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Montana Canvas Tent Structure Design

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Eric Schowengerdt & Nick Morales

Abstract

Montana Canvas is one of the premier tent building companies in the world. Their product line includes backcountry tents, wall tents, and large scale shipping tarps. Currently they are looking to expand their product line to include large party tents of up to 60' in width. Eric Schowengerdt and Nick Morales, both Mechanical Engineering students at Montana Tech, have both designed fixtures and verified several of the fixtures already in use by Montana Canvas. These fixtures were put through finite element analysis on a computer and many static hand calculations, which simulated the loading on them from 120 mph to 85 mph wind conditions. This report will outline the processes used to determine the max loading area, alternative solutions to the structure, and finite element analysis on the structure.

Contents

Introduction

Montana Canvas is a company located in Belgrade Montana that specializes in wall tents and cargo tarps. They recently decided to expand their business to include manufacture of large scale tents for large outdoor events. Fixtures were made by a Spokane Washington machine shop to make a tent that was 30 feet wide by 30 feet long; to expand their business they wanted to know if these fixtures could be used in larger size tents. The sizes they wanted to expand to were (40X80, 50X100, and 60X120) feet. To determine if these fixture are suitable for these different tent sizes, the project has been broken into two parts.

The scope of the first part of this project is to understand wind loads and how the topography can affect the velocity of the wind. These factors come from ASCE (American Society of Civil Engineers) book. In this document, wind loads can be transformed into pressures based off of the different zones of the structure. These pressures are determined from the location, occupancy, and exposure to the elements of the tent.

The scope of the second part was being able to apply these loads to the tent structure. With the structure built in SolidWorks, wind loads, setup loads, and snow loads can be applied to perform an overall structural finite element analysis. However issues arose from using SolidWorks, and the infinite analysis had to be hand calculated. It was determined that the aluminum poles for the roof structure in sections B and E of the wind analysis were the weak link in the structure. This analysis was applied to a 40'X80' tent structure and will be integral in determining how to size each of the parts of the frame to handle this worst case scenario. From this worst case scenario of 85 mph, the data can then be applied to larger tents as needed by the company.

Wind Load Analysis

We were able to calculate winds loads by summing internal and external pressures applied to horizontal and vertical projections of the tent structure. The main equation that defined this is:

$$\boldsymbol{P_s = \lambda I K_{zt} P_{s30}}$$

This equation comes from the ASCE (American Society of Civil Engineers) book of codes under chapter 28 page 244 (Wind Loads on Buildings). Each variable of the equation is defined below.

λ is defined as the adjustment factor for building height and exposure (Chapter 26 page 190). To be conservative with the tent structure, exposure C was selected. Exposure C is defined as a structure site that is in open terrain with scattered obstructions having heights generally less than 30 feet (Chapter 26 page 195). The adjustment factor can then be determined with the mean roof height of the tent structure and the table below.

Table 1: Adjustment Factor for Building Height and Exposure. (ASCE Chapter 28 page 247)

Adjustment Factor for Building Height and Exposure, λ

Mean roof height (ft)	Exposure		
	B	C	D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

$\boldsymbol{I}$ is defined as an occupancy factor. Category I is intended for buildings that have a "low hazard to human life in the event of a failure". This includes buildings where there's no human occupancy, or only for a very short time, mainly just long enough to store things or to tend to livestock. Examples are agricultural facilities, certain temporary facilities, and minor storage facilities. Since the tent structure is a temporary, the occupancy factor is considered to be 1. (Chapter 2 of Structural Analysis of Structures)

$\boldsymbol{K_{zt}}$ is defined as the topographic factor (Chapter 26 page 189 ASCE). There are three other factors that make up this variable. They are called topographic multipliers that take in account for whether the tent is located on a ridge or peak and how close the tent is to the side of the ridge or peak. The equation for the topographic factor is:

$$\boldsymbol{K_{zt} = (1 + K_1 K_2 K_3)^2}$$

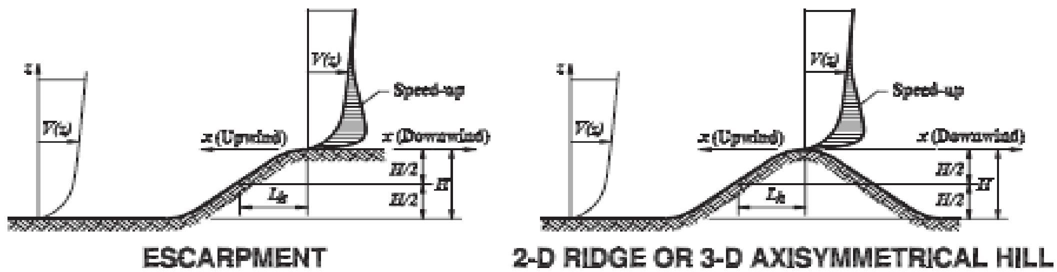
$\boldsymbol{K_1}$ is defined by the equation of $\frac{H}{L_h}$ where H is the height of the ridge or peak and L_h is the distance the tent is from the edge of the peak or ridge half way up.

$\boldsymbol{K_2}$ is defined by the equation of $\frac{x}{L_h}$ where x is the horizontal location of the tent relative to the direction of wind flow and L_h is the distance the tent is from the edge of the peak or ridge half way up.

$\boldsymbol{K_3}$ is defined by the equation of $\frac{z}{L_h}$ where z is the vertical location of the tent relative to the direction of wind flow and L_h is the distance the tent is from the edge of the peak or ridge half way up.

The ratio of these three equations are used to define the three K multipliers by using the following tables.

Table 2: K multiplier tables for the topographic factor. (ASCE Chapter 26 page 196)



Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier			x/L_h	K_2 Multiplier		z/L_h	K_3 Multiplier		
	2-D Ridge	2-D Escarp.	3-D Axisym. Hill		2-D Escarp.	All Other Cases		2-D Ridge	2-D Escarp.	3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

Notes:

1. For values of H/L_h, x/L_h and z/L_h other than those shown, linear interpolation is permitted.
2. For $H/L_h > 0.5$, assume $H/L_h = 0.5$ for evaluating K_1 and substitute 2H for L_h for evaluating K_2 and K_3.
3. Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.
4. Notation:
   H: Height of hill or escarpment relative to the upwind terrain, in feet (meters).
   L_h: Distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in feet (meters).
   K_1: Factor to account for shape of topographic feature and maximum speed-up effect.
   K_2: Factor to account for reduction in speed-up with distance upwind or downwind of crest.
   K_3: Factor to account for reduction in speed-up with height above local terrain.
   x: Distance (upwind or downwind) from the crest to the building site, in feet (meters).
   z: Height above ground surface at building site, in feet (meters).
   μ: Horizontal attenuation factor.
   γ: Height attenuation factor.

In all three multipliers, worst case scenarios were assumed to compensate for many different locations that the tent structure could be assembled at.

$\boldsymbol{P_{s30}}$ is defined by the tent structure being broken down into zones A-H. The area of each zone is then calculated as if the wind is blowing on the side and front of the structure. The figure below shows the structure and how the zones are developed.

Zone A (wall end zone)

Zone B (roof end zone)

Zone C (wall interior zone)

Zone D (roof interior zone)

End zone and interior zone locations to be considered for vertical pressures on the horizontal projection of the building surface include (Figs. 2.7*a* and *b*)

Zone E (windward roof end zone)

Zone F (leeward roof end zone)

Zone G (windward roof interior zone)

Zone H (leeward roof interior zone)

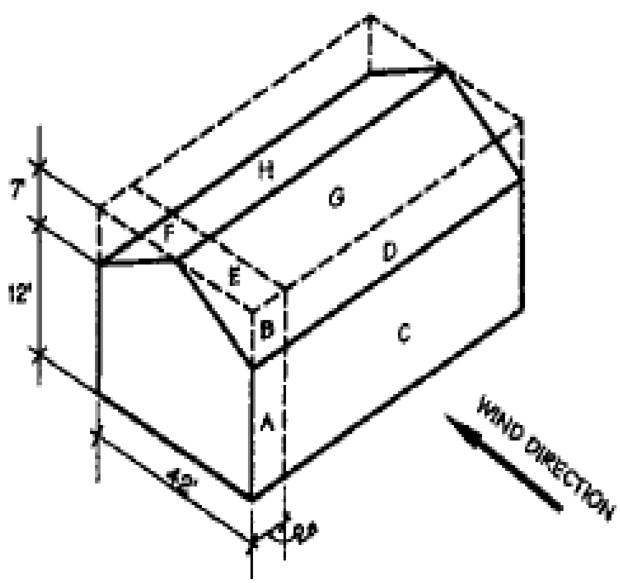


Figure 2.7a Wind pressure zones on vertical and horizontal projections of building surfaces for main wind-force-resisting systems; wind direction parallel to transverse walls (end walls).

Figure 1: Example of the tent being zoned out with the windward being on the side

Horizontal and vertical pressure were then interpolated from the table below for the different zones of the structure. It was determined that a 60 foot wide by 120 foot long tent would have a roof angle of 21.14 degrees.

Table 3: Designed wind pressures for enclosed structures. (ASCE Chapter 28 page 246)

Basic Wind Speed (mph)	Roof Angle (degrees)	Load Case	Zones									
			Horizontal Pressures				Vertical Pressures				Overhangs	
			A	B	C	D	E	F	G	H	E_{OH}	G_{OH}
110	0 to 5°	1	19.2	-10.0	12.7	-5.9	-23.1	-13.1	-16.0	-10.1	-32.3	-25.3
	10°	1	21.6	-9.0	14.4	-5.2	-23.1	-14.1	-16.0	-10.8	-32.3	-25.3
	15°	1	24.1	-8.0	16.0	-4.6	-23.1	-15.1	-16.0	-11.5	-32.3	-25.3
	20°	1	26.6	-7.0	17.7	-3.9	-23.1	-16.0	-16.0	-12.2	-32.3	-25.3
	25°	1	24.1	3.9	17.4	4.0	-10.7	-14.6	-7.7	-11.7	-19.9	-17.0
		2	--------	--------	--------	--------	-4.1	-7.9	-1.1	-5.1	--------	--------
	30 to 45	1	21.6	14.8	17.2	11.8	1.7	-13.1	0.6	-11.3	-7.6	-8.7
		2	21.6	14.8	17.2	11.8	8.3	-6.5	7.2	-4.6	-7.6	-8.7
115	0 to 5°	1	21.0	-10.9	13.9	-6.5	-25.2	-14.3	-17.5	-11.1	-35.3	-27.6
	10°	1	23.7	-9.8	15.7	-5.7	-25.2	-15.4	-17.5	-11.8	-35.3	-27.6
	15°	1	26.3	-8.7	17.5	-5.0	-25.2	-16.5	-17.5	-12.6	-35.3	-27.6
	20°	1	29.0	-7.7	19.4	-4.2	-25.2	-17.5	-17.5	-13.3	-35.3	-27.6
	25°	1	26.3	4.2	19.1	4.3	-11.7	-15.9	-8.5	-12.8	-21.8	-18.5
		2	--------	--------	--------	--------	-4.4	-8.7	-1.2	-5.5	--------	--------
	30 to 45	1	23.6	16.1	18.8	12.9	1.8	-14.3	0.6	-12.3	-8.3	-9.5
		2	23.6	16.1	18.8	12.9	9.1	-7.1	7.9	-5.0	-8.3	-9.5
120	0 to 5°	1	22.8	-11.9	15.1	-7.0	-27.4	-15.6	-19.1	-12.1	-38.4	-30.1
	10°	1	25.8	-10.7	17.1	-6.2	-27.4	-16.8	-19.1	-12.9	-38.4	-30.1
	15°	1	28.7	-9.5	19.1	-5.4	-27.4	-17.9	-19.1	-13.7	-38.4	-30.1
	20°	1	31.6	-8.3	21.1	-4.6	-27.4	-19.1	-19.1	-14.5	-38.4	-30.1
	25°	1	28.6	4.6	20.7	4.7	-12.7	-17.3	-9.2	-13.9	-23.7	-20.2
		2	--------	--------	--------	--------	-4.8	-9.4	-1.3	-6.0	--------	--------
	30 to 45	1	25.7	17.6	20.4	14.0	2.0	-15.6	0.7	-13.4	-9.0	-10.3
		2	25.7	17.6	20.4	14.0	9.9	-7.7	8.6	-5.5	-9.0	-10.3
130	0 to 5°	1	26.8	-13.9	17.8	-8.2	-32.2	-18.3	-22.4	-14.2	-45.1	-35.3
	10°	1	30.2	-12.5	20.1	-7.3	-32.2	-19.7	-22.4	-15.1	-45.1	-35.3
	15°	1	33.7	-11.2	22.4	-6.4	-32.2	-21.0	-22.4	-16.1	-45.1	-35.3
	20°	1	37.1	-9.8	24.7	-5.4	-32.2	-22.4	-22.4	-17.0	-45.1	-35.3
	25°	1	33.6	5.4	24.3	5.5	-14.9	-20.4	-10.8	-16.4	-27.8	-23.7
		2	--------	--------	--------	--------	-5.7	-11.1	-1.5	-7.1	--------	--------
	30 to 45	1	30.1	20.6	24.0	16.5	2.3	-18.3	0.8	-15.7	-10.6	-12.1
		2	30.1	20.6	24.0	16.5	11.6	-9.0	10.0	-6.4	-10.6	-12.1
140	0 to 5°	1	31.1	-16.1	20.6	-9.6	-37.3	-21.2	-26.0	-16.4	-52.3	-40.9
	10°	1	35.1	-14.5	23.3	-8.5	-37.3	-22.8	-26.0	-17.5	-52.3	-40.9
	15°	1	39.0	-12.9	26.0	-7.4	-37.3	-24.4	-26.0	-18.6	-52.3	-40.9
	20°	1	43.0	-11.4	28.7	-6.3	-37.3	-26.0	-26.0	-19.7	-52.3	-40.9
	25°	1	39.0	6.3	28.2	6.4	-17.3	-23.6	-12.5	-19.0	-32.3	-27.5
		2	--------	--------	--------	--------	-6.6	-12.8	-1.8	-8.2	--------	--------
	30 to 45	1	35.0	23.9	27.8	19.1	2.7	-21.2	0.9	-18.2	-12.3	-14.0
		2	35.0	23.9	27.8	19.1	13.4	-10.5	11.7	-7.5	-12.3	-14.0
150	0 to 5°	1	35.7	-18.5	23.7	-11.0	-42.9	-24.4	-29.8	-18.9	-60.0	-47.0
	10°	1	40.2	-16.7	26.8	-9.7	-42.9	-26.2	-29.8	-20.1	-60.0	-47.0
	15°	1	44.8	-14.9	29.8	-8.5	-42.9	-28.0	-29.8	-21.4	-60.0	-47.0
	20°	1	49.4	-13.0	32.9	-7.2	-42.9	-29.8	-29.8	-22.6	-60.0	-47.0
	25°	1	44.8	7.2	32.4	7.4	-19.9	-27.1	-14.4	-21.8	-37.0	-31.6
		2	--------	--------	--------	--------	-7.5	-14.7	-2.1	-9.4	--------	--------
	30 to 45	1	40.1	27.4	31.9	22.0	3.1	-24.4	1.0	-20.9	-14.1	-16.1
		2	40.1	27.4	31.9	22.0	15.4	-12.0	13.4	-8.6	-14.1	-16.1

The worst case scenario of a 120 mph wind was used with the roof angle of 21.14 degrees to develop wind pressures for each zone. The wind pressures were then multiplied by the area of each zone to come up with the pressures of the structure.

Application of Load Analysis

Initially SolidWorks was used to perform an overall structural finite element analysis, since the fixtures were already made in SolidWorks prior to the project. The aluminum tent poles were then created and applied to the program to get an overall skeleton of a 40’X80’ tent. A picture of the tent structure can be seen on the next page in figure two.

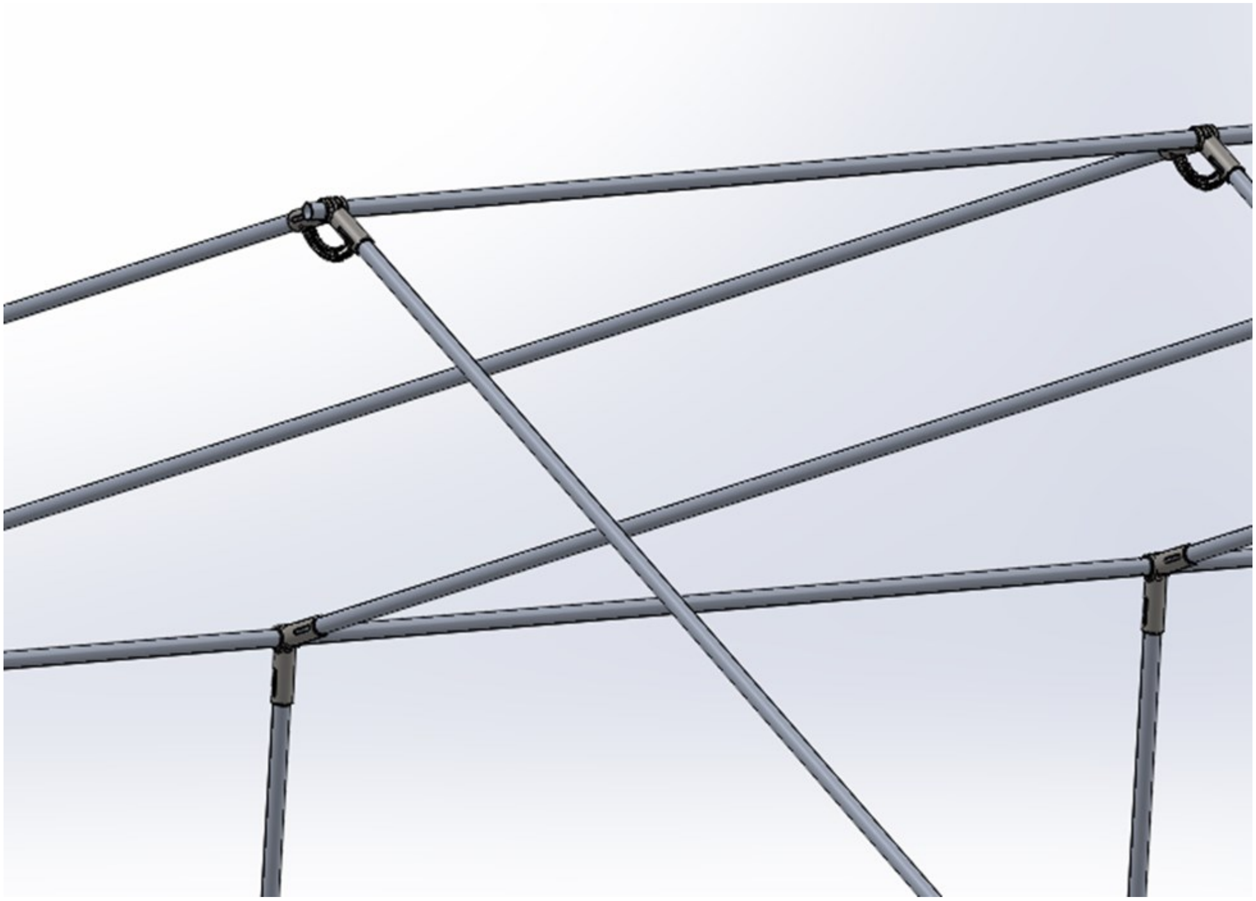


Figure 2: An example of the tent structure skeleton that was designed in SolidWorks.

Once the structure was completed, finite element analysis was applied to the structure, but we were never able to get it to run correctly due to the complex files of the fixtures and size of the tent. This process would cause the program to fail without any results.

Since SolidWorks could not give us the data we needed, we were forced to hand calculate the loads of the tent by using method of sections for a truss system. The wind loads of each zone calculated from above were applied to the structure. Then the moments were summed at the based pole on the left hand side of the structure. With the moments summed at that point, the forces then could be summed in the vertical direction to find the last missing force. This then completed our free body diagram of the tent structure and provided the location of the largest load on the tent. This load was located from the peak of the roof gable to the side vertical pole of the tent. The pole was determined to have a bending stress of 391 kips per square inch at 120 mph. Since 6061 aluminum alloy has a yield strength of 16 kips per square inch, it was determined that the tent would definitely fail at 120 mph winds. It was then decided to try a smaller wind load calculation and or a different tent pole size. With an 85 mph wind load the frame member would be receiving a force of 4323 pounds. The aluminum alloy still proved to fail even with a larger diameter pole. We then decided that a single pole will not work with a tent structure of 40’X80’ or larger.

We decided to look at various other tent structures and decided to try to apply the same calculations to a structure that has a truss structure system instead of one pole. Figure three below shows a picture of a truss structure that we have designed to allow a larger stress.

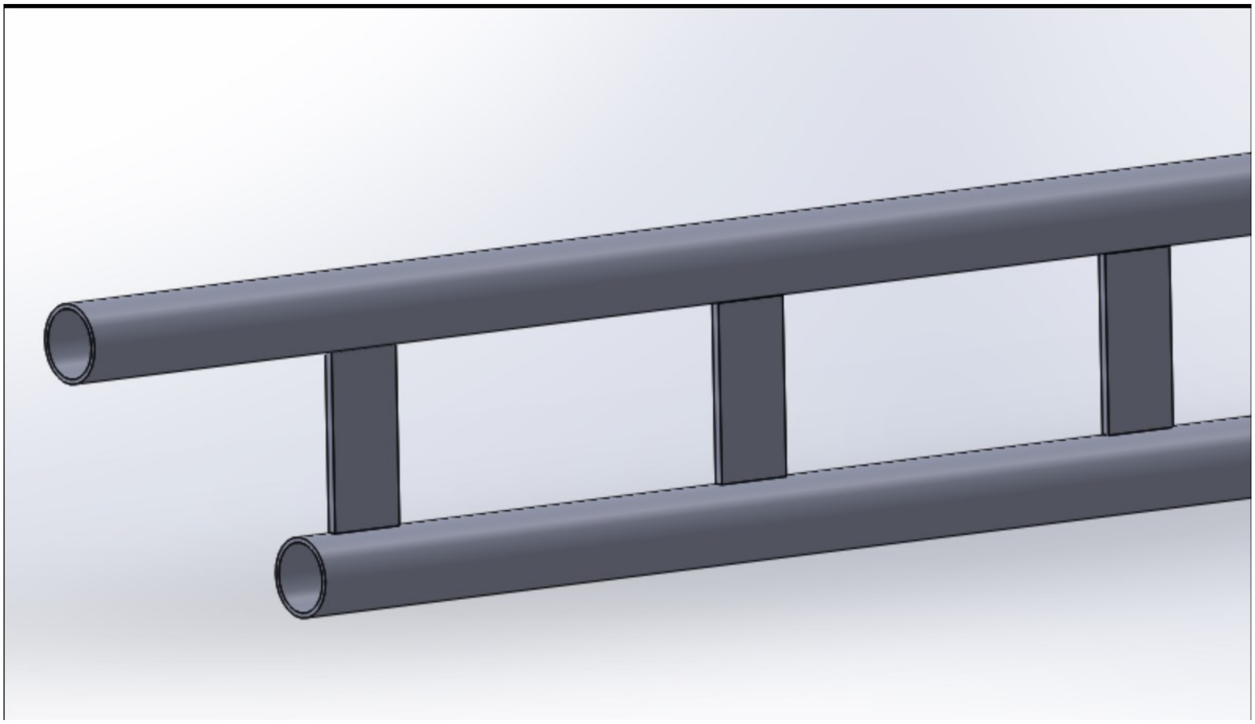


Figure 3: An example of a truss structure that would allow a larger force on a tent structure.

The 6061 aluminum alloy that was two inch diameter was then used in the truss structure illustrated above. Calculations were then run again to see if the aluminum alloy applied in this manner could handle the bending stress. We found that it could but at the expense of the distance in which the two pipes were separated. We found that with the two inch diameter aluminum alloy had to be separated at a distance of 24 inches to handle the force applied.

We then decided to work the calculations backwards from 16 kips per square inch, to the max wind load that 6061 aluminum alloy poles could handle. This was determined by using the two equations below.

$$P = \frac{F}{A\ x\ Cd}$$

$$V = (\frac{P}{0.00256})^{\frac{1}{2}}$$

Where in equation one P is equal to pressure, F is equal to force, A is equal to area, and Cd is the drag coefficient which was equal to 20. By plugging the found pressure in equation one into equation two, the wind velocity can be found in mph. It was determined that with a two inch separation of the poles that the max wind load that the aluminum 6061 alloy could withstand would be a 31 mph wind load.

Though this is a temporary structure and chances of having it set in a large wind load would be rare, we wanted to be able to come up with a solution to having a tent withstand the parameters of an 85 mph wind load. At this point since we were testing so many different scenarios, we decided to make an excel sheet that we could just enter in the size of the tubes, the separation distance between the tubes, the force perpendicular to the beam, and the length of the beam to come up with the bending stress. An example of the program can be seen in Figure four on the next page with 301 stainless steel above and 6061 aluminum alloy below.

This calculates the bending stress of a 2 pipe truss beam (pipes must be same)								
Instruction: enter information into bold boxes (5)								
					Bending Stress with no cross piece (psi):			
Pipe Outside Diameter (in):			2					31571
Pipe Inside Diameter (in):			1.75		**Bending Stress with cross piece (psi):**			
								15786
Separation Distance (in):			24		*cross piece on a tent frame divides the stress			
					between 2 beams			
Ybar composite calculation				I composite calculation				
shape	*Area*	*Ybar*	*Area*Ybar*	*shape*	*Ii*	*Ai*	*di*	*Ii+Ai(di^2)*
1	0.736311	27	19.88039	1	0.325012	0.736311	13	124.7615
2	0.736311	1	0.736311	2	0.325012	0.736311	13	124.7615
sum	1.472622		20.6167	sum				249.5231
Ybar composite (in):				**I composite (in^4):**				
	14				249.5231			
Force perpendicular (lbf):			4362	**Moment (in*lb):**				
					562698			
length of beam (in):			258					

This calculates the bending stress of a 2 pipe truss beam (pipes must be same)								
Instruction: enter information into bold boxes (5)								
					Bending Stress with no cross piece (psi):			
Pipe Outside Diameter (in):			2					147580
Pipe Inside Diameter (in):			1.75		**Bending Stress with cross piece (psi):**			
								73790
Separation Distance (in):			4.5		*cross piece on a tent frame divides the stress			
					between 2 beams			
Ybar composite calculation				I composite calculation				
shape	*Area*	*Ybar*	*Area*Ybar*	*shape*	*Ii*	*Ai*	*di*	*Ii+Ai(di^2)*
1	0.736311	7.5	5.522331	1	0.325012	0.736311	3.25	8.102295
2	0.736311	1	0.736311	2	0.325012	0.736311	3.25	8.102295
sum	1.472622		6.258642	sum				16.20459
Ybar composite (in):				**I composite (in^4):**				
	4.25				16.20459			
Force perpendicular (lbf):			4362	**Moment (in*lb):**				
					562698			
length of beam (in):			258					

Figure 3: An example of an excel program to calculate the bending stress given the dimensions in the boxed areas.

The solution we came up with was to use a quarter inch hard 301 stainless steel with a two inch diameter. As seen above in figure three this material could withstand a bending strength of 148 kips per square inch with a separation of 4.5 inches. This type of material could also be scalable to larger tents with such a larger yield strength.

Currently Produced Parts

The parts shown in the figures below are the ones currently produced by the machine shop in Spokane, WA and will be evaluated in our analysis, along with other alternatives which we may or may not deem more suitable. These parts are currently used in conjunction with standard aluminum alloy piping as the long pieces of the structure, but can easily be used with the 301 stainless steel that is made with a two inch outside diameter.

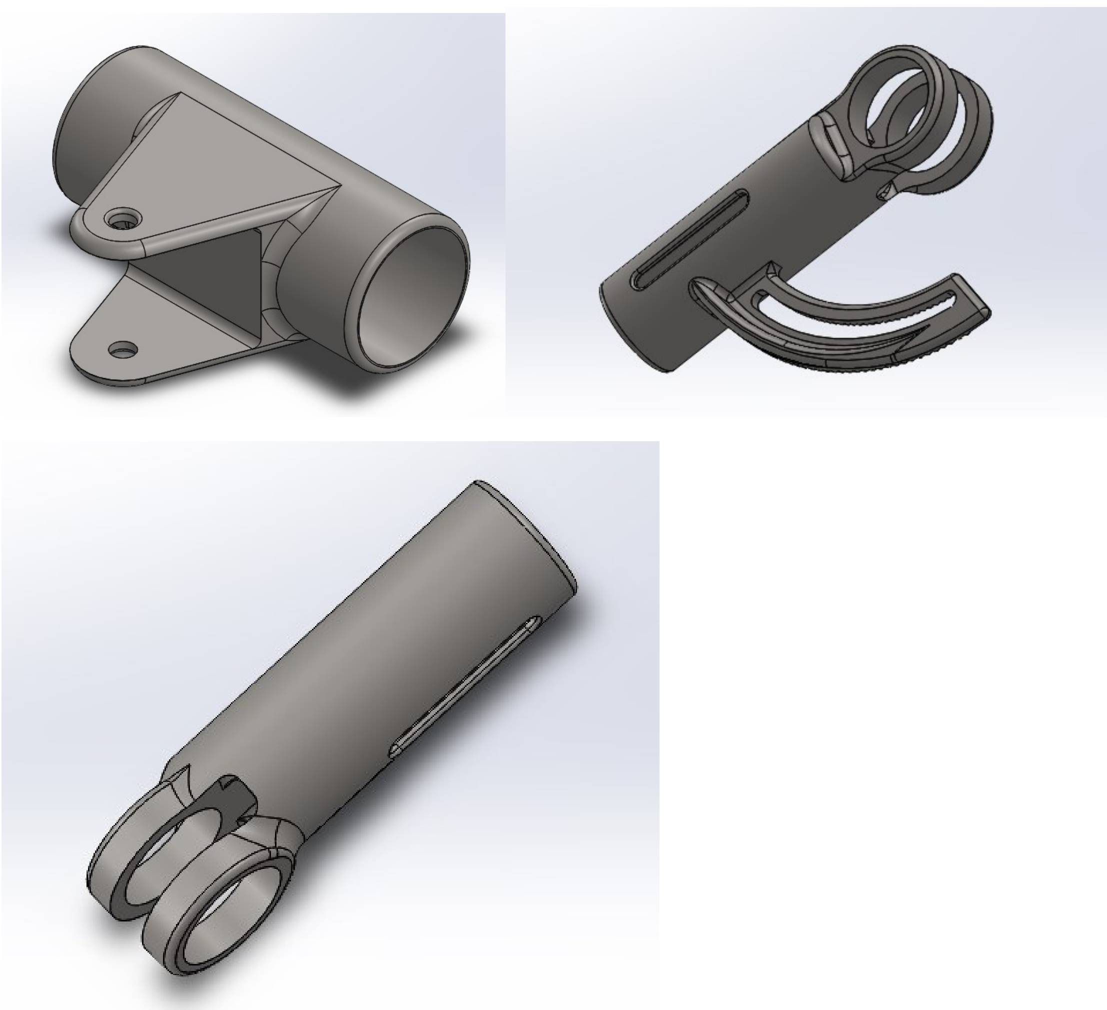


Figure 4: Slider, apex endcap with adjustable angle setting, and free-floating endcap.

Project Status

The project was going as planned until the application of SolidWorks. The fact that we could not run any structural finite element analysis had set us back. This is due to having to hand calculate the forces on the structure and understand where the weakest element would be. The wind pressures have been determined for a 60'X120', 30'X60', and 40'X80' tent. These calculations can be observed on the attached excel spreadsheet for a 60'X120' tent. We have found that a 40'X80' tent would be able to withstand 85 mph wind loads as long as the truss structure introduced above was applied. The 6061 aluminum alloy would work as long as there was a separation of 24 inches between the poles. The better alternative would be to use the quarter inch harden 301 stainless steel which had a greater yield strength and only had to be separated by 4.5 inches. There has been a total of 117 man hours dedicated to this project so far. The hours and description of time have also been attached to this report and can be observed in the attached excel spreadsheets.

The next step for this project is to apply these forces from the truss structure to the fixtures in SolidWorks. We started to apply these loads to the fixtures but still have come across the same problem as stated above. The SolidWorks program crashes when the analysis is applied. This could be due to the outdated computers that Montana Tech has. The fixtures still have not been verified to handle the loads calculated with the tent poles above. The plan in the future would be for the next senior design group to be able to apply these loads in SolidWorks and get some reasonable data with new computers.

Conclusion

Originally the scope of this project entailed the structural analysis of the supplied fixtures and how they can be applied to larger tents of 40'X80', 50'X100', and 60'X120'. The wind loads of the various size tents where determined but could not be applied when using the SolidWorks program. We found the program to crash when the finite structural analysis was applied to the various structures. This caused us to hand calculate the loads for a 30'X60' and 40'X80' tent, which made unexpected delays in finishing the project as outlined above. However because of the delay we were able to determine that the weakest link in the tent structure was a roof tent pole made of 6061 aluminum alloy. This alloy only had a yield strength of 16 kips per square inch and we had calculated the bending stress to be 56 kips per square inch. It was determined that the roof structure had to be made into a truss structure to be able to withstand the 85 mph wind loads.

An Excel program was made to quickly calculate the bending stress in a double tube truss beam when the program is given the size of the tubes, the separation distance between the tubes, the force perpendicular to the beam, and the length of the beam.

The aluminum, having a maximum allowable stress (based on yielding) of 16ksi, needed a separation distance of 24 inches to sustain the wind load at 85mph. The ¼ hard 301 stainless steel performed much better in this simulation, needing only 4.5 inches of separation distance in the beam. These calculations show that the ¼ hard 301 stainless is the superior option for building these large tents. This excel program can be used to further calculate what beam dimensions are needed for greater and lighter loads, and was given to Montana Canvas.

There has been progress in this project, but not to the scope of which is stated above. There has been a solution presented to the tent poles and making a truss structure, but there is still no analysis to the fixtures. The bending stress calculated for the truss system has to be applied to the fixtures. Since the fixtures are made of stainless steel, it can be assumed that they can withstand a larger load than the 6061 aluminum alloy poles. Best practice would be to run a finite structural analysis to the fixtures using SolidWorks or by hand calculations.

References

Breyer, D. (2007). Chapter 2 Design loads. In *Design of wood structures--ASD/LRFD* (6th ed.). New York: McGraw-Hill.

American Society of Civil Engineers (2013). Minimum Design Loads for Buildings and Other Structures. Published by American Society of Civil Engineers

http://www.aksteel.com/pdf/markets_products/stainless/austenitic/301_Stainless_Steel_PDB_201512.pdf

Personal Weekly Advising meetings

Kukay, B. (2015, September 30). Weekly advising meetings [Personal interview].

Personal Weekly Advising meetings

Hunter, L. (16, January 16). Weekly advising meetings [Personal interview].

Appendix A

Contained in this appendix are the hours worked sheet, and the excel spreadsheet showing calculations pertaining to the wind load analysis calculations

Project Hours for Montana Canvas

	Date	Hours	Description		Date	Hours	Description
Eric Schowengerdt	9/1/2015	1.5	Meet with Monatan Canvas for scope	Nick Morales	9/1/2015	1.5	Meet with Monatan Canvas for scope
	9/23/2015	2	Went to Montana Canvas to see operations		9/23/2015	2	Went to Montana Canvas to see operations
	9/30/2015	1	Met with Larry to discuss the scope of work		9/30/2015	1	Met with Larry to discuss the scope of work
	10/7/2015	2	Met with Kukay to start calculations on wind loads		10/7/2015	2	Met with Kukay to start calculations on wind loads
	10/12/2015	3	Read through ASCE Ch 26-30 and Structure anaylsis wind loads chapters		10/12/2015	3	Read through ASCE Ch 26-30 and Structure anaylsis wind loads chapters
	10/21/2015	2	Met with Kukay discussed what we read and started to define variables		10/21/2015	2	Met with Kukay discussed what we read and started to define variables
	10/26/2015	3	Broke tent structure into zones for front and side and determined K values		10/26/2015	3	Broke tent structure into zones for front and side and determined K values
	11/4/2015	2	Met with Kukay to determine K values, occupancey factor,		11/4/2015	2	Met with Kukay to determine K values, occupancey factor,
	11/9/2015	3	Build equation spreadsheet, interploated wind pressure, calc zones for 60X120 tent		11/9/2015	3	Build equation spreadsheet, interploated wind pressure, calc zones for 60X120 tent
	11/16/2015	1	Met with Kukay about previous tasks		11/16/2015	1	Met with Kukay about previous tasks
	11/27/2015	2	Build word doc of description of equations		12/1/2015	7	Worked on paper, presentation, solidworks, and hour sheet
	12/1/2015	7	Worked on paper, presentation, solidworks, and hour sheet				
	Total Hours	29.5			Total Hours	27.5	

Wind Load Calculations

λ	1.29										
Adjustment factor for building height and exposure. (pg											
Topographic multipliers for exposure C. (pg 196 ASCE)		H = Height of hill or escarpment L_h = Distance upwind of crest or escarpment x = Distance upwind or downwind of crest z = Height above ground le									
K_1	H	L_h =	0.5		**K_2**	x =	0		**K_3**	z =	0
	1	2				0				0	
Refer to pg 196 for multipliers		**K_1**	0.72			**K_2**	1			**K_3**	1
K_{zt}	2.9584										
I	1										
Occupancy category 2 table 1.1 in ASCE or IBC											
Calculated area of zones A-H for tent	a	A	B	C	D	E	F	G	H	total area	
windward (side)	12	192	278.4	768	1113.6	720	720	2880	2880	9552	
windward (front)	6	123.84				771.84	771.84	1157.8	1157.8	3983	
Pressure per zone @ 21.14 degree. Interpolated from		30.92	-5.36	21.01	-2.48	-24.05	-18.69	-16.84	-14.36		
$P_{s30\ (side)}$		5936.6	-1492	16136	-2762	-17316	-13457	-48499	-41357		
$P_{s30\ (front)}$		3829.1	0	0	0	-18563	-14426	-19497	-16625		
P_{side} =		22656	-5695	61579	-10540	-66084	-51356	-2E+05	-2E+05		
P_{front} =		14613	0	0	0	-70842	-55053	-74406	-63448		

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 2/1/16

Last week we were tasked with designing a 30X60 tent structure in SolidWorks. The purpose of this was to apply wind loads to the structure as a whole to understand how the fixtures react. The main fixture we were focusing on was the gable fixture. The problem were are running into is that we are having a hard time with making the canvas attach to the tent frame. We need this attachment because without it there is no accurate place to apply the calculated wind loads. We also need to design the connection for the 15 foot horizontal members. We anticipate this to set us back one week.

Tasks completed: 30X60 tent structure in SolidWorks
Wind load calculations for a 30X60 structure

Date	Eric Hours	Nick Hours
1/26/16	2	2
1/28/16	2	2
2/1/16	2	2
Total hours	6	6

Goals for this week:
- Finish 30X60 structure with canvas
- Make new horizontal member
- Apply wind loads to structure
- Analyze gable member

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 2/8/16

Last week we struggled to make the 30X60 structure in solid works with the tent canvas on it. It was suggested to make the exterior canvas a solid rigid plane. So we calculated the different wind zones and made individual planes to represent each wind zone on the tent. We have been able to merge the planes with the tent structure and started to apply loads. When trying to run the simulation we had many interferences. This could be due to the way the fixtures were made in Spokane. We used the stubby fixture to attach the horizontal cross members that were 15 feet long.

Tasks completed: 30X60 tent structure with outer canvas shell in SolidWorks
Corrected wind load calculations for a 30X60 structure

Date	Eric Hours	Nick Hours
1/26/16	2	2
1/28/16	2	2
2/1/16	2	2
2/2/16	1.5	1.5
2/4/16	2	2
2/8/16	2	2
Total hours	11.5	11.5

Goals for this week: Finish 30X60 structure with canvas
Make new horizontal member
Apply wind loads to structure
Analyze gable member

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 2/15/16

We still continue to struggle with running a load analysis on the tent structure. Last week scheduled a meeting with Steve Tarrant to see if he could point us in the right direction. We had submitted our program with him to look at it. He re mated the fixtures to make the geometry better. This solved the rebuild errors we got before but now we are getting mesh errors. Since the project won't mesh we can't run the simulation. We have sent off an email to SolidWorks to see if we can get some help. We are also going to schedule another meeting with Steve.

Tasks completed: 30X60 tent structure with outer canvas shell in SolidWorks
Corrected wind load calculations for a 30X60 structure
Finish 30X60 structure with canvas

Date	Eric Hours	Nick Hours	
1/26/16	2	2	
1/28/16	2	2	
2/1/16	2	2	
2/2/16	1.5	1.5	
2/4/16	2	2	
2/8/16	2	2	
2/9/16	1	1	
2/10/16	1	1	
2/16/16	1	1	
2/17/16	1	1	Met with Steve
2/18/16	1	1	
2/22/16	2	3	
Total hours	18.5	19.5	

Goals for this week:	Meet with Steve again Analyze email from SolidWorks Finish 30X60 structure with canvas Make new horizontal member Apply wind loads to structure Analyze gable member

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 2/29/16

With the issues of running the analysis through SolidWorks, it was decided to try to make calculate the forces in just the front structure. By doing this we could narrow down the pole with the most force on it and spec the tent structure to that. This was decided during our presentation on 2-29. With the loads we could also try to simplify the analysis on SolidWorks to just the pole or members. So far we have determined the forces on the front structure by summing the moments and forces in the y direction. We also developed a shear moment diagram to see which force is greater on that beam. Based off this information we were able to size the pipe that would be needed to make this basic structure work.

Tasks completed:

- 30X60 tent structure with outer canvas shell in SolidWorks
- Corrected wind load calculations for a 30X60 structure
- Finish 30X60 structure with canvas
- Load calculations on front tent assembly
- Shear/Moment diagram of pole with largest loads
- Determined size of pipe for structure as is

Date	Eric Hours	Nick Hours	
1/26/16	2	2	
1/28/16	2	2	
2/1/16	2	2	
2/2/16	1.5	1.5	
2/4/16	2	2	
2/8/16	2	2	
2/9/16	1	1	
2/10/16	1	1	
2/16/16	1	1	
2/17/16	1	1	Met with Steve
2/18/16	1	1	
2/22/16	2	3	

2/24/16	2	2	
2/28/16	3	3	
2/29/16	2	2	Presentation on Status
3/3/16	1	1	
3/7/16	2	2	
Total hours	28.5	29.5	

Goals for this week:
- To put hand calculations into excel
- Apply loads to members in solid works
- Run analysis in SolidWorks to compare hand calculations
- Analyze gable member

Montana Canvas Tent Structure Design

Weekly report

Eric Schowengerdt
Nick Morales

Date 3/7/16

It was determined that with a wind load of 120 mph, that the current structure could not handle this. So it was suggested to work backwards using a wind load of 80 mph to determine if the current structure could handle this. We have also researched other tent structure types and have found one that looks like a great idea. It has actual truss support opposed to just one pole. We have now started calculations to see if that could hold 120 mph wind load with the fixtures designed. We also decided to try to work it backwards to see what size pole can work with an 80 mph wind load.

Tasks completed:

- 30X60 tent structure with outer canvas shell in SolidWorks
- Corrected wind load calculations for a 30X60 structure
- Finish 30X60 structure with canvas
- Load calculations on front tent assembly
- Shear/Moment diagram of pole with largest loads
- Determined size of pipe for structure as is
- Found new structure to apply loads to
- Determined loads calculated for current structure and 120mph wind

Date	Eric Hours	Nick Hours	
1/26/16	2	2	
1/28/16	2	2	
2/1/16	2	2	
2/2/16	1.5	1.5	
2/4/16	2	2	
2/8/16	2	2	
2/9/16	1	1	
2/10/16	1	1	
2/16/16	1	1	
2/17/16	1	1	Met with

			Steve
2/18/16	1	1	
2/22/16	2	3	
2/24/16	2	2	
2/28/16	3	3	
2/29/16	2	2	Presentation on Status
3/3/16	1	1	
3/7/16	2	2	
3/9/16	3	3	
3/21/16	2	2	
Total hours	33.5	34.5	

Goals for this week:

- To put hand calculations into excel
- Apply loads to members in solid works
- Run analysis in SolidWorks to compare hand calculations
- Analyze gable member
- Load calculations for new structure

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 3/21/16

We found that the 15.875 foot pole could not handle loads of 85mph alone. There will have to be support applied to the pole based off of our new structural design of the tent. This means making the poles into a truss form and adding another horizontal member. We will move forward by determining whether the new design can handle the new loads. We are still calculating a simple truss that can handle a 120mph wind load.

Tasks completed:
- 30X60 tent structure with outer canvas shell in SolidWorks
- Corrected wind load calculations for a 30X60 structure
- Finish 30X60 structure with canvas
- Load calculations on front tent assembly
- Shear/Moment diagram of pole with largest loads
- Determined size of pipe for structure as is
- Found new structure to apply loads to
- Determined loads calculated for current new structure at 80mph wind

Date	Eric Hours	Nick Hours	
1/26/16	2	2	
1/28/16	2	2	
2/1/16	2	2	
2/2/16	1.5	1.5	
2/4/16	2	2	
2/8/16	2	2	
2/9/16	1	1	
2/10/16	1	1	
2/16/16	1	1	
2/17/16	1	1	Met with

			Steve
2/18/16	1	1	
2/22/16	2	3	
2/24/16	2	2	
2/28/16	3	3	
2/29/16	2	2	Presentation on Status
3/3/16	1	1	
3/7/16	2	2	
3/9/16	3	3	
3/21/16	2	2	
3/21/16	2	2	
3/23/16	1	1	
3/28/16	2	2	
Total hours	38.5	39.5	

Goals for this week: To put hand calculations into excel
Load calculations for new structure

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 3/21/16

We started working on 40X80 tent. We calculated the bending stress at 85 mph. With the cross pieces the bending stress ended up being 55774 psi on a truss piece that is a one inch tube on top of a 3 inch tube and separated by 4 inches. We need to be at 32,000 or less for stainless steel because that is its yield strength. We worked the tubes backwards to get the max wind speed that the tent can handle.

Tasks completed:
- 30X60 tent structure with outer canvas shell in SolidWorks
- Corrected wind load calculations for a 30X60 structure
- Finish 30X60 structure with canvas
- Load calculations on front tent assembly
- Shear/Moment diagram of pole with largest loads
- Determined size of pipe for structure as is
- Found new structure to apply loads to
- Determined loads calculated for current new structure at 80mph wind
- Designed new truss structure for tent
- Calculated yield strength of new truss section
- Found psf for zone B=2.48 and zone E=3.93
- Found yield strength of truss 32,000 psi
- Found force with 85 mph of 40X80 tent to be 55,774 psi

Date	Eric Hours	Nick Hours
1/26/16	2	2
1/28/16	2	2
2/1/16	2	2
2/2/16	1.5	1.5
2/4/16	2	2
2/8/16	2	2

2/9/16	1	1	
2/10/16	1	1	
2/16/16	1	1	
2/17/16	1	1	Met with Steve
2/18/16	1	1	
2/22/16	2	3	
2/24/16	2	2	
2/28/16	3	3	
2/29/16	2	2	Presentation on Status
3/3/16	1	1	
3/7/16	2	2	
3/9/16	3	3	
3/21/16	2	2	
3/21/16	2	2	
3/23/16	1	1	
3/28/16	2	2	
3/29/16	1	1	
3/31/16	4	4	
4/4/16	1	1	
Total hours	44.5	45.5	

Montana Canvas Tent Structure Design
Weekly report

Eric Schowengerdt
Nick Morales

Date 4/4/16

We started to calculate the truss with the same size tubing on top and bottom. We need to figure out the separation distance to make the truss work with a reasonable wind pressure. Once this is accomplished we will apply the forces to the fixtures in solid works. The next step will be looking at a 50X100 size tent and apply the same procedure, time permitting.

Tasks completed:

- 30X60 tent structure with outer canvas shell in SolidWorks
- Corrected wind load calculations for a 30X60 structure
- Finish 30X60 structure with canvas
- Load calculations on front tent assembly
- Shear/Moment diagram of pole with largest loads
- Determined size of pipe for structure as is
- Found new structure to apply loads to
- Determined loads calculated for current new structure at 80mph wind
- Designed new truss structure for tent
- Calculated yield strength of new truss section
- Found psf for zone B=2.48 and zone E=3.93
- Found yield strength of truss 32,000 psi
- Found force with 85 mph of 40X80 tent to be 55,774 psi
- Determined the yield strength of the 2X2 inch tube truss
- Researched possible metals that might work for truss

Date	Eric Hours	Nick Hours	
1/26/16	2	2	
1/28/16	2	2	
2/1/16	2	2	
2/2/16	1.5	1.5	
2/4/16	2	2	
2/8/16	2	2	
2/9/16	1	1	
2/10/16	1	1	
2/16/16	1	1	
2/17/16	1	1	Met with Steve
2/18/16	1	1	
2/22/16	2	3	
2/24/16	2	2	
2/28/16	3	3	
2/29/16	2	2	Presentation on Status
3/3/16	1	1	
3/7/16	2	2	
3/9/16	3	3	
3/21/16	2	2	
3/21/16	2	2	
3/23/16	1	1	
3/28/16	2	2	
3/29/16	1	1	
3/31/16	4	4	
4/4/16	1	1	
4/6/16	2	2	
4/11/16	1	1	
Total hours	47.5	48.5	

Goals for this week:
- Determine the distance between the 2 two inch tubes for truss
- Apply determined loads to the fixtures in SolidWorks
- Work on Poster
- Repeat for larger tent
- Find alternative metal that would handle larger loads