drainage area (ac)	= 0.600	Runoff coeff. (C)	= 0.3
Rainfall Inten (in/hr)	= 7.238	Tc by TR55 (min)	= 5
IDF Curve	= SampleExpress.IDF	Rec limb factor	= 1.00

Hydrograph Volume = 391 (cuft); 0.009 (acft)

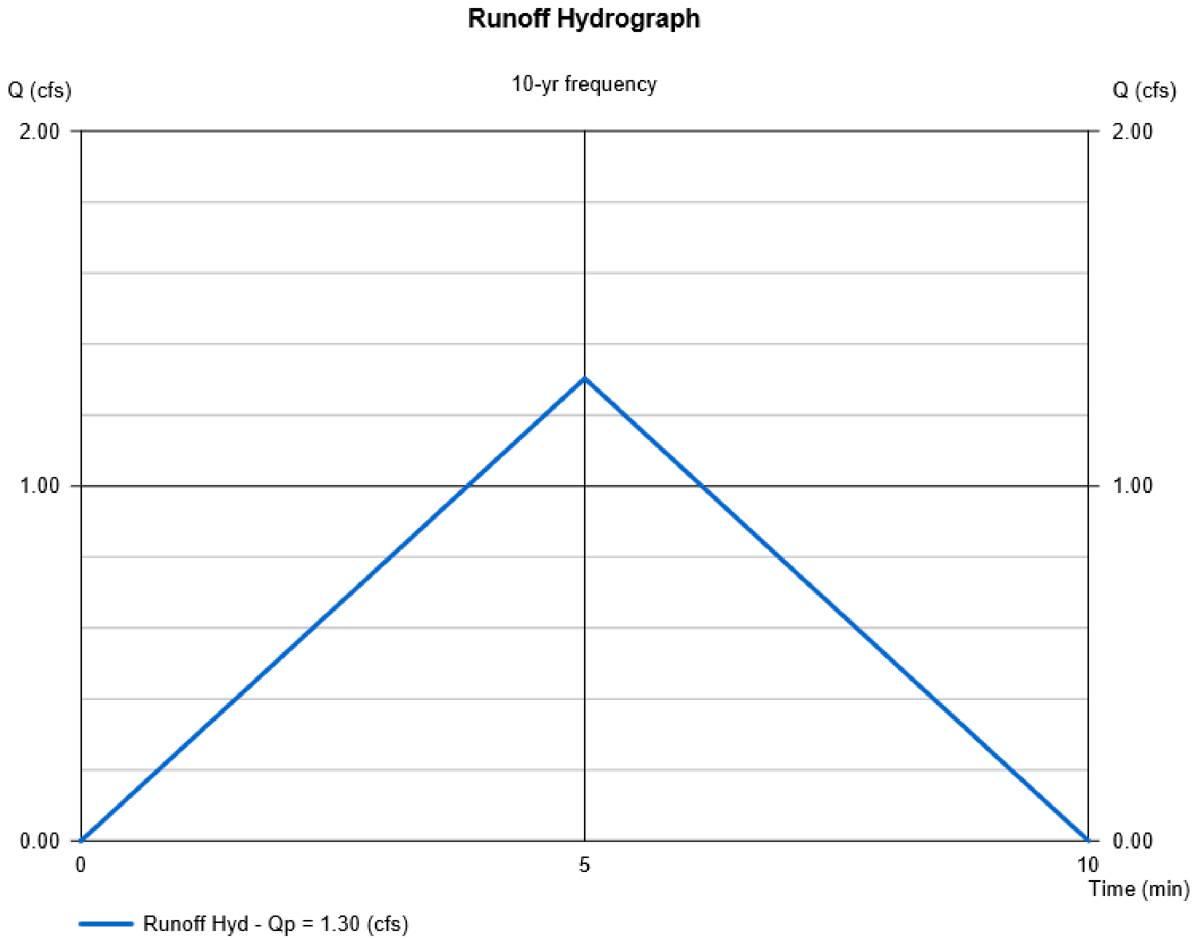


Figure 14: Zone 3, Pre- Development Hydrology Report

Table 7: Zone 3, Pre- Development TR55 Tc Worksheet

TR55 Tc Worksheet

Hydraflow Express by Intelisolve

Rational

<Name>

Description		A		B		C		Totals
Sheet Flow								
Manning's n-value	=	0.240		0.011		0.011		
Flow length (ft)	=	30.0		0.0		0.0		
Two-year 24-hr precip. ((in))	=	3.08		0.00		0.00		
Land slope (%)	=	4.00		0.00		0.00		
Travel Time (min)	**=**	**4.21**	**+**	**0.00**	**+**	**0.00**	**=**	**4.21**
Shallow Concentrated Flow								
Flow length (ft)	=	300.00		0.00		0.00		
Watercourse slope (%)	=	33.30		0.00		0.00		
Surface description	=	Unpaved		Paved		Paved		
Average velocity (ft/s)	=	9.31		0.00		0.00		
Travel Time (min)	**=**	**0.54**	**+**	**0.00**	**+**	**0.00**	**=**	**0.54**
Channel Flow								
X sectional flow area ((sqft))	=	0.00		0.00		0.00		
Wetted perimeter ((ft))	=	0.00		0.00		0.00		
Channel slope (%)	=	0.00		0.00		0.00		
Manning's n-value	=	0.015		0.015		0.015		
Velocity (ft/s)	=	0.00		0.00		0.00		
Flow length (ft)	=	0.0		0.0		0.0		
Travel Time (min)	**=**	**0**	**+**	**0**	**+**	**0**	**=**	**0.00**

Total Travel Time, Tc .... 5.00 min

Hydrology Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Friday, Dec 7 2018

<Name>

Hydrograph type	= Rational	Peak discharge (cfs)	= 2.574
Storm frequency (yrs)	= 10	Time interval (min)	= 1
Drainage area (ac)	= 0.985	Runoff coeff. (C)	= 0.39
Rainfall Inten (in/hr)	= 6.701	Tc by TR55 (min)	= 7
IDF Curve	= SampleExpress.IDF	Rec limb factor	= 1.00

Hydrograph Volume = 1,081 (cuft); 0.025 (acft)

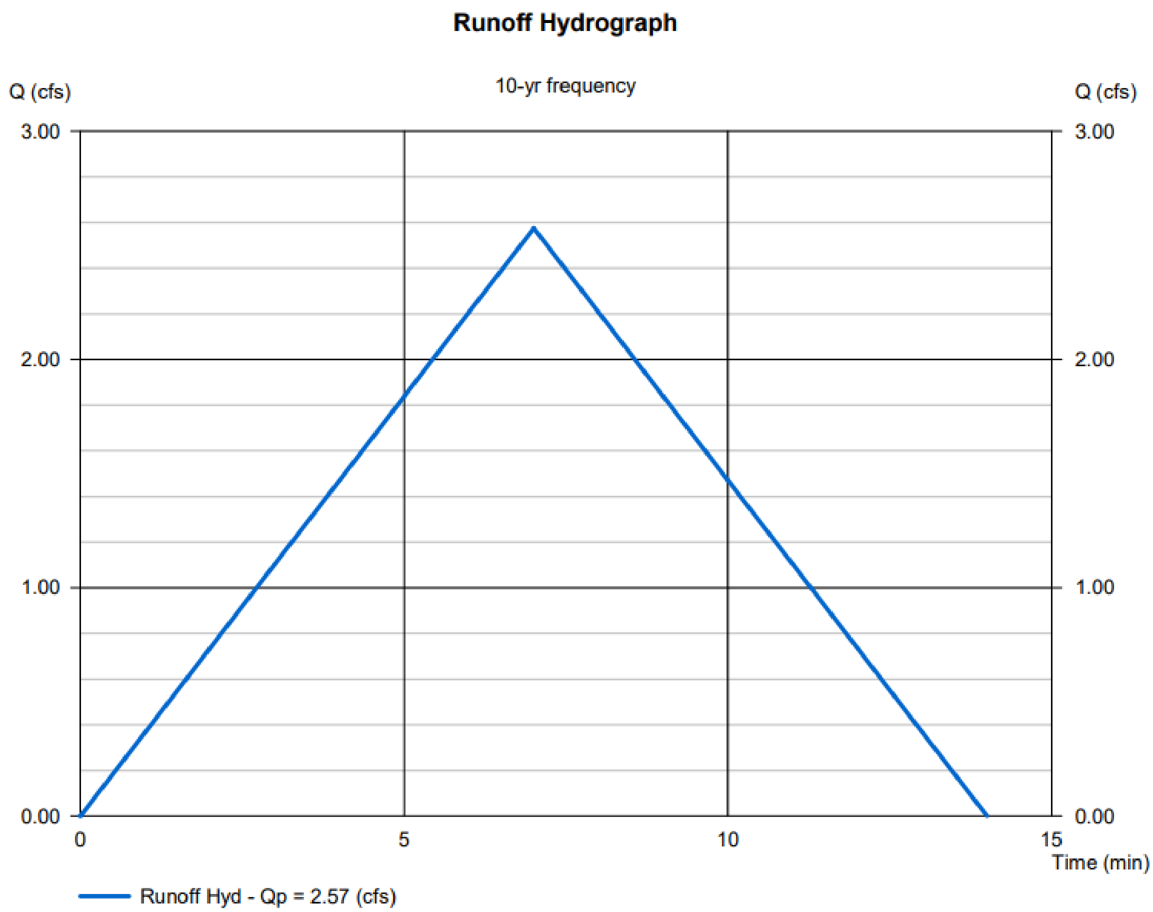


Figure 15 Post- Development Hydrology Report

Table 8 Post- Development TR5 Tc Worksheet

TR55 Tc Worksheet

Hydraflow Express by Intelisolve

Rational

<Name>

Description		**A**		**B**		**C**		**Totals**
Sheet Flow								
Manning's n-value	=	0.240		0.011		0.011		
Flow length (ft)	=	10.0		0.0		0.0		
Two-year 24-hr precip. ((in))	=	3.08		0.00		0.00		
Land slope (%)	=	2.00		0.00		0.00		
Travel Time (min)	**=**	**2.31**	**+**	**0.00**	**+**	**0.00**	**=**	**2.31**
Shallow Concentrated Flow								
Flow length (ft)	=	0.00		0.00		0.00		
Watercourse slope (%)	=	0.00		0.00		0.00		
Surface description	=	Paved		Paved		Paved		
Average velocity (ft/s)	=	0.00		0.00		0.00		
Travel Time (min)	**=**	**0.00**	**+**	**0.00**	**+**	**0.00**	**=**	**0.00**
Channel Flow								
X sectional flow area ((sqft))	=	2.25		5.63		0.00		
Wetted perimeter ((ft))	=	12.18		15.24		0.00		
Channel slope (%)	=	10.76		4.30		0.00		
Manning's n-value	=	0.140		0.140		0.015		
Velocity (ft/s)	=	1.13		1.13		0.00		
Flow length (ft)	=	220.0		130.0		0.0		
Travel Time (min)	**=**	**3.256330+00**		**1.9143330.00**		**0**	**=**	**5.17**

Total Travel Time, Tc .... 7.00 min

Appendix D: Design Calculations

Design Loads

Assumptions:

- Timber members will be built with Select Structural Douglas Fir- Larch refrennce design values can be found in appendix

$SG := 0.5$

Truss design:

-2x8 w/ 20 ft span @ 24' spacing O.C.

$S := 24\ in$

Columns:

-assume column placed under ends of truss span
-Columns are sized at 6"x6" with an effective length of 12'
-Stone encasing will add additional weight TBD

$l_u := 12\ ft$

$$P_{C.self} := \left(\frac{5.5 \cdot 5.5}{144}\right) \cdot SG \cdot 62.4 \cdot 12 = 78.65 \quad lbs$$

Floor:

-assume 6" reinforced normal weight concrete (6"x 150psf) = 75 psf

Girders:

Girders are taken as 4x10 beams

$$P_{G.self} := 2 \cdot \left(\frac{1.5 \cdot 9.25}{144}\right) \cdot SG \cdot 62.4 \cdot 16 = 96.2\ lbs$$

Sheathing:

-Choose OSB sheathing, placed perpendicular to supports
- span rating of 24/0
-choose panel thickness 1/2"

Dead load: (neglecting self weights until analysis)

Upper Roof Dead Load Components	Material	load(psf)
roof covering	Asphalt shingles	2
roof insulation	Rigid insulation, general	1.5
roof insulation thickness	0	in.
roof underlayment	Waterproofing membrane, single-ply felt	0.7
roof sheathing	Plywood/OSB, 1/2 in	1.6
roof framing	2X8 @24OC	5.8
roof slope	4:12	12

Total upper roof Dead Load	4.3	psf
Total lower roof Dead Load	1	psf

$D_{up} := 4.3\ psf$

$D_{upper} := D_{up} \cdot S = 8.6\ \frac{lbf}{ft}$

$D_{low} := 1\ psf$

$D_{lower} := D_{low} \cdot S = 2\ \frac{lbf}{ft}$

Live Loads:

$L_r := 20\ psf$

$$L_{rsloped} := \frac{L_r}{\sqrt{\left(\frac{4}{12}\right)^2 + \left(\frac{12}{12}\right)^2}} = 18.974\ psf$$

$$L_{rtop} := L_{rsloped} \cdot S = 37.947\ \frac{lbf}{ft}$$

Snow Loads: $C_t := 1.2$ $C_s := 0.90$ $C_e := 0.9$ $I_s := 1.0$

For Ogden, IA: $p_g := 25\ psf$ $P_s := p_g \cdot C_s = 22.5\ psf$

$p_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g = 18.9\ psf$

$$P_{sSloped} := \frac{P_s}{\sqrt{\left(\frac{4}{12}\right)^2 + \left(\frac{12}{12}\right)^2}} = 21.345\ psf$$

$$P_{sSloped} := P_{sSloped} \cdot S = 42.691\ \frac{lbf}{ft}$$

Wind Loads:

Assume: $h_e := 12\ ft$

- wind if coming from the N
- use loading combination B
- Surface roughness C
- Exposure C
- Assume Clear Wind Flow
- building is considered open, A0 > 0.8Ag

$V := 115\ mph$ $K_{zt} := 1.0$

$GC_{pi} := 0.00$ open building

mean roof height: $h := \dfrac{h_e + (h_e + 2\ ft + 8\ in)}{2} = 13.333\ ft$ $\lambda := 1.21$

velocity pressures:

For MWFRS: $K_z := 0.57$ $K_d := 0.85$

$$q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 = 16.403\ \ psf$$

For C+C: $K_z := 0.70$

$$q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 = 20.144\ \ psf$$

Design Wind Pressures:

For C+C: $G := 0.85$

		A			B	
		Cnw	Cnl		Cnw	Cnl
15		1.1	-0.4		0.1	-1.1
18.435		1.1	-0.171		0.0084	-0.9626
22.5		1.1	0.1		-0.1	-0.8

$$p := q_z \cdot G \cdot 1.1 = 18.835\ \ psf$$

$$W_{Aw} := p \cdot 1.1 \cdot \lambda \cdot \frac{24}{12} = 50.139 \frac{lbf}{ft}$$

$$W_{Al} := (q_z \cdot G \cdot -0.171) \cdot \lambda \cdot \frac{24}{12} = -7.086\ \ \frac{lbf}{ft}$$

$$W_{Bw} := (q_z \cdot G \cdot 0.0084) \cdot \lambda \cdot \frac{24}{12} = 0.348\ \ \frac{lbf}{ft}$$

$$W_{Bl} := (q_z \cdot G \cdot -0.9626) \cdot \lambda \cdot \frac{24}{12} = -39.887\ \ \frac{lbf}{ft}$$

Loading Case Combinations (Allowable Strength Design ASCE 7-16):

(1) D

(2) D+L — Combination 2 not applicable since no live load

(3) D+S

(4) D+0.75*S

(5) D+0.6*W

(6) D+0.75*(0.6*W)+0.75*D

(7) 0.6*D+0.6*W

Highest reaction force on girder support: $R_G := 869.39 \quad lbf$

Column Size Design

$C_M := 1 \quad C_t := 1 \quad C_i := 1 \quad C := 0.8 \quad C_F := 1.0 \quad C_D := 1.15 \quad C_p := 0.7 \quad SG := 0.50$

$K_e := 1.0$

$E := 1900000$

$E_{min} := 690000$

$F_c := 1700$

$F_{cperp} := 625$

$F_v := 180$

$F_t := 1000$

$F_b := 1500$

$$P_c := 10 \cdot R_G + \frac{21}{16} P_{G.self} = 8925.381 \quad lbf$$

$$A_g := \frac{P_c}{F_{cperp} \cdot C_p} = 20.401 \quad in^2$$

Try 6x6 column

$$F_{CE} := \frac{0.822 \cdot E_{min}}{\left(\frac{l_u \cdot 12}{5.5}\right)^2} \qquad \left(\frac{l_u \cdot 12}{5.5}\right) = 26.182 \qquad F_c'' := F_{cperp} \cdot C_F \cdot C_D = 718.75$$

$$C_P := \frac{1 + \frac{F_{CE}}{F_c''}}{2 \cdot C} - \sqrt{\left(\frac{1 + \frac{F_{CE}}{F_c''}}{2 \cdot C}\right)^2 - \frac{\frac{F_{CE}}{F_c''}}{C}} = 0.737$$

$$F_c' := F_c'' \cdot C_P = 529.937$$

$$f_c := \frac{P_c}{5.5 \cdot 5.5} = 295.054 \qquad DCR := \frac{f_c}{F_c'} = 0.557$$

6x6 column is adequate, but will use 8x8 in design

Girder Design

longest beam span = 16'

largest tributary length = 15'-6"

test) Girder as 6x10

$S := 82.73$ in^3

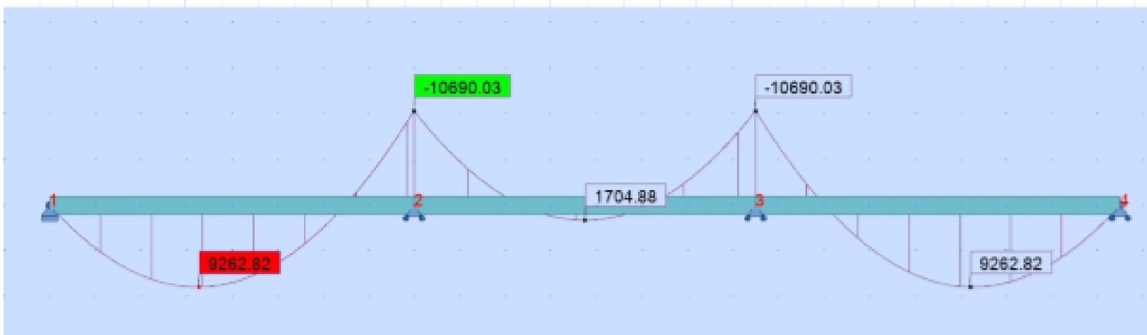
$I := 393$ in^4

$A := 52.25$ in^2

Span length:

$$w_{tot} := \frac{A}{144} \cdot (SG \cdot 62.4) + \frac{(8 \cdot R_G)}{16} = 446.016 \quad \frac{lbf}{ft}$$

Girder verification bending:



Governing case:

$M_{pos} := 9262.82 \quad lbf \cdot ft$ $\qquad f_{bpos} := \frac{M_{pos} \cdot 12}{S} = 1343.574 \quad psi$

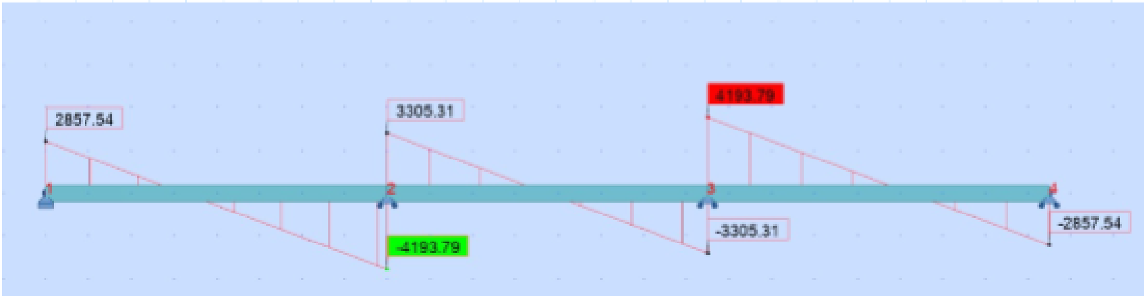
$M_{neg} := 10690.03 \quad lbf \cdot ft$ $\qquad f_{bneg} := \frac{M_{neg} \cdot 12}{S} = 1550.591 \quad psi$

$C_l := 1 \quad C_m := 1 \quad C_d := 1 \quad C_t := 1 \quad C_f := 1.2 \quad C_{fu} := 1 \quad C_i := 1 \quad C_r := 1.15$

$F_b' := F_b \cdot C_d \cdot C_f \cdot C_r \cdot C_i = 2070$ psi

$DCR := \frac{f_{bneg}}{F_b'} = 0.749$ $\qquad f_{bneg} < F_b' = 1$

Beam 1 verification shear:



Governing case:

$V := 4193.79$ lb $\qquad f_v := \dfrac{3 \cdot (V)}{2 \cdot (5.5 \cdot 9.25)} = 123.65$ psi

$F_v' := F_v \cdot C_d \cdot C_m \cdot C_t \cdot C_i = 180$ psi

$DCR := \dfrac{f_v}{F_v'} = 0.687 \qquad f_v < F_v' = 1$

Maximum values from truss analysis:

Top Chord:	$P_c := 190.17$ lbf	Case 4
	$M := 194.72$ lbf · ft	Case 6, Wind Case A
Bottom Chord:	$P_t := 26.77$ lbf	Case 4
	$M := 118.38$ lbf · ft	Case 6, wind case A
Web:	$P_t := 7.3$ lbf	Case 4
	$P_c := 11.11$ lbf	Case 6, wind case A

Additional Design values for 2x8 Select Structural Douglas Fir-Larch:

$b := 1.5\ in$

$d := 7.25\ in$

$l_u := \frac{24}{12}\ ft + \frac{2 \cdot \left(\frac{24}{12}\ ft\right)}{2} = 4\ ft$

$\frac{l_u}{d} = 6.621 \qquad \frac{l_u}{d} < 7 = 1$

$l_e := 2.06 \cdot l_u = 8.24\ ft$ (NDS Table 3.3.3)

$S := 13.14\ in^3$

$A := 10.88\ in^2$

$I := 47.63\ in^4$

$C_i := 1.0$

$C_m := 1.0$

$C_l := 1.0$

$C_{fu} := 1.0$

$C_t := 1.0$

$C_{fb} := 1.2$

$C_d := 1.25$

$C_{fc} := 1.05$

$C_r := 1.15$

$C_f := 1.2$

$E_{min}' := E_{min} \cdot C_t \cdot C_m \cdot C_i = 690000$

Top Chord Analysis:

$P_c := \sqrt{208.03^2 + 1497.32^2}\ lbf$ Case 4

$M := 194.72\ lbf - ft$ Case 6, Wind Case A

$F_c'' := F_c \cdot C_i \cdot C_{fc} \cdot C_m \cdot C_t \cdot C_d = 2231.25$

$F_{CE} := \frac{0.822 \cdot E_{min}'}{\left(\frac{8.24 \cdot 12}{7.25}\right)^2} = 3049.159$

$C_p := \left(\frac{1 + \frac{F_{CE}}{F_c''}}{2 \cdot 0.8}\right) - \sqrt{\left(\frac{1 + \frac{F_{CE}}{F_c''}}{2 \cdot 0.8}\right)^2 - \frac{\left(\frac{F_{CE}}{F_c''}\right)}{0.8}} = 0.787$

$F_b' := F_b \cdot C_l \cdot C_m \cdot C_d \cdot C_t \cdot C_{fu} \cdot C_{fb} \cdot C_i \cdot C_r = 2587.5$

$f_b := \frac{M \cdot 12}{S} = 177.826$

$F_c' := F_c \cdot C_m \cdot C_d \cdot C_t \cdot C_{fc} \cdot C_i \cdot C_p = 1755.137$

$f_c := \frac{P_c}{A} = 138.943$

$\beta := \frac{1}{1 - \frac{f_c}{F_{CE}}} = 1.048$

$\left(\frac{f_c}{F_c'}\right)^2 + \beta \cdot \left(\frac{f_b}{F_b'}\right) = 0.078$

Bottom Chord Analysis:

$$P_t := \sqrt{1355.2^2 + 42.95^2} \quad lbf$$

$$M := 121.75 \quad lbf - ft$$

$$F_b'' := F_b \cdot C_f \cdot C_d = 2250$$

$$F_{BE} := \frac{1.2 \cdot E_{min}}{\left(\frac{l_e \cdot d}{b^2}\right)} = 2598.761$$

$$C_p := \left(\frac{1 + \frac{F_{BE}}{F_b''}}{2 \cdot 0.95}\right) - \sqrt{\left(\frac{1 + \frac{F_{CE}}{F_b''}}{2 \cdot 0.95}\right)^2 - \frac{\left(\frac{F_{BE}}{F_b''}\right)}{0.95}} = 0.568$$

$$F_b' := F_b \cdot C_l \cdot C_m \cdot C_d \cdot C_t \cdot C_{fu} \cdot C_{fb} \cdot C_i \cdot C_r = 2587.5$$

$$f_b := \frac{M \cdot 12}{S} = 111.187$$

$$F_t' := F_t \cdot C_m \cdot C_d \cdot C_t \cdot C_{fc} \cdot C_i \cdot C_p = 745.338$$

$$f_t := \frac{P_t}{A} = 124.621$$

$$\beta := \frac{1}{1 - \frac{f_b}{F_{BE}}} = 1.045$$

$$\left(\frac{f_t}{F_t'}\right)^2 + \beta \cdot \left(\frac{f_b}{F_b'}\right) = 0.073$$

Web Analysis:

$$P_c := \sqrt{279.92^2 + 55.61^2} \; lbf$$

$$P_t := \sqrt{55.61^2 + 279.92^2} \; lbf$$

$$f_t := \frac{P_t}{A} = 26.231 \; lbf$$

$$\frac{f_t}{F_t'} = 0.035 \; lbf$$

$$f_c := \frac{P_c}{A} = 26.231 \; lbf$$

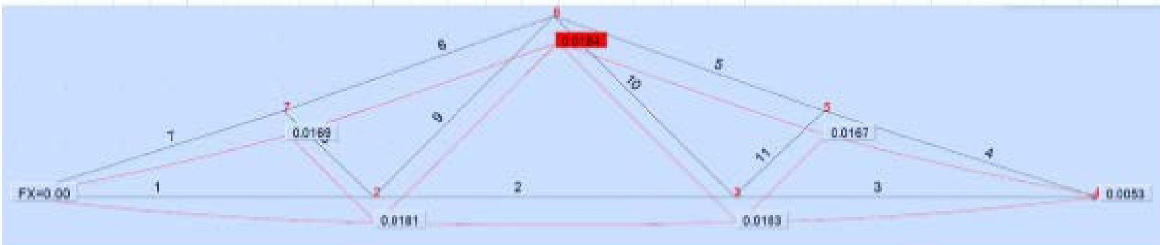
$$\frac{f_c}{F_c'} = 0.015 \; lbf$$

Deflection Analysis:

$$l := 16\ ft$$

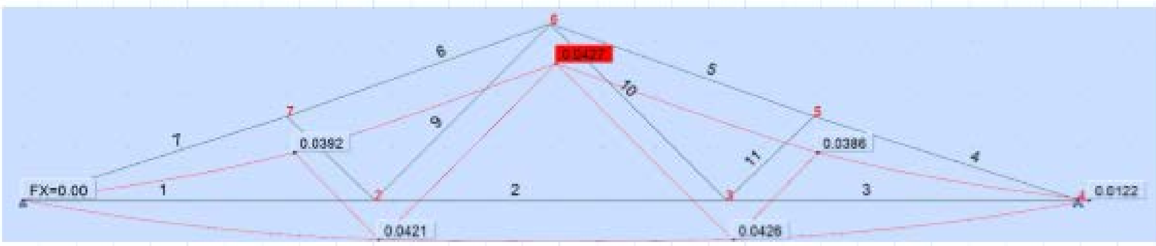
$$\delta_{allow.total} := \frac{l}{240} = 0.8\ in \qquad \delta_{allow.service} := \frac{l}{360} = 0.533\ in$$

Short term Deflection:



$$ST_{top} := 0.0184\ in \qquad ST_{bot} := 0.0183\ in$$

Long term Deflection:



$$LT_{top} := 0.0427\ in \qquad LT_{bot} := 0.0426\ in$$

$$\delta_{top.total} := 1.5 \cdot LT_{top} + ST_{top} = 0.082\ in$$

meets NDS requirements

$$\delta_{bot.total} := 1.5 \cdot LT_{bot} + ST_{bot} = 0.082\ in$$

Footing Design:

Assumptions:

- In- situ type is Hayden-Storden loams
  - Assume Soil friction angle is 32 deg (ref. USCS)
  - Soil density is 89 pfc
  - Saturated bulk density is 94 pcf
  - Soil Pore water pressure is 36%
- Backfill soil is granular with a bulk density of 120 pcf
  - Unform surcharge pressure of backfill on foundation is 100 psf due to pedestrian loading
- Foundation is pier with a spread footing
- Frost depth in Ogden, IA is 4', depth of footing will be 4'-6"
  (Boone County minimum 42" depth)

356G	Hayden-Storden loams, 25 to 50 percent slopes	Very limited	Hayden (40%)	Slope (1.00)	19,763.5	5.4%
				Low strength (1.00)		
				Frost action (0.50)		
				Shrink-swell (0.25)		
			Storden (40%)	Slope (1.00)		
				Frost action (0.50)		
			Salida (20%)	Slope (1.00)		

$\gamma_w := 62.4$ $\quad \gamma := 89$ $\quad \gamma_{sat} := 94$ $\quad \mu_s := 0.36$ $\quad \gamma_f := 120$ $\quad \gamma_c := 150$ $\quad p_a := 2000$

Assume:

$\alpha := 90$ $\quad \beta := 0$ $\quad \phi' := 32$

$$K_a := \left(\tan\left(\left(45 - \frac{\phi'}{2}\right) \cdot \left(\frac{\pi}{180}\right)\right)\right)^2 = 0.307$$

$$K_p := \left(\tan\left(\left(45 + \frac{\phi'}{2}\right) \cdot \left(\frac{\pi}{180}\right)\right)\right)^2 = 3.255$$

vesic's;

$$N_q := e^{\pi \cdot \tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right)} \cdot \left(\tan\left(\left(45 + \frac{\phi'}{2}\right) \cdot \left(\frac{\pi}{180}\right)\right)\right)^2 = 23.177$$

$$N_c := \frac{\left(N_q - 1\right)}{\tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right)} = 35.49$$

$$N_\gamma := 2\left(N_q + 1\right) \cdot \tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right) = 30.215$$

Column Footing design:

Column force on foundation:

$$P_C := \frac{27.75}{144}\cdot(SG\cdot 62.4)\cdot 21 + \frac{30.25}{144}\cdot(SG\cdot 62.4)\cdot 12 + 11\cdot R_G + \gamma_c\cdot((15.5\cdot 10)+(4.5\cdot 10))\cdot\frac{6}{12} + \gamma_c\cdot(3\cdot 2\cdot 2) = 26568.203$$

$$B_1 := 2 + \frac{2}{12} \quad B_2 := 1 \quad B_3 := B_1 \quad t_f := 1 \quad ft \quad D_f := 4.5\ ft$$

$$B := B_1 + B_2 + B_3 = 5.333 \quad L := B \quad z_a := \frac{D_f}{3} = 1.5 \quad ft$$

$$q_s := 100 \quad \frac{lb}{ft^2}$$

$$M_C := W_{Aw}\cdot 16\cdot 12\cdot \cos\left(\operatorname{atan}\left(\frac{4}{12}\right)\right) = 9132.607 \quad lbf-ft$$

$$P_a := \frac{K_a\cdot D_f\cdot(D_f\cdot\gamma_f + q_s)}{1000} = 0.885 \quad KLF$$

$$M_o := \frac{K_a\cdot D_f\cdot(D_f\cdot\gamma_f\cdot .5)\cdot z_a + q_s\cdot K_a\cdot D_f\cdot .5\cdot D_f}{1000} = 0.871 \quad \frac{kip-ft}{ft}$$

$$w_1 := \frac{\gamma_f\cdot(3.5\cdot B_3)}{1000} = 0.91 \quad KLF$$

$$w_2 := \gamma_c\cdot\frac{(4.5)\cdot B_2}{1000} = 0.675 \quad KLF$$

$$w_3 := \gamma_c\cdot\frac{(t_f)\cdot B}{1000} = 0.8 \quad KLF$$

Check for overturning:

$$M_R := \frac{P_C}{1000}\cdot\left(\frac{B_2}{2} + B_3\right) + w_2\cdot\left(\frac{B_2}{2} + B_3\right) + w_3\cdot(.5\cdot B) + w_1\cdot\frac{B_3}{2} = 75.768$$

$$FS_o := \frac{M_R}{M_o} = 86.982$$

Recommended FSo=3, design OK

Check for Sliding:

$$P := \frac{P_C}{1000} + w_1 + w_2 + w_3 + \frac{q_s\cdot D_f}{1000} = 29.403 \quad KLF$$

$$F_{max} := P\cdot\tan\left((\phi')\cdot\left(\frac{\pi}{180}\right)\right) = 18.373$$

$$FS_V := \frac{F_{max}}{P_a} = 20.763$$

Reccomended FSv=2, design OK

Check Uplift: $U := 140.53$ lb

$P_U := U \cdot 12 = 1686.36$ lb $P_C = 26568.203$ lb $FS_U := \dfrac{P_C}{P_U} = 15.755$

$FS_U \geq 1.5$ satisfied, Uplift ofter designed

Check for bearing capacity failure

$$e := \frac{M_C}{P \cdot 1000} = 0.311$$

$$B' := B - 2 \cdot e = 4.712$$

$s_c := 1$ $d_c := 1$
$s_q := 1$ $d_q := 1$
$s_\gamma := 1$ $d_\gamma := 1$

$m := 2$
$H_i := P_a$

$$\frac{F_{max}}{\tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right)} = 29.403$$

$$i_q := \left(1 - \frac{H_i}{\frac{F_{max}}{\tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right)}}\right)^2 = 0.941$$

$$i_\gamma := \left(i_q\right)^{\frac{3}{2}} = 0.912$$

$$i_c := i_q - \left(\frac{1 - i_q}{N_q - 1}\right) = 0.938$$

$$q_{N}' := \gamma_f \cdot D_f \cdot N_q \cdot i_q + .5 \cdot \left(\gamma_f\right) \cdot B' \cdot N_\gamma \cdot i_\gamma = 19567.712$$

$$P_{N}' := q_{N}' \cdot \frac{B'}{1000} = 92.206$$

$$FS_q := \frac{P_{N}'}{P} = 3.136$$

Reccomended FSq=3, design OK

Design for back wall footing: $LL := 100 \quad psf$

Wind pressure on back wall: $q_z := 16.403 \quad psf$

$$F := q_z \cdot (17 \cdot 12) = 3346.212 \quad lbf$$

$$M := F \cdot \frac{12}{2} = 20077.272 \quad \frac{lbf}{ft}$$

$$P_C := (SG \cdot 62.4) \cdot (17 \cdot 12 \cdot 1) + 7 \cdot R_G + (5.5 \cdot 20) \cdot \gamma_c \cdot \frac{1}{2} + (5.5 \cdot 20) \cdot LL = 31700.53 \quad lbf$$

$B := 6 \quad ft$ $\quad L := 17 \quad ft$ $\quad t_f := 1.5 \quad ft$ $\quad D_f := 5$

$$e := \frac{M}{P_C} = 0.633 \quad ft$$

$$B' := B - e = 5.367 \qquad (edgefooting)$$

$$s_q := 1 + \frac{B'}{L} \cdot \tan(\phi') = 1.209 \qquad k := \operatorname{atan}\left(\frac{D_f}{B}\right) = 0.695$$

$$s_\gamma := 1 - .4 \cdot \frac{B'}{L} = 0.874 \qquad Re := 1 - \sqrt{\frac{e}{B}} = 0.675$$

$$d_q := 1 + 2 \cdot \tan(\phi') \left(1 - \sin(\phi')\right)^2 \cdot k = 1.185 \qquad d_\gamma := 1$$

$$q_N := 130 \cdot 4 \cdot N_q \cdot d_q \cdot s_q + .5 \cdot (135) \cdot B \cdot N_\gamma \cdot d_\gamma \cdot s_\gamma$$

$$q_N' := q_N \cdot Re$$

$$q_{max} := \frac{P_C}{B} \left(1 + \frac{6 \cdot e}{B}\right)$$

$$P_N := q_N' \cdot B' \cdot L = 1721532.228$$

$$P := q_{max} \cdot B \cdot L = 880222.634$$

$$P_N' := q_N' \cdot B' = 101266.602$$

$$FS_q := \frac{P_N'}{P_C} = 3.194$$

Reccomended FSq=3, design OK

$$P_a := \frac{K_a \cdot D_f \cdot (D_f \cdot \gamma_f + q_s)}{1000} = 1.075 \quad KLF$$

$$M_o := \frac{K_a \cdot D_f \cdot (D_f \cdot \gamma_f \cdot .5) \cdot z_a + q_s \cdot K_a \cdot D_f \cdot .5 \cdot D_f}{1000} = 1.075 \quad \frac{kip-ft}{ft}$$

$$w_1 := \frac{\gamma_f \cdot (3.5 \cdot B_3)}{1000} = 0.91 \quad KLF$$

$$w_2 := \gamma_c \cdot \frac{(4.5) \cdot B_2}{1000} = 0.675 \quad KLF$$

$$w_3 := \gamma_c \cdot \frac{(t_f) \cdot B}{1000} = 1.35 \quad KLF$$

Check for overturning:

$$M_R := \frac{P_C}{1000} \cdot \left(\frac{B_2}{2} + B_3\right) + w_2 \cdot \left(\frac{B_2}{2} + B_3\right) + w_3 \cdot (.5 \cdot B) + w_1 \cdot \frac{B_3}{2} = 91.371$$

$$FS_o := \frac{M_R}{M_o} = 84.964$$

Recommended FSo=3, design OK

Check for Sliding:

$$P := \frac{P_C}{1000} + w_1 + w_2 + w_3 + \frac{q_s \cdot D_f}{1000} = 35.136 \quad KLF$$

$$F_{max} := P \cdot \tan\left((\phi') \cdot \left(\frac{\pi}{180}\right)\right) = 21.955$$

$$FS_V := \frac{F_{max}}{P_a} = 20.416$$

Reccomended FSv=2, design OK

Check Uplift:

$$U := 64.66$$

$$F_U := U \cdot 6 = 387.96 \qquad F_F := \gamma_c \cdot (4 \cdot 1 \cdot 17 + 5 \cdot 1 \cdot 17) = 22950$$

$$FS_U := \frac{F_F}{F_U} = 59.156$$

$FS_U \geq 1.5$ satisfied, Uplift ofter designed

Check for bearing capacity failure

$$e := \frac{M}{P_C} = 0.633 \qquad B' := B - 2 \cdot e = 4.733$$

$$s_c := 1 \qquad d_c := 1$$
$$s_q := 1 \qquad d_q := 1$$
$$s_\gamma := 1 \qquad d_\gamma := 1$$

$$m := 2$$
$$H_i := P_a$$

$$\frac{F_{max}}{\tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right)} = 35.136$$

$$i_q := \left(1 - \frac{H_i}{\frac{F_{max}}{\tan\left(\phi' \cdot \left(\frac{\pi}{180}\right)\right)}}\right)^2 = 0.94$$

$$i_\gamma := \left(i_q\right)^{\frac{3}{2}} = 0.911$$

$$i_c := i_q - \left(\frac{1 - i_q}{N_q - 1}\right) = 0.937$$

$$q_N' := \gamma_f \cdot D_f \cdot N_q \cdot i_q + .5 \cdot (\gamma_f) \cdot B' \cdot N_\gamma \cdot i_\gamma = 20884.72$$

$$P_N' := q_N' \cdot B' = 98853.988$$

$$FS_q := \frac{P_N'}{P_C} = 3.118$$

Reccomended FSq=3, design OK

Appendix A:

Sheathing:

UNIFORM LOADS (PSF) ON APA RATED PLYWOOD SHEATHING.
MULTI-SPAN, NORMAL DURATION OF LOAD, DRY CONDITIONS, PANELS 24 INCHES OR WIDER

Span Rating[b]	Load Governed By[c]	Strength Axis[a] — Perpendicular to Supports Span Center-to-Center of Supports (inches)										Parallel to Supports Span Center-to-Center of Supports (inches)		
		12	16	19.2	24	30	32	36	40	48	60	12	16	24
24/0	L/360	287	108	59	29	14	11	10				16		
	L/240	431	162	89	43	21	17	15				23		
	L/180	574	216	118	57	28	23	20				31		
	Bending	208	117	81	52	33	29	19				45		
	Shear	295	214	175	138	109	102	86				524		
32/16	L/360	544	205	112	54	27	22	19	14			35	13	
	L/240	816	307	168	81	40	32	29	21			53	20	
	L/180	1,088	409	224	108	53	43	38	27			70	27	
	Bending	308	173	120	77	49	43	27	22			77	43	
	Shear	381	276	226	178	140	131	111	100			657	476	
40/20	L/360	1,088	409	224	108	53	43	38	27	18		78	29	10
	L/240	1,631	614	336	163	80	65	57	41	27		117	44	15
	L/180	2,175	818	448	217	106	87	76	55	36		157	59	20
	Bending	521	293	203	130	83	73	46	38	26		125	70	25
	Shear	467	338	277	218	172	161	136	122	106		819	593	367
48/24	L/360	1,914	720	394	191	94	76	67	48	31	15	283	106	36
	L/240	2,871	1,080	591	286	140	114	100	72	47	23	424	160	54
	L/180	3,828	1,440	788	382	187	152	134	96	63	31	566	213	72
	Bending	775	436	303	194	124	109	69	56	39	25	225	127	45
	Shear	571	414	339	267	211	197	167	150	129	102	1,381	1,000	619

(a) The strength axis is the long panel dimension unless otherwise identified.

(b) Nominal thickness may vary within Span Rating. For range of thicknesses, see Table 5 of APA's *Panel Design Specification*, Form D510.

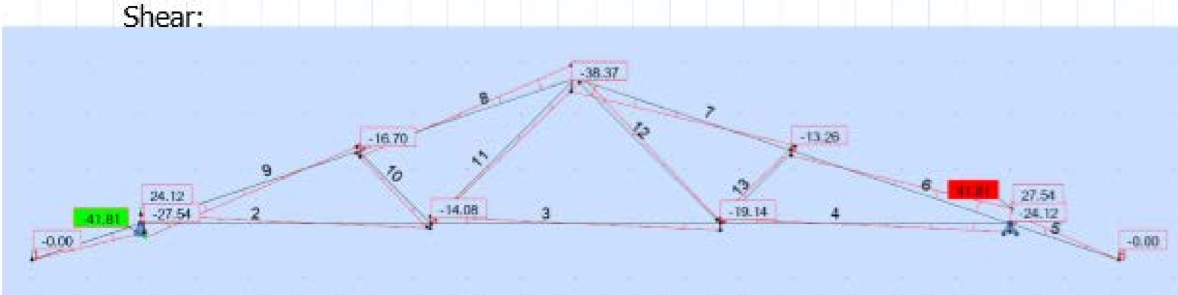
(c) Tabulated values are based on the most conservative plywood construction, as shown in Table 6. Some capacities may be increased by application of formulas in *Panel Design Specification*, Form D510.

Appendix B:

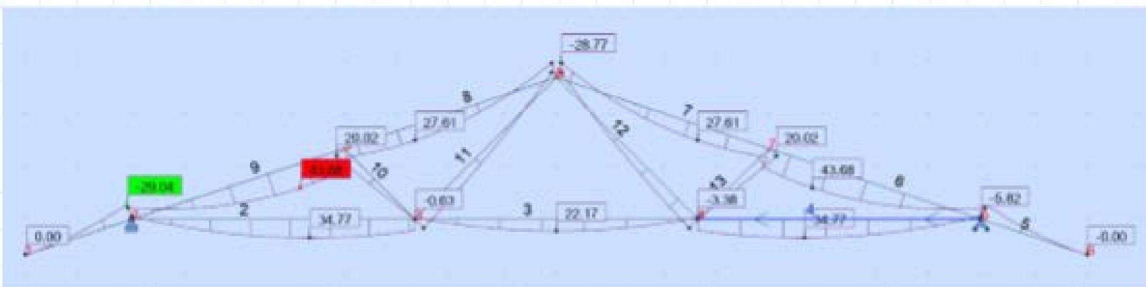
Loading diagrams for Truss

ASD case 1:

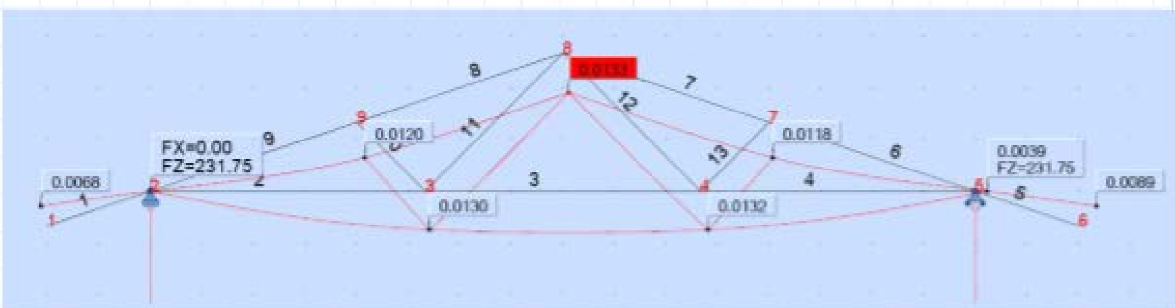
Shear:



Bending moment:

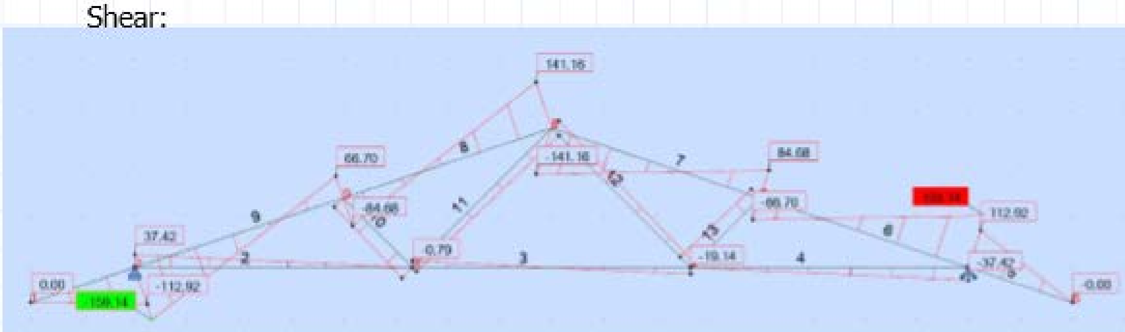


Deformation:

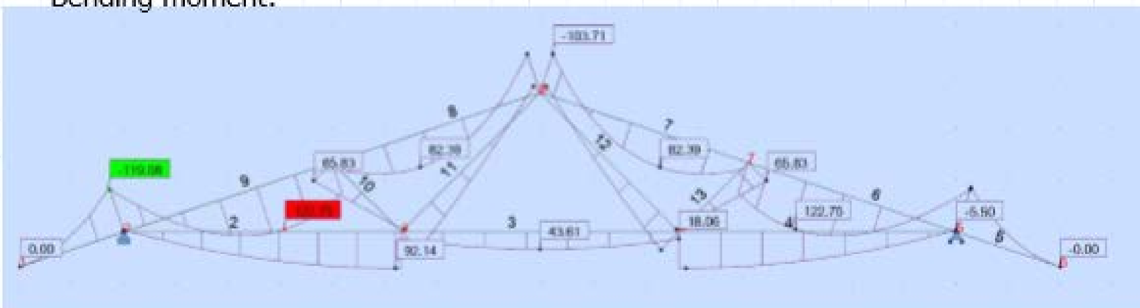


ASD case 3:

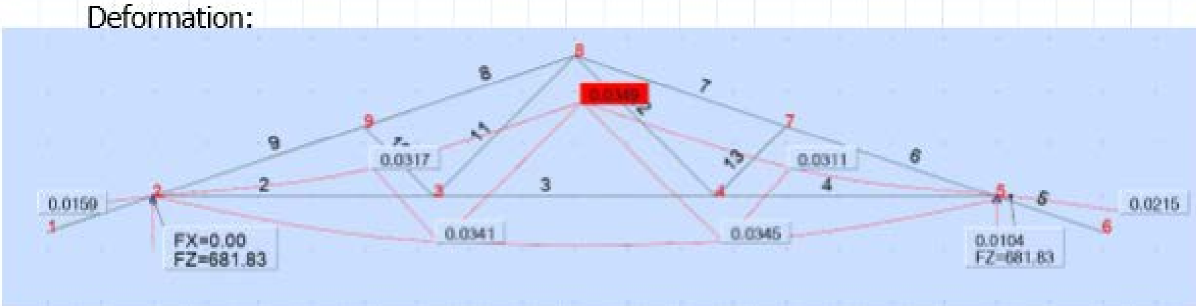
Shear:



Bending moment:

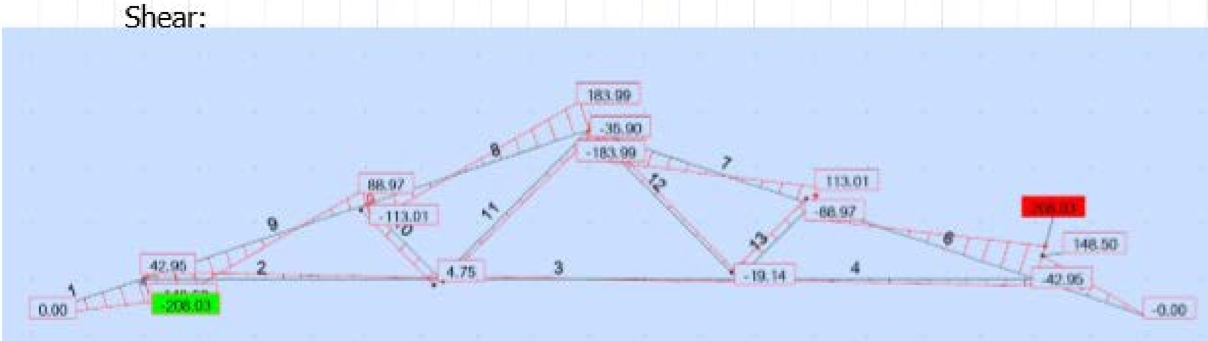


Deformation:

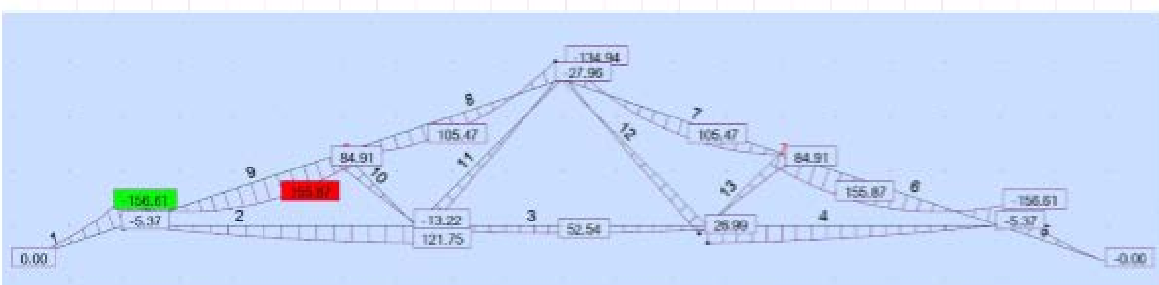


ASD case 4:

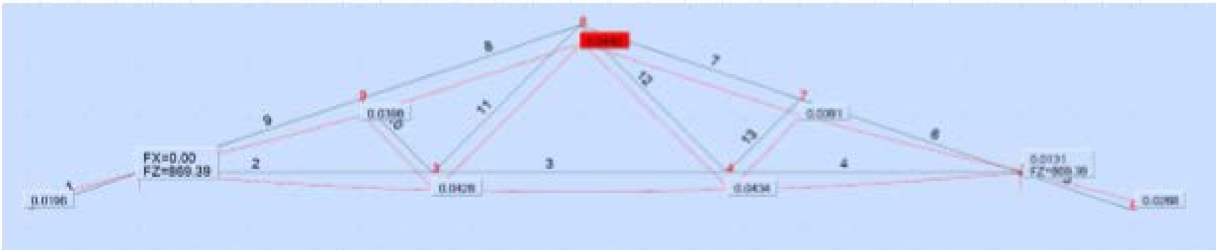
Shear:



Bending moment:

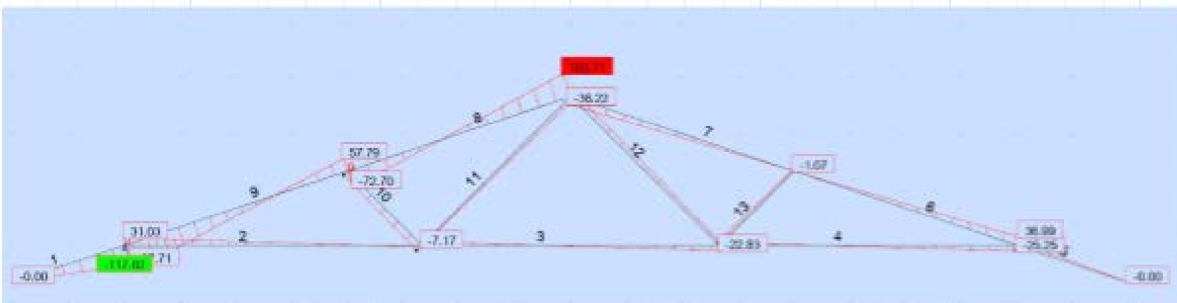


Deformation:

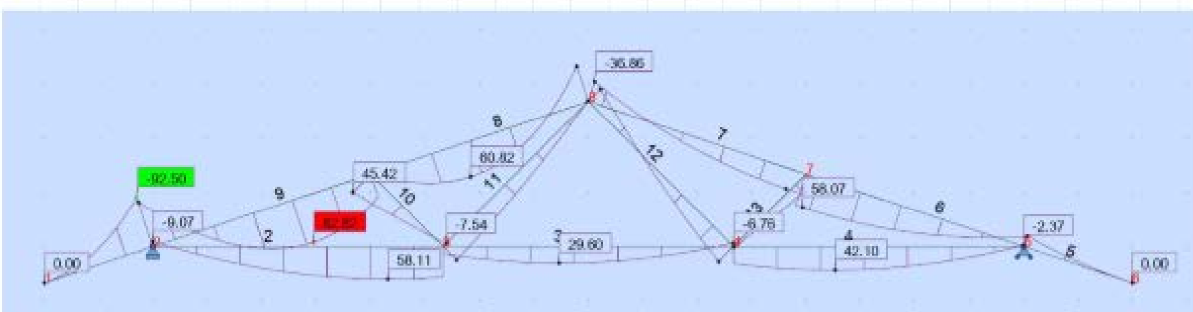


ASD case 5, Wind Case A:

Shear:



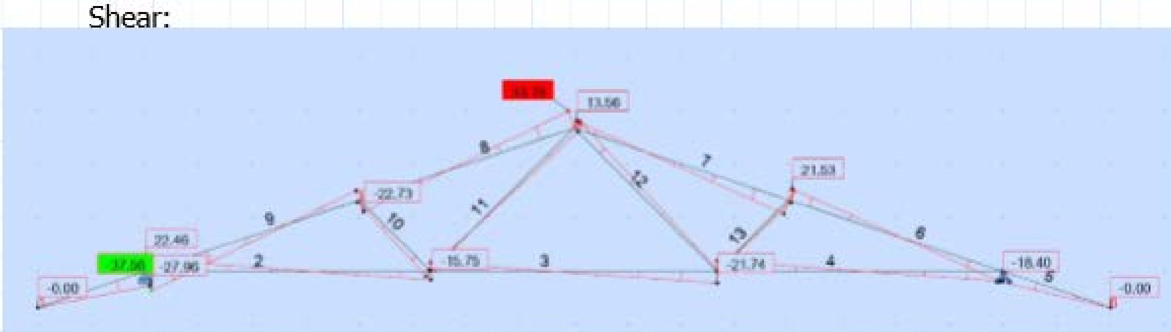
Bending moment:



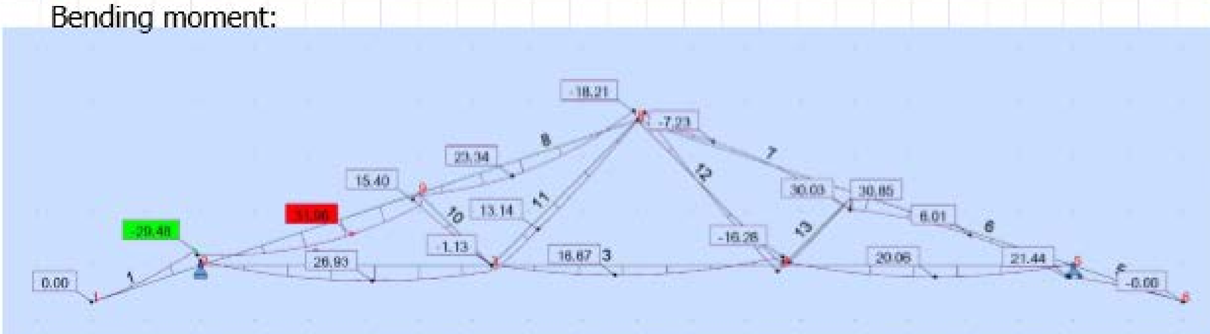
Deformation:

ASD case 5, Wind case B:

Shear:



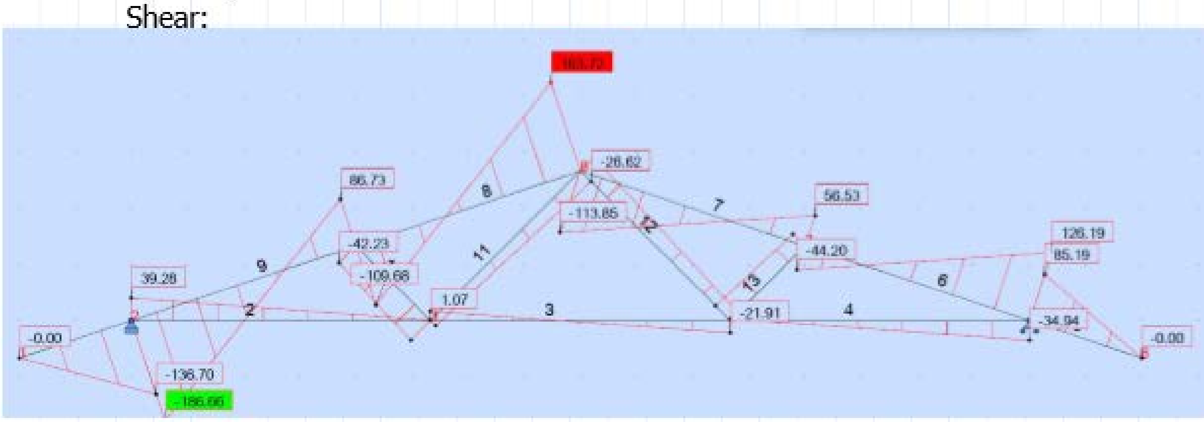
Bending moment:



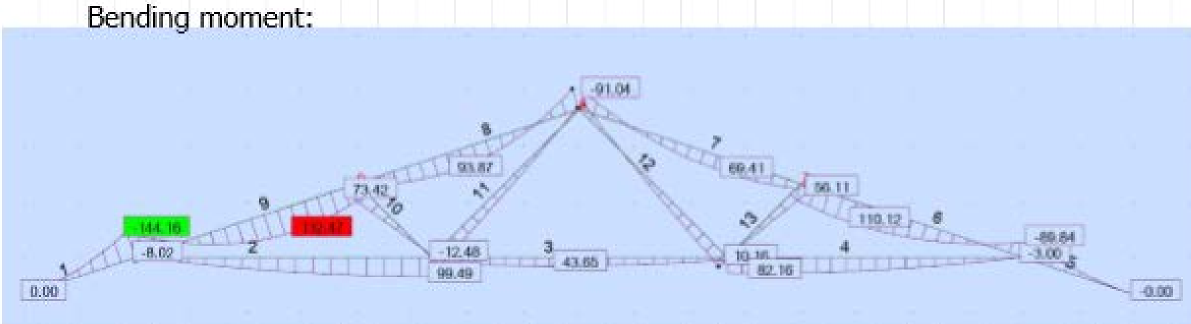
Deformation:

ASD case 6, Wind case A:

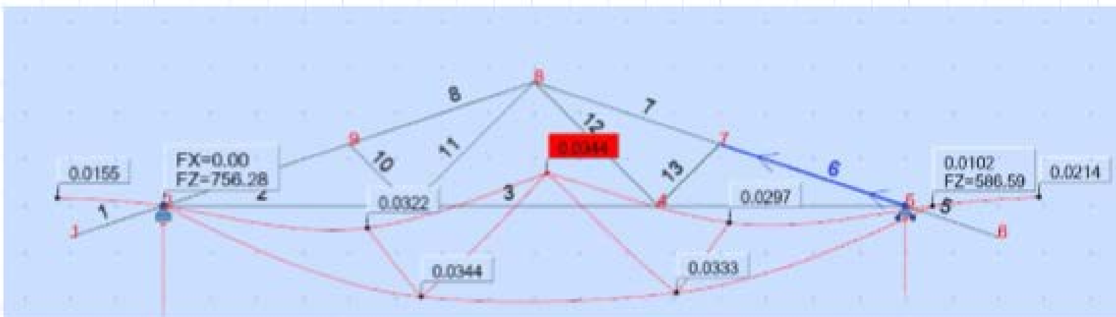
Shear:



Bending moment:



Deformation:

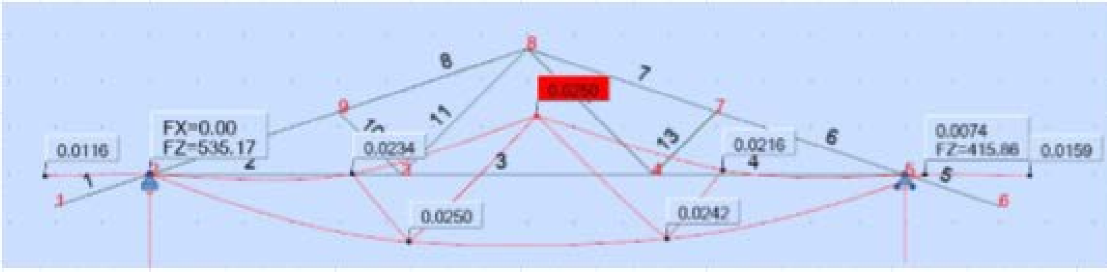


ASD case 6, Wind Case B:

Shear:

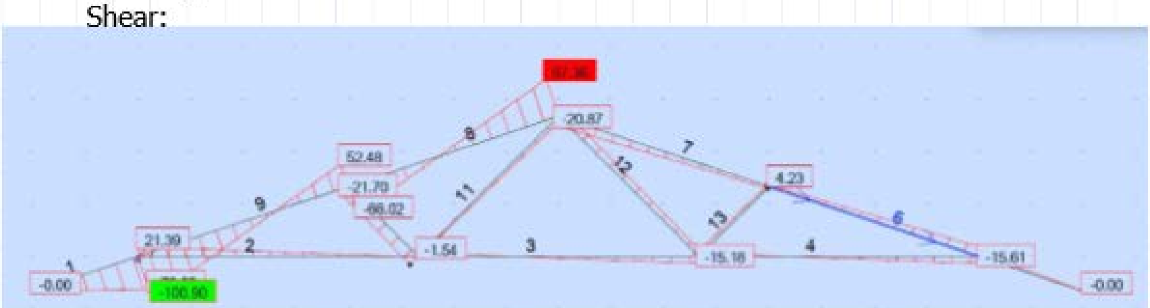
Bending moment:

Deformation:

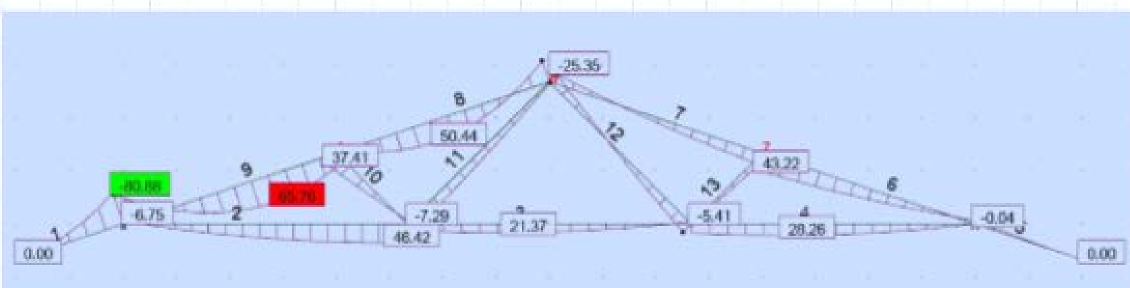


ASD case 7, Wind Case A:

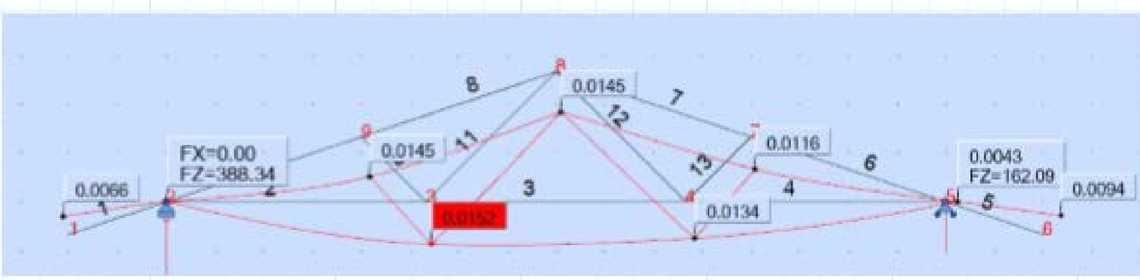
Shear:



Bending moment:

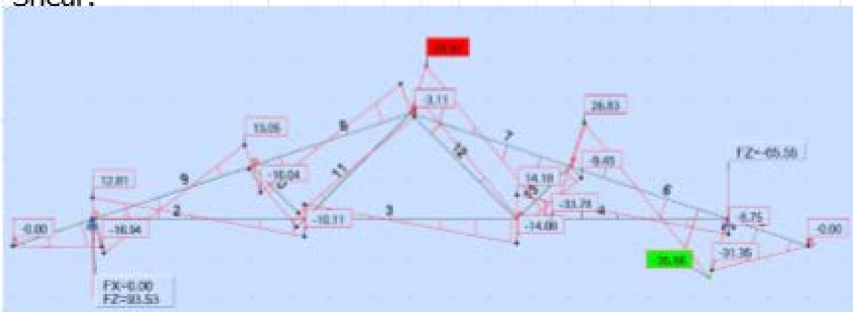


Deformation:

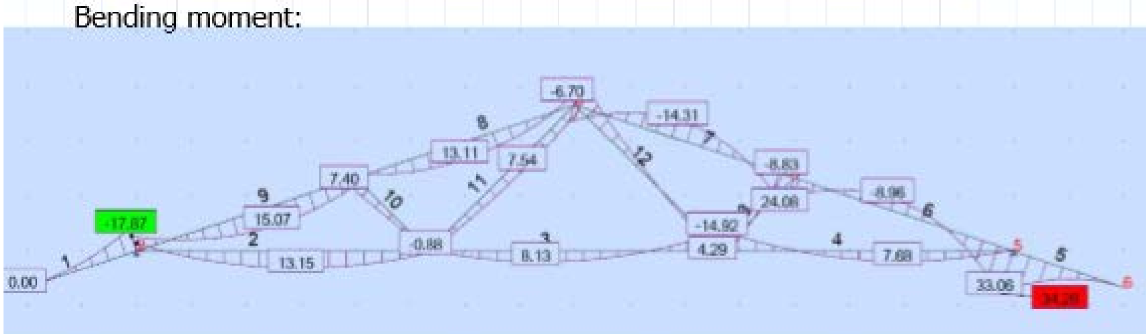


ASD case 7, Wind Case B:

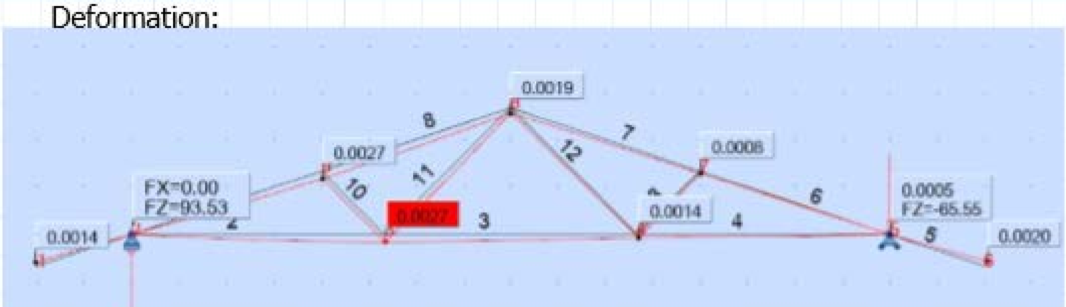
Shear:



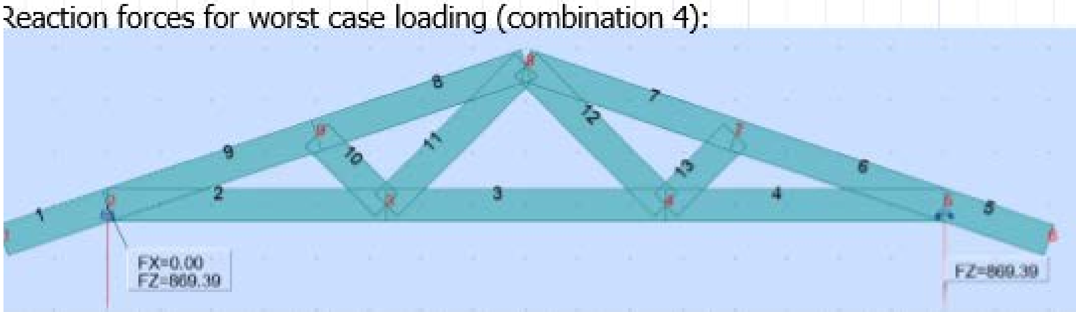
Bending moment:



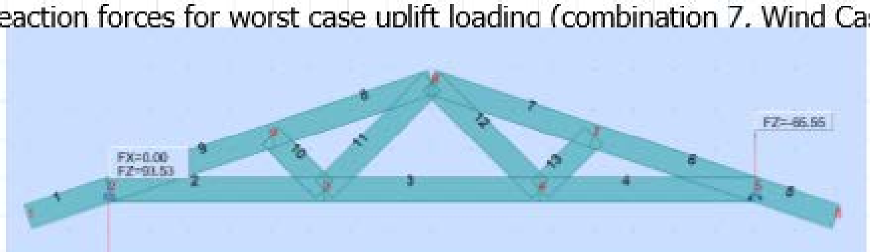
Deformation:



Reaction forces for worst case loading (combination 4):

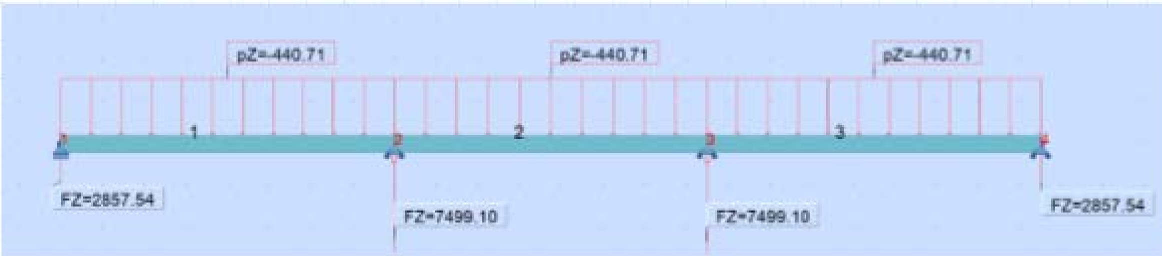


Reaction forces for worst case uplift loading (combination 7, Wind Case B):

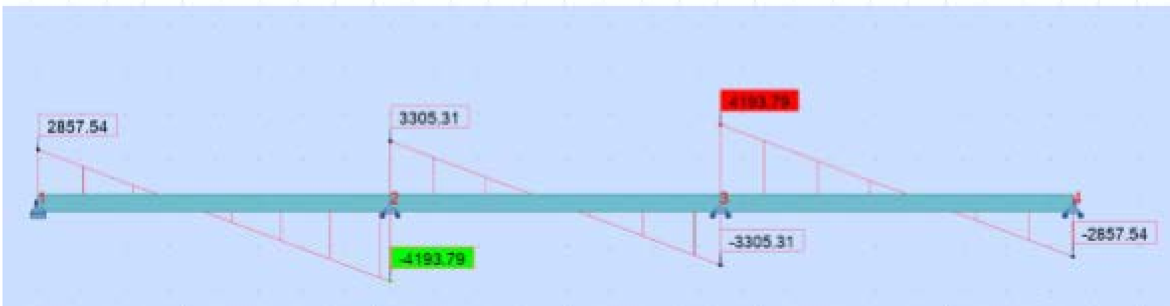


Girder Loading Diagrams:

Column reaction forces:

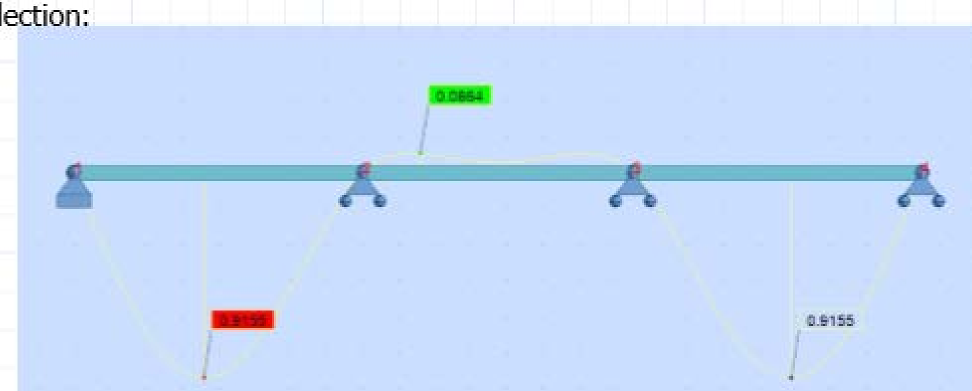


Shear:



Bending Moment:

Deflection:



Shear analysis on grass lined open channel on side of road. slopes of 4:1 and 3:1 when peak flow is occuring of a 10 year storm event.

$S_o := 10.75\% = 0.108$

$d_{75} := 0.05\ mm = 0.002\ in$

$\gamma := 9790\ \frac{N}{m^3}$ $C_f := 0.9$

$n_s := 0.016$

Assume Class C linning type with Sod growth form in good conditions of kentucky bluegrass. Table 5.11 and 5.12

$Q_{peak} := 2.25\ \frac{ft^3}{s}$ $C_s := 106$

$A := 1.434\ ft^2$

$P := 4.66\ ft$ $R := \frac{A}{P} = 3.693\ in$

$h_{grass} := 20\ cm = 7.874\ in$

$y := 0.64\ ft = 7.68\ in$ $C_n := 0.35 \cdot C_s^{0.1} \cdot h_{grass}^{0.528} = 0.239\ m^{\frac{66}{125}}$

$C_n := 0.24$

$\tau_o := \gamma \cdot R \cdot S_o = 98.712\ Pa$ $\tau_o := 192.56$

$n := C_n \cdot \tau_o^{-0.4} = 0.029$

$\tau_b := y \cdot \gamma \cdot S_o = 205.299\ Pa$

Effective Shear Stress: $\tau_e := \tau_b \cdot (1 - C_f) \cdot \left(\frac{n_s}{n}\right)^2 = 6.136\ Pa$

From table 5.10 PI is equal to 20 $PI := 20$

$c_1 := 1.07$ $c_2 := 14.3$ $c_3 := 47.7$ $c_4 := 1.48$

$c_5 := -0.57$ $c_6 := 4.8 \cdot 10^{-3}$

Permissible shear stress: $e := 0.4$

$\tau_{pc} := \left(c_1 \cdot PI^2 + c_2 \cdot PI + c_3\right) \cdot \left(c_4 + c_5 \cdot e\right)^2 \cdot c_6 = 5.731$

$\tau_{pc} := 5.731\ Pa$

$m := 3$

$K_s := 0.066 \cdot m + 0.67 = 0.868$

$\tau_{max} := \tau_e \cdot K_s = 5.326\ \boldsymbol{Pa}$

$\tau_{max} < \tau_{pc} = 1$

Because the effective shear stress on sides of the triangular channel (τ_{max}) is less then permissible shear stress τ_{pc} erosion of the grass lining will not occur.

Appendix E: Estimated Cost Breakdown

Table 9: Asphalt Parking Lot Cost Breakdown

Parking Lot Cost Estimate Asphalt				
Item	Units	Unit price	Quantity	Total Cost
Asphaltic concrete paving, 6"stone base, 3"base course,2" topping	SF	3.62	3280	$ 11,873.60
Rough Grading 3100-5000 S.F.	Each	1825	1	$ 1,825.00
Finish Grade Sub grade for base course, roadways	SY	0.55	364.4444444	$ 200.44
minimum labor/equipment charge machine grading	Job	965	1	$ 965.00
Pavement markings, handicap symbol	Stall	60	1	$ 60.00
Pavement markings, lines on parking stalls	Stall	8.85	9	$ 79.65
finish grading slopes gentle	SY	0.26	92.11	$ 23.95
Top Soil Stripping and Stockpiling, 200 H.P. dozer, ideal conditions	CY	1.04	6.38	$ 6.64
Compaction Riding, vibrating roller, 12" lifts, 2 Passes	SY	0.28	364.4444444	$ 102.04
White pine tree, BxB	EA	97.5		
wood parking bumpers, timber w/ saddles, treated type, 6" by 6" for trucks	LF	11.6	42	$ 487.20
			Total:	$ 15,623.52

Table 10: Asphalt Roadway Cost Breakdown

Road Way Cost Estimate option #1 (Asphalt)				
Item	Units	Unit price	Quantity	Total Cost
Asphaltic concrete paving, 6"stone base, 3"base course,2" topping	SF	3.62	4640	$ 16,796.80
Finish Grade, Steep slope	SY	0.27	568.6	$ 153.52
Finish Grade Sub grade for base course, roadways	SY	0.55	515.6	$ 283.58
minimum labor/equipment charge machine grading	Job	965	1	$ 965.00
Rough Grading 3100-5000 S.F.	Each	1825	1	$ 1,825.00
Compaction Riding, vibrating roller, 12" lifts, 2 Passes	SY	0.28	515.6	$ 144.37
Cut and Chip light trees to 6" Diam.	Acre	4825	0.11	$ 530.75
Top Soil Strippng and Stockpiling, 200 H.P. dozer, adverse conditions	C.Y	2.08	165	$ 343.20
			Total	$21,042.22

Table 11: Overlook Pavilion Cost Breakdown

Pavilion				
Item	Units	Unit price	Quantity	Total Cost
Cut and Chip light trees to 6" Diam.	Acre	4825	0.218	$1,051.85
Backfill Structural, Dozer or F.E. loader, from existing stockpile, no compaction 80 HP, 150' Haul common earth	LCY	2.8	73.781	$ 206.59
Compaction Riding, vibrating roller, 12" lifts, 2 Passes	SY	0.28	155.55	$43.55
Structural excavation for minor structures, hand, pits to 6' deep, Normal soil	BCY	147	66.228	$9,735.52
finish grading slopes gentle	SY	0.26	155.55	$40.44
Columns	LF	12.85	160	$2,056.00
Girders	LF	9.25	136	$1,258.00
Bolted Con. MED	EA	14.55	92	$1,338.60
OSB sheathing	SF	1.28	1448.92	$1,854.62
Truss	SF	3.17	1400	$4,438.00
Slab	CY	210	51.85185	$10,888.89
Cast in concrete Anchor	EA	75.5	10	$755.00
Spread footings	CY	315	3.333333	$1,050.00
Continuous footings	CY	315	6.296296296	$1,983.33
CMU Hanger Connection to Wood Girder	EA.	120	2	$240.00
Rebar column footing	ton	1950	0.08684	$169.34
Foundation Columns	CY	1275	3.33	$4,245.75
Asphalt shingles	SF	1.98	1448.92	$2,868.86
Wheather Barrier	SF	0.23	1448.92	$333.25
Column veneer (masonry housing)	VLF	57.5	30	$1,725.00
Column veneer (finish)	SF	36	180	$6,480.00
Back wall (CMU)	SF	11.3	272	$3,073.60
Back wall (masonry veneer Finish)	SF	36	408	$14,688.00
Fireplace (prefab only)		2877	1	$2,877.00
Fireplace (Masonry Veneer)	SF	36	134.64	$4,847.04
finish grading slopes gentle	SY	0.26	124.43	$32.35
Rebar (Foundation/Backwall)	ton	1950	0.39245	$765.28
Control Joints, in green concrete 1" depth	LF	0.67	170	$113.90
			Total:	$79,159.76

Table 12: Concrete Sidewalk Cost Breakdown

Sidewalks:				
Item	Units	Unit Price	Quantity	Total Cost
Expansion Joints at sidewalks, Keyed, poured asphalt, plain 1/2" x 1"	LF	$ 1.89	8	$15.12
Concrete expansion joint, recycled paper and fiber, 1/2" x 6"	LF	$ 1.99	16	$31.84
concrete sidewalk 4" thick, 4" gravel base, 4' wide	LF	$ 24.85	50	$ 1,242.50
ADA Truncated Domes Surface Applied detectable warnings, 2' by 4'	Each	$ 114.00	2	$ 228.00
			Total:	$1,517.46

Table 13: Cost Breakdown for sodding

sodding cost of entire project:				
Item	Units	Unit Price	Quantity	Total Cost
Sodding 1" deep, blue grass sod on level ground , over 8 M.S.F	M.S.F	390	9.372	$3,655.08

Table 14: Erosion prevention cost breakdown

Erosion Control				
Item	Units	Unit price	Quantity	Total Cost
6 inch Rip Rap	15.20 tons	33.5	405.33	$536.00
			Total	$536.00

Table 15: Cost for Open Channel

Open Channel				
Item	Units	Unit price	Quantity	Total Cost
Top Soil Strippng and Stockpiling, 200 H.P. dozer, ideal conditions	C.Y	1.04	73.05	$ 75.97
			Total:	$ 75.97