Final Report for 4 Seasons Tent

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DEPARTMENT OF MECHANICAL ENGINEERING

4 Seasons Tent

Final Report

Sponsoring Company

Alsalam Charity Organization

by

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In partial fulfillment of the requirements of the course

ME 459

Engineering Design

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Executive Summary

A tent exists from a long time, and people are trying their best to develop it in order to help the humanity. The actual starting of the development of the tents was during world war 1 to provide a portable shelter for support activities and supplies which called ERA tent [1]. Nowadays, WeatherHYDE tent which is made by Billion Bricks in 2016 is considered as an effective tent to provide a safe place to rest in for camping and such activities [2]. In addition, this tent can be used for homeless people and refugees because as known the number of homeless is increasing year by year. Billion Bricks used special materials to build this tent which it can be developed to be helpful through the most dangerous conditions. In this study, the 4 seasons tent is modifying from an effective tent. This search discussed the product design specification the need statement based on the results of the surveys that is solved by homeless and refugee people in Urfa, Turkey, also the survey has been given for Tarahom group which is a volunteer campaign. This group visited refugees in Turkey on 25 of February 2020.

Homeless people in Urfa are living in worn tents, which have a weak frame structure that are collapsing due to strong wind. In addition, the rain leakage problem inside the tent, snow sticking on the top of the tent, and flammable cover are common problems with most existing tents. The aim of this project is to improve the current tents to provide a safe shelter to live in. 4 Seasons Tent cover is made of three layers of different materials (insulation, water resistance and reflective), where a waterproof floor is used to prevent the leakage of rain and snow. Its frame is made of PVC pipes and fittings, nevertheless, windows and removable doors are used to provide a natural ventilation. A thermal and structural analyses were done on a 3D model of the tent. Based on analysis, 4 seasons tent frame withstands winds of 50 km/h. Furthermore, inside environment will be kept at least 6 degrees warmer than the outside in winter, and at least 6 degrees cooler in summer. 4 seasons cover is reversible and can be used in all seasons. This tent is waterproof, fire-resistant, portable, breathable, and has a lightweight which can be installed by one person. The cost of this tent is acceptable and has 4-year service life.

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Nomenclature

F	Force
P	Pressure
T	Temperature
q''	Heat flux
A	Area
V	Volume
D_o	Outer diameter
D_i	Inner diameter
T_o	Outer temperature
T_i	Inner temperature
I	Moment of inertia
h	Convective heat transfer coefficient
k	Thermal conductivity
C_p	Specific heat
σ	Stefan-Boltzmann constant
ε	Emissivity
m	Mass
g	Acceleration due to gravity
R	Thermal resistance
q	Heat transfer rate
E	Energy
t	Thickness
L	Length
r_m	Mean radius
A_m	Mean area
E	Modules of elasticity
α	Coefficient of linear expansion
S_y	Tensile yield strength
ρ	Density
v	Poisson’s ratio
σ_b	Bending stress

σ_{yield}	Yield stress
F_W	Force due to wind
F_s	Force due to snow
P_d	Dynamic pressure
V_m	Maximum velocity
y	Deformation
w	Load per unit length
$\frac{d\rho}{dt}$	Change of air density
$\vec{U}$	Velocity of air
R_e	Reynolds number
R_a	Rayleigh number
μ	Viscosity of air
T_s	Surface temperature
T_f	Film temperature
α	Thermal diffusivity
β	Fluids volumetric thermal expansion coefficient
γ	Kinematic viscosity
Q	Ventilation
C_d	Discharge coefficient
$\dot{m}$	Mass flow rate
C_p	Pressure coefficient

Scope

The contents of this report were prepared by senior mechanical engineering students at Kuwait University. We feel confident in our work as students. However, all material should be reviewed by an appropriate professional before implementation.

Introduction

Bad weather conditions can cause death for people especially for homeless and refugees. Extreme change of weather could kill 1300 persons per year in the United State [3] Especially with global warming issues, where every summer is hotter and unbearable than the last. In addition to the natural disasters such as tornados, massive fires, earthquakes, volcanos, and floods. These phenomena lead to damages and death, especially for those who do not have any safe place to seek shelter. On the other hand, war and political issues are damaging people’s houses and putting their lives at a major risk. Today, there are millions of refugees worldwide. People are living in tents and informal settlements on the borders. These families are relying on the aid of the others, and they are the only hope that they have got. In winter, where the temperatures set to drop up to minus 12 degrees in Lebanon’s borders. These families cannot help their children and keep them warm and safe [4] Kuwait has always been one of the most countries that helps those in-need. There are a lot of Kuwaiti charity organizations such as Tarahom group, Alsalam group, Human Rights Organization and International Islamic Charity Organization.

Tarahom group organized a voluntary visit to Urfa, Turkey in 25-26, February 2020. They used to help Syrian refugees and homeless in all around the world. In their last trip, smiles were spread on the refugees faces. They celebrated the National days of Kuwait with them by playing traditional games, delivering food, blankets, clothes and gifts.

In this course, a tent would be designed for homeless people. This tent will provide a warm and safe place for them. It will heat the place in winter and cool it in summer. The goal is to have a safe and comfortable place for the customers. The customers can be workers in work sites and areas, homeless, etc. In addition, the tent can be used for people in countries where natural disasters occur. This tent will have a special design and protects from rain, snow, extreme hot, extreme cold and dust.

Background

Patents:

The main concept of the shelter was discussed in one of the United States patents under title: **Rapid deployment shelters and shelter systems** [5]

. Any shelter could consist of walls, roof and floor, where it is an enclosed place. The temporary modular shelter system can be disassembled and assembled without any heavy tools. The walls consist of layers that made of special materials. They are somehow connected to the roof and floor; so, the components are supporting each other. The structure of the shelter is thermally insulated by using insulation layer. In addition, the expandable connector can be used in the roof to provide large shaded area.

Portable, protective shelter patent that has a number of 10,428,541 in United States patents site [6] . This invention is a waterproof, collapsible, portable, transportable, and detachable shelter. The shelter is made of lightweight and weatherproof materials. The wall, roof and floor are semi-rigid. One of the layers is fabric layer, which consists of fiber and coating layer. Briefly, the shelter components are consisting of base material, insulating material, reinforcing material, coating layer, wallpaper, and paint. The shelter has geometric shapes such as cubic, rectangular, octagon, pentagon, dome, and pyramid. Magnetic fasteners are used to connect between the components of the shelter; they are located at edges of the wall and roof, Figure 1.

US010428541B2

(12) **United States Patent**
Harve et al.

(10) **Patent No.: US 10,428,541 B2**
(45) **Date of Patent: Oct. 1, 2019**

(54) **PORTABLE, PROTECTIVE SHELTER**

(71) Applicants: **Shweta Harve**, Plano, TX (US); **Fermin Baeza**, Bonham, TX (US)

(72) Inventors: **Shweta Harve**, Plano, TX (US); **Fermin Baeza**, Bonham, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/636,691**

(22) Filed: **Jun. 29, 2017**

(65) **Prior Publication Data**

US 2018/0002939 A1 Jan. 4, 2018

Related U.S. Application Data

(60) Provisional application No. 62/356,277, filed on Jun. 29, 2016.

(51) **Int. Cl.**

E04H 1/12 (2006.01)
E04H 15/48 (2006.01)
E04B 1/12 (2006.01)
E04B 1/343 (2006.01)
A01K 1/03 (2006.01)
E04B 1/00 (2006.01)
E04B 1/61 (2006.01)
E04H 15/18 (2006.01)

(52) **U.S. Cl.**

CPC ***E04H 1/1205*** (2013.01); ***A01K 1/033*** (2013.01); ***E04B 1/12*** (2013.01); ***E04B 1/34321*** (2013.01); ***E04H 15/48*** (2013.01); *E04B 1/34384* (2013.01); *E04B 2001/0053* (2013.01); *E04B 2001/6195* (2013.01); *E04H 1/12* (2013.01); *E04H 15/18* (2013.01)

(58) **Field of Classification Search**

CPC .. E04B 1/343; E04B 1/34315; E04B 1/34321; E04B 1/34357; E04B 1/34384; E04B 2001/34389

See application file for complete search history.

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(57) **ABSTRACT**

A shelter includes: at least two side walls; a back wall; and a roof, wherein the side walls, the back wall, and the roof comprise a material that is weatherproof and insulated, and wherein the shelter is collapsible, detachable, and portable. The shelter can also include at least two side walls, wherein an upper end of the at least two side walls conjoin to form a roof. The shelter is lightweight, detachable, and portable. The shelter can be weatherproof and insulated for permanently or temporarily housing people and/or animals. The shelter can be transported to a desired location and assembled on-site with ease. When the use of the shelter is no longer desired, the shelter can be quickly disassembled and transported to another location.

16 Claims, 8 Drawing Sheets

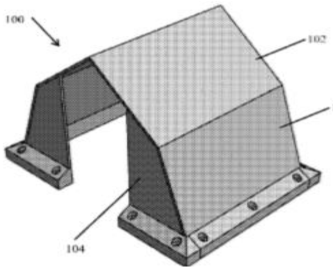

Figure 1: Portable, protective shelter

Collapsible structure with fabric covering could have a folding frame system. Folding elements provide a tent that can be easily deployed. These elements have a self-resting lock mechanism. More information and details about these mechanisms can be explained in United States patents website under title: **Rapidly deployable modular shelter system**, which has number 10,392,828 [7].

Hydroponic tent is one of the effective inventions, where it provides specific weather conditions and controls the inside environment [8]. The frame is supplied by linkages, which provide stability and reduce the risk of collapsing accidents. The inside surface is covered by polyester resin coating, which is a light-reflective and waterproof material. In order to achieve the necessary environmental conditions, electrical equipment may be used, which are very heavy comparing with the tent's weight. This type of tents is useful for plants growing under certain environmental conditions.

US00D872818S

(12) **United States Design Patent**
Zhu

(10) **Patent No.:** **US D872,818 S**
(45) **Date of Patent:** ** **Jan. 14, 2020**

(54) **TENT**

(71) Applicant: **Wenjie Zhu**, Danyang (CN)

(72) Inventor: **Wenjie Zhu**, Danyang (CN)

(**) Term: **15 Years**

(21) Appl. No.: **29/673,230**

(22) Filed: **Dec. 13, 2018**

(51) **LOC (12) Cl.** **21-04**

(52) **U.S. Cl.**
USPC **D21/837**

(58) **Field of Classification Search**
USPC D21/834, 837, 839; D25/22, 56, 61
CPC E04H 15/00; E04H 15/02; E04H 15/18; E04H 15/28; E04H 15/32; E04H 15/34; E04H 15/40; E04H 15/42; E04H 15/425; E04H 15/50
See application file for complete search history.

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D775,296	S	*	12/2016	Shir	D21/837
D778,383	S	*	2/2017	Xu	D21/837
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Primary Examiner — Cynthia M. Chin
(74) *Attorney, Agent, or Firm* — Law Offices of Steven W. Weinrieb

(57) **CLAIM**

The ornamental design for a tent, as shown and described.

DESCRIPTION

FIG. **1** is a front, right side, top perspective view of the tent showing my new design;
FIG. **2** is a rear, left side, top perspective view thereof;
FIG. **3** is a rear, right side, bottom perspective view;
FIG. **4** is a front elevational view thereof;
FIG. **5** is a rear elevational view thereof;
FIG. **6** is a left side elevational view thereof;
FIG. **7** is a right side elevational view thereof;
FIG. **8** is a top plan view thereof;
FIG. **9** is a bottom plan view thereof; and,
FIG. **10** is a front, right side, top perspective view thereof showing the tent in a state of use.
The broken lines are for the purpose of illustrating portions of the article that form no part of the claim.

1 Claim, 10 Drawing Sheets

Figure 2: Tent's structure patent

In order to know the problems in the current tents and what are needed to improve them, where two surveys have been done, one for refugees who lived in Urfa in Turkey and the other one is for the charity organizations.

Customers responding test

In order to know the problems in the current tents and what are needed to improve them, where two surveys have been done, one for refugees who lived in Urfa in Turkey and the other one is for the charity organizations. These surveys were conducted in February 2020.

The aim of the first survey is to find out the customer needs (refugees). One of the findings from this survey is the current tent is not comfortable to spend 7-10 hours in it. Based on the results and findings, the tent should have the descriptions that are represented in Table 1.

Table 1: Tent descriptions

	Agree	Strongly Agree	Others/Neutral
Warm in Winter	25%	85%	-
Cool in Summer	49%	51%	-
Rain resistance	49%	51%	-
Enough for 1	5%	85%	10%
Light Source	10%	22%	68%
USB Charger	5%	11%	84%

The aim of the second survey is to find out the sponsors requirements. The findings of this survey are clarified in Table 2.

Table 2: Sponsor requirements

<table>
<tr><td>Families and Children</td><td colspan="4">Higher than 80</td></tr>
<tr><td>Family Members</td><td colspan="4">4 to 7</td></tr>
<tr><td>Organization Level</td><td colspan="2">International</td><td colspan="2">Refugees Community National</td></tr>
<tr><td>Helping Fields</td><td>Feed</td><td>Residence</td><td>Health and Medical Care</td><td>Education</td></tr>
<tr><td>Acceptable Cost</td><td colspan="4">100 to 150 KD</td></tr>
</table>

These recommendations from the participating organization (Al-Tarahum Group) will be taken into consideration during design this shelter. The details of the surveys questions and answers are shown in Appendix A.

Problem Statement and PDS

The number of homeless people in the world who do not have protections from rain, snow and extreme weather varies are approximately 150 million [9]. Those homeless people depend on assistance from charity organizations. Those charity organizations provide tents, food, and clothes for the homeless people. The aim of this project is to improve the current tents and grow them to become more comfortable for homeless people. For this project, the tent will be used for refugee people from Urfa in Turkey to provide a safe place and shelter for them. Figure 3 shows the current tents for refugee people in Urfa.

Figure 3: Current tents for refugee people in Urfa.

The current tents are not strong enough and not safe, they are collapsing due to the strong wind as shown from the previous Figure.

In addition, it can be noticed from Figure 3 that the current tents are not comfortable, the rain leaks inside the tent which makes a disaster and hard for the people who lives inside the tent. In addition, Figure 4 shows another problem in the current tents, which is the snow sticks on the top and sides of the tent that makes the weather inside the tent very cold which affects the nature of their lives.

Figure 4: The problem of snow in the current tent [10]

The following Figure shows another problem in the current tents, which is the tent, is not fire resistant.

Figure 5: The problem of fire in the current tents [11]

Figure 5 shows an actual accident happened in 2015, in this accident two children died because of the tent is not fire resistance [11]. So, those refugee people should be protected from the previous problems. From those problems, the need statements for this project are concluded which provides a shelter and safe place for refugee people, provides a cool place in summer and warm place in winter by using special materials for the cover of the tent, aim to preserve from rain and snow by using water resistance materials for the tent and protects from strong wind by using strong structure for the tent. As said before, the Urfa in Turkey will be the case study for this project. The maximum Temperature in Urfa is 40 degree Celsius while the minimum temperature is 0 degree Celsius. The maximum rain fall amount is found to be 264.3 mm, the maximum snow fall amount is 8.1 cm, the maximum speed of the wind equals 29.2 Kmph and the maximum Ultra-Violet (UV) Index is 9 [12] ; Urfa climate details are shown in Appendix B.

Product Design Specifications

Design brief

After a long research, it has been decided that a shelter need to be designed. This shelter is a tent that has warmer weather in winter then the outside, and cooler weather inside than outside in summer by using special materials. In addition, this tent withstands winds and huge fire. The tent should be portable, installable, lightweight, and secure.

The Performance of 4 Seasons tent is:

- Waterproof tent so, the water will not leak inside the tent.
- Portable tent, which can be carried by one person.
- Comfortable for two adults and one child.
- Fire resistance tent, by using fire protection coating.
- It gives a safe place and shelter.
- It provides a cool place in summer.
- It provides a cool place in winter.
- Efficiency of the product is high preferably in the area of 40 – 45 %.

Product life span:

- The life span of this product is approximately 4 years, which is discussed in appendix H.

Life in service:

- The 4 seasons tent should withstand an operating period of 24 hours uninterrupted use per day for 1 to 4 years.

Shelf life:

- The shelf life is expected to be 5 years.

Target cost:

- The product has a cost no more than 250 – 350 KD, where the most aim for this project is to have a low cost because it will be used for refugees Appendix H.
- The cost of packing and shipping less than 5% of the product cost.

Quantities:

- 10,000 tents per year, since the number of refugee families is increasing year by year.

Maintenance:

- There will be an alternative Velcro with sewing tools.
- There will be a patch of the cover fabric.
- Fittings and pipes (PVC) can be changed and replaced.

Marketing:

- The applicable markets for this product are:
    1. Tarahom group.
    2. International Islamic charity organization.
    3. Dinarain group.
    4. Human rights club ‘Gust’.
    5. Alsalam community organization.
- Summary of market requirements:
    1. Portable tent.
    2. To be used in all seasons.

Packaging:

- The cost of packing and shipping less than 5% of the product cost.
- It will be transmitted by a fabric bag.

Size and weight restrictions:

- Total weight equals 24.5 kg since this tent should be lightweight.
- Length equals 2 m. (Depends on standard size of sleeping bags)
- Width equals 2 m. (Depends on standard size of sleeping bags)
- Peak height equals 1.8 m. (Standard size for the standing peak height of the camping tent)
- Eave (Side Wall) height equals 0.8 m.

- Desired slope equals $\sqrt{2}$ m.
- One person could carry package size.

Shipping:

- The product will be shipped by plane within charity organizations to Turkey.

Aesthetics:

- The color of the tent should be dark for the privacy especially for women.
- The tent looks good, acceptable, and comfortable to look.

Ergonomics:

- Good human factors, since the size of the tent follows the standard size of sleeping bag for two adults "shown in standards and specifications".

Customer requirements:

- See marketing.

Competition:

- This product is competing with similar product, which is weatherHYDE by Billion Bricks.
- The product should be assembled and disassembled by one person.
- There will be Velcro and patches for repairing.

Quality and reliability:

- The product could withstand for 4 years, approximately.

Standards and specifications:

- In order to decide the tent width and length, sleeping bag size has been used to calculate the area for two sleeping bags since the tent will be designed for two adults and one child, the dimensions are taken from a company standard (criterion company), the following link is the reference for this standard: **https://www.criterion-sleepingbags.co.uk/technology/sleeping-bag-sizes/**
- For choosing the height of the tent, camping tent standard has been used. The standing height, which is 1.8 meters is used as peak height since this height will allow the customers to move inside the tent and change their clothes easily, the following link is the reference for this standard: **https://www.campetent.com/family-camping-tent-sizes.html**

Company constraints:

- None.

Processes:

- The cover of the tent will coat with fire resistant material.
- Sewing process for the cover.

Safety:

- Fire resistance tent.
- Waterproof tent.
- The PVC pipes are strong enough so, the tent will not collapse.

Testing:

- Structure strength check.
- Material reflection testing.
- Thermal testing.

Installation:

- This tent is installable.
- One person without additional tools can install it.

Documentation:

- There will be a manual that guide the users to build the tent and the life span of the tent will be included in this manual.

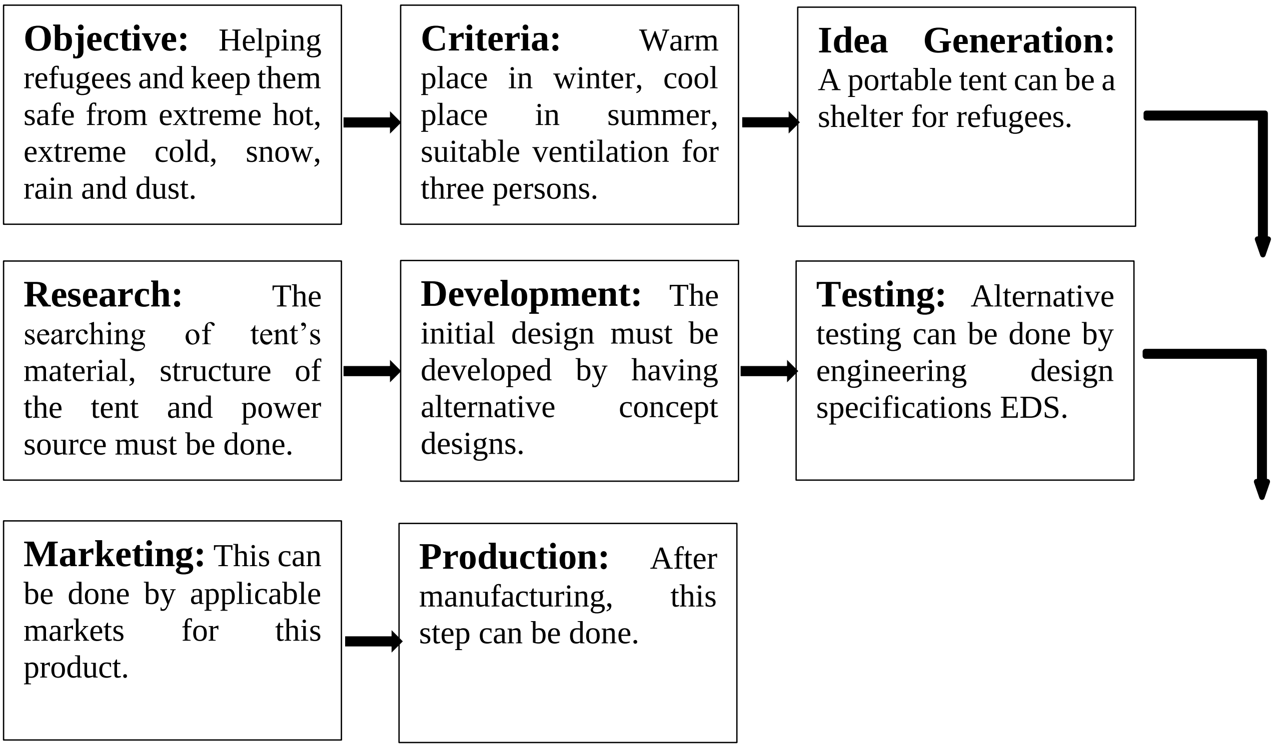
Disposal:

- Most of the chosen materials had a plastic as a main component in it, and it is possible but not easy to recycle the plastic material.

Project Milestones

In case to have this product to be done, a following product planning must be studied and confirmed.

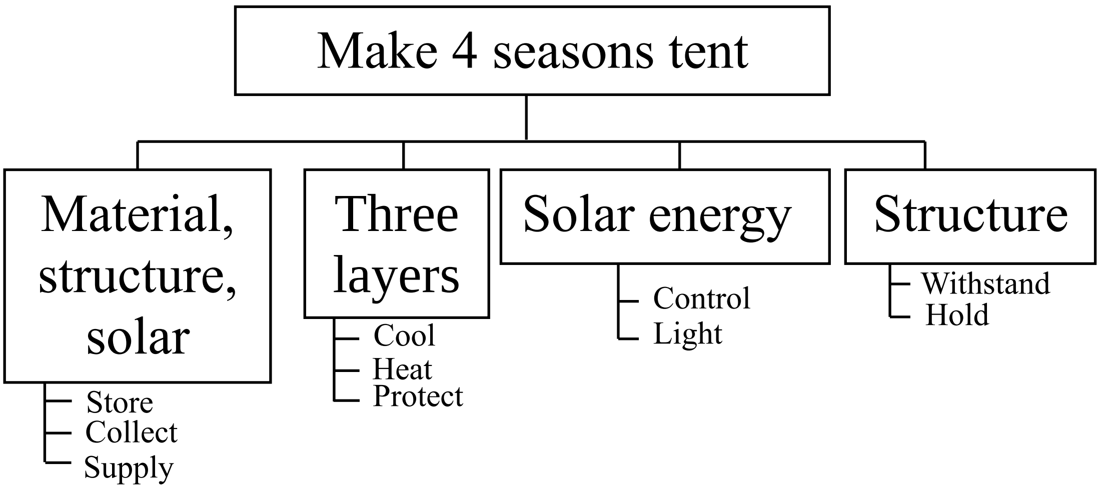
Product Planning:



Each box in the previous block diagram will be clarified in the Gantt Chart in the next section.

After brain storming, decomposition diagram can clear the steps and actions briefly to have the 4 seasons tent.

Decomposition diagram:



Schedule

In this section, all the tasks and their durations are clear in the following chart (Gantt chart) Figure 37.

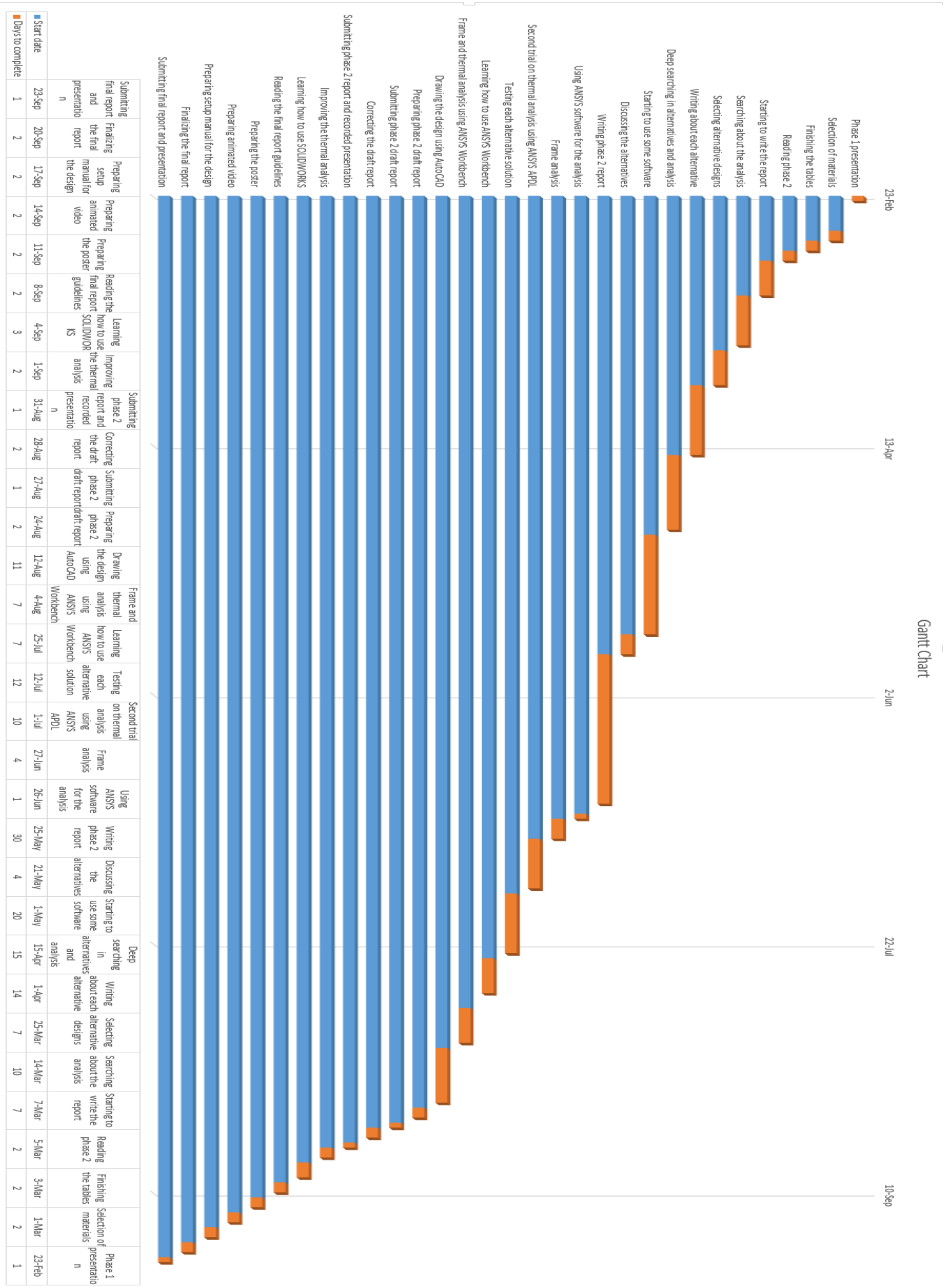


Figure 6: Gantt chart

Most of the tasks are done as a teamwork. Some of the tasks are divided equally on the team members such as the typing report parts. In summary, each of the team members spent around 6 hours daily on the project during weekdays and on weekends; 6 hours are spent as a total number of spending hours. However, 16 hours is the maximum spent time.

Possible Alternative solutions

The design will be chosen based on some criteria. The weighting criteria are as follows:

Table 3: Weighting criteria

Rating	Value
Unsatisfactory	0
Just Tolerable	1
Adequate	2
Good	3
Very Good	4
Excellent	5

The following tables demonstrate the weighting alternative criteria for each material.

Table 4: Weighing alternative criteria for reflective materials

	Mylar			Foylon	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score
Environmentally friendly	5%	1.0	0.05	1.0	0.05
Reflection	35%	4.5	1.58	4.5	1.58
Waterproof	30%	5.0	1.50	5.0	1.50
Low Cost	10%	5.0	0.50	1.0	0.10
Life Span	10%	5.0	0.50	4.0	0.20
Light Weight	10%	5.0	0.50	5.0	0.50
Total Score			4.63		3.93

Table 5: Weighing alternative criteria for waterproof materials part a

	190T PU Coating Polyester			Nylon Silicone Coating	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	5%	1	0.05	5	0.25
Waterproof	30%	5	1.50	5	1.50
Low Cost	10%	5	0.50	1	0.10
Life Span	10%	5	0.50	4	0.40

Light Weight	10%	5	0.50	5	0.50
UV-Protection	10%	5	0.50	2	0.20
Breathability	10%	5	0.50	0	0.00
Fire Resistance	15%	5	0.75	0	0.00
Total Score			4.75		2.95

Table 6: Weighing alternative criteria for waterproof materials part b

	Lexi Cotton		**Kevlar**	
Selection criteria	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	5	0.25	5	0.25
Waterproof	5	1.50	5	1.50
Low Cost	5	0.50	1	0.10
Life Span	4	0.40	5	0.50
Light Weight	5	0.50	5	0.50
UV-Protection	2	0.20	0	0.00
Breathability	5	0.50	5	0.50
Fire Resistance	0	0.75	5	0.75
Total Score		4.60		3.60

Table 7: Weighing alternative criteria for opening and closing materials

	Polyester Velcro			**Nylon Velcro**		**Zipper**	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	5%	2	0.10	5	0.25	1	0.05
UV-Protection	30%	5	1.50	3	0.90	5	1.50
Easy to be Used	10%	4	0.40	4	0.40	2	0.20
Waterproof	10%	5	0.50	5	0.50	5	0.50
Low Cost	15%	5	0.75	4	0.60	4	0.60
Life Span	15%	4	0.60	5	0.75	3	0.45
Light Weight	15%	5	0.75	5	0.75	5	0.75
Total Score			4.60		4.15		4.05

Table 8: Weighing alternative criteria for insulation materials

		Rockwool		**Polyester Wool**		**Cellulose**	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	0.05	5.00	0.25	1.00	0.05	5.00	0.25
Insulate Heat	0.35	4.50	1.58	4.50	1.58	4.00	1.40
Insulate Sound	0.05	5.00	0.25	5.00	0.25	2.00	0.10
Low Cost	0.25	2.00	0.50	5.00	1.25	5.00	1.25
Life Span	0.10	2.00	0.20	4.00	0.40	5.00	0.50
Light Weight	0.10	5.00	0.50	5.00	0.50	5.00	0.50
Total Score			3.28		4.03		4.00

Table 9: Weighing alternative criteria for floor materials

		Foam Mat Floor		Inflatable Base		Water-resistant Fiber Reinforced Mylar	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	5%	2	0.10	3	0.15	3	0.15
Waterproof	30%	5	1.50	4	1.20	5	1.50
Softer	15%	5	0.75	4	0.60	2	0.30
Shock Absorber	15%	5	0.75	3	0.45	2	0.30
Low Cost	10%	1	0.10	3	0.30	4	0.40
Life Span	10%	4	0.40	1	0.10	3	0.30
Light Weight	15%	2	0.30	4	0.60	5	0.75
Total Score			3.90		3.40		3.70

Table 10: Weighing alternative criteria for structure

		PVC Pipe Schedule 40		Aluminum Schedule 40		PVC Pipe Schedule 80		Aluminum Schedule 80	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	10%	1	0.10	5	0.50	1.0	0.10	5	0.50
Strong	20%	3	0.60	4	0.80	3.5	0.70	5	1.00
Low Cost	30%	5	1.50	3	0.90	2.0	0.60	3	0.90
Life Span	15%	5	0.75	5	0.75	5.0	0.75	5	0.75
Light Weight	25%	5	1.25	4	1.00	4.5	1.13	3	0.75
Total Score			4.20		3.95		3.28		3.90

Table 11: Weighing alternative criteria for window materials

		Clear PVC Fabric		Pineapple Ripstop Polyester		DuraTop	
Selection Criteria	Weight	Rating	Weighting Score	Rating	Weighting Score	Rating	Weighting Score
Environmentally Friendly	5%	4	0.20	2	0.10	2	0.10
UV-Protection	10%	3	0.30	3	0.30	5	0.50
Waterproof	10%	4	0.40	5	0.50	5	0.50
Windproof	10%	3	0.30	5	0.50	4	0.40
Breathable	25%	4	1.40	5	1.75	5	1.25
Low Cost	10%	4	0.40	2	0.20	4	0.40
Life Span	10%	3	0.30	4	0.40	5	0.50
Light Weight	10%	5	0.50	2	0.20	5	0.50
Less Elongation	10%	3	0.30	3	0.30	5	0.50
Total Score			3.70		3.95		4.65

Therefore, four possible alternative solutions have been investigated from the previous tables, they are:

Alternative 1 → Foylon, Kevlar, Zipper, Rockwool, Inflatable Base, PVC Schedule 40, and Clear PVC Fabric.

Alternative 2 → Foylon, Nylon Silicone Coating, Nylon Velcro, Cellulose, Foam Mat Floor, PVC pipe schedule 80, and Clear PVC Fabric.

Alternative 3 → Mylar, Lexi Cotton, Polyester Velcro, Cellulose, Foam Mat Floor, Aluminum pipe schedule 40, and Clear PVC Fabric.

Alternative 4 → Mylar, 190T PU Coating Polyester, Polyester Velcro, Polyester Wool, Water-resistant Fiber Reinforced Mylar, PVC pipe schedule 80, and DuraTop.

The chosen alternative design should have a low cost, acceptable inner surface temperature in winter and summer, since the ambient internal temperature for convection is assumed in both summer and winter. In addition, the best alternative should have minimum heat gain into the tent in summer, and minimum heat loss from the tent in winter. Also, the frame should be strong enough and it should not collapse because of the climate changes that occurs such as: strong wind and snow that is accumulated on the roof.

Nevertheless, it should have a lightweight that can be carried by one person. Rough analysis is done for each alternative solution to decide which design is most efficient.
In order to model the alternative solution, some conditions and assumptions have been considered. The maximum wind speed recorded in Urfa in July 2019, which equals 29.2 kmph, appendix B. On the other hand, the modeling is applying for a wind speed equals 50 km/h, which is approximately double the maximum speed reached on Urfa. So, if the frame withstands with this wind speed it will withstand with other speeds. The forces that will be affected on the frame in summer are due to its weight and wind load, where there will be an extra load in winter due to the snow that accumulated on the roof. The snow load will be calculated for snow depth equals 18 cm, which is the maximum snow depth reaches in Urfa in February 2020, appendix B. The pressure due to wind load is assumed to occur from right to left side on the tent and the pressure due to snow load will be located on the roof. Therefore, if the frame withstands with these values of loads, it will withstand in other days in summer and winter. The ANSYS

APDL and ANSYS workbench programs have been used to study the structural and thermal analyses of the alternative solutions.
It is assumed that one adult person will be inside the tent. As known, this person will generate approximately 106 W of energy. This amount of energy generated by a person inside the tent will be taken into consideration in order to measure the temperature inside the tent.

In summer:
One of the most important purposes of this project is to provide a cooler weather inside the tent in summer instead of outside hot environment. The calculations are done under assumed conditions the outside temperature equals 41 ℃, the outside convection coefficient assumed to be 12 W/m^2K and the inside convection coefficient assumed to be 3 W/m^2K with an ambient temperature 20 $°C$. In addition, the activity of a person inside the tent assumed to be light and primarily sedentary activity.

In winter:
It is an important thing to retain the inside environment warm in winter especially in very cold places as Urfa. Another important purpose of this project is to provide a warm weather inside the tent in winter. The calculations are taken with assumed conditions, the outside temperature equals 1 ℃, the outside convection coefficient is assumed to be 12 $W/m^2.℃$ and inside convection coefficient is assumed to be 3 $W/m^2.℃$ with an ambient temperature 17 $°C$.
A 2D model of the tent is simulated to record the approximate inner surface temperature. Since the tent is symmetric about y-axis, only the right side is studied in ANSYS for each alternative solution. Detailed results and discussions are done for each alternative solution in Appendix E.

Alternative solution 1

Alternative Solution 1 consists of the following materials for the cover of the tent, which are Foylon, Rockwool, and Kevlar. The material used for the frame and the structure of the tent is PVC pipe schedule 40 with standard inside diameter equals 20.42 mm and outside diameter equals 26.67 mm. The material used for the floor is inflatable base and the material used for the window is Clear PVC fabric, and the way that is used for opening and closing is zipper. The properties of these materials are shown in appendix section.

The following Figure shows the frame shape for this alternative solution with its dimensions.

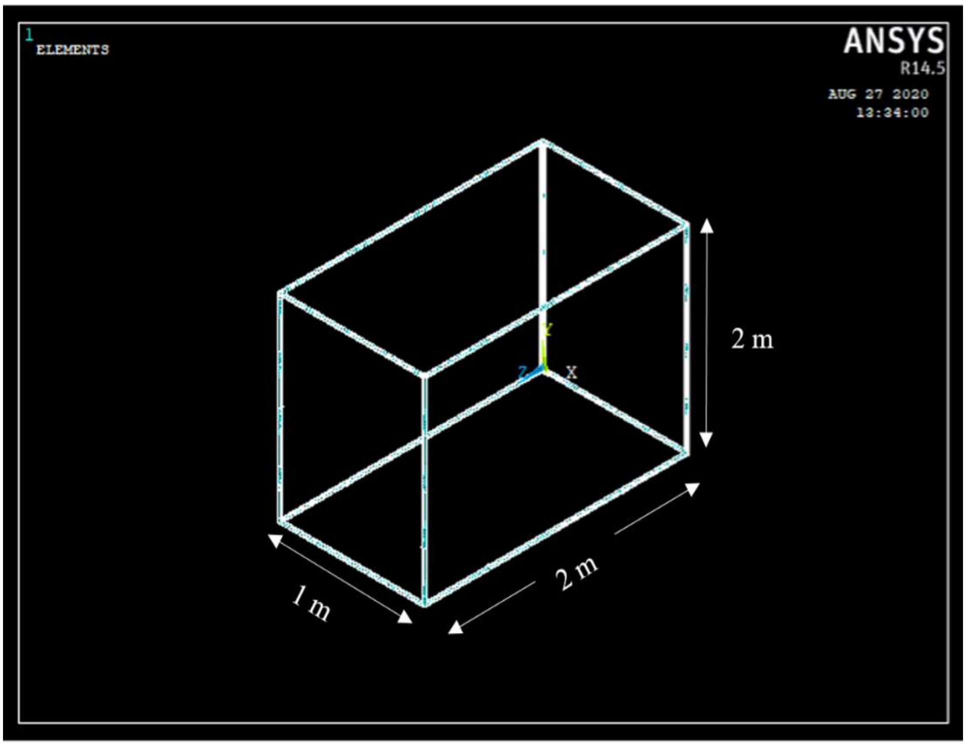
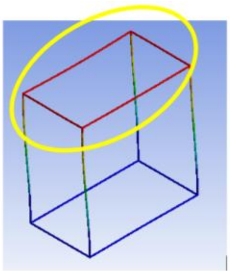
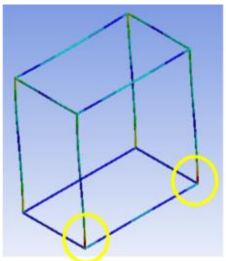


Figure 7: The frame of the first alternative solution

The results of this alternative are shown in Table 12.

Table 12: Alternative solution 1 results

<table>
<tr><th colspan="4">Alternative Solution 1</th></tr>
<tr><td>Frame Material</td><td>PVC Pipe Schedule 40</td><td rowspan="2">Insulation Thickness [cm]</td><td rowspan="2">0.5</td></tr>
<tr><td>Maximum Deflection [mm]</td><td>109.7</td></tr>
<tr><td>Maximum Deflection Location</td><td></td><td>Inside Surface Temp. in Summer [°C]</td><td>35</td></tr>
<tr><td>Max. bending stress [MPa]</td><td>120</td><td>Heat Flow in Summer [w]</td><td>509</td></tr>
</table>

<table>
<tr><td></td><td></td><td>Inside Surface Temp. in Winter [°C]</td><td>7.5</td></tr>
<tr><td>Max bending Stress Location</td><td></td><td rowspan="2">Heat Flow in Winter [W]</td><td rowspan="2">-433</td></tr>
<tr><td>Factor of Safety</td><td>0.425</td></tr>
</table>

As noticed from previous Table, the maximum bending stress equals 120 $x10^6$ Pa, which is higher than the yield stress. Moreover, the factor of safety is found to be 0.425. On the other hand, the value of maximum deformation in the frame is high which reaches 109.7 m and that effect on the strength of the pipe. Therefore, the structure is not safe enough. The internal surface temperature equals 35 °C in summer; as known the surface temperature is cooler than the inside ambient temperature in the tent, so, the internal temperature is higher than 35, which is hot. In addition, the total amount of heat flow entering the tent in summer equals 156.7 w. The inside surface temperature in winter equals 7.5 °C with a total value of heat losses equals 104 w.

Floor material is inflatable base. The idea of using the inflatable base comes when thinking about more comfortable floor, since it has a varying thickness. Inflatable mats are thick, and this skill gives a better support for the curves of the human body, offering more comfort. Generally, inflatable pads are lighter in the weight than foam pads. The lightest inflatable pad weights around 8 ounces or 225 grams. However, those inflatable bases are more expensive than Foam mat floor and the Water-resistant fiber reinforced Mylar, which are the other choices to use for the tent floor. One of its disadvantages that it will need maintenance between time to time since it can easily be punctured. In addition, those inflatable mats will take a bit of effort to inflate and deflate which can become a nuisance. While searching about tent window materials, it has been found that the most common used material is the clear PVC fabric. This fabric has many advantages and relatively inexpensive. Moreover, clear PVC fabric has excellent stability at both high and low temperatures. This material can prevent insects, small sand parts, rain, and snow from entering inside the tent.

From the previous results, the frame is not strong enough, the inside temperature in summer is hot and in winter is too cold. Also, this alternative solution is not comfortable, since the roof is flat, so the rain and snow will accumulate at the roof. Therefore, this alternative solution is not efficient enough.

Alternative solution 2

Alternative solution 2 consists of Aluminum schedule 40 pipe for the frame with standard diameters. The standard diameters have been taken as 26.67 and 21 mm outer and inner diameters, foam mat is used for the floor, Clear PVC fabric is used for the window and Nylon Velcro is used for the opening and closing door and window. The cover consists of three layers Foylon which is reflective material, Cellulose which is the insulation material and Nylon Silicone coating. The properties of these materials are shown in appendix section. The following Figure shows the frame shape of this alternative solution.

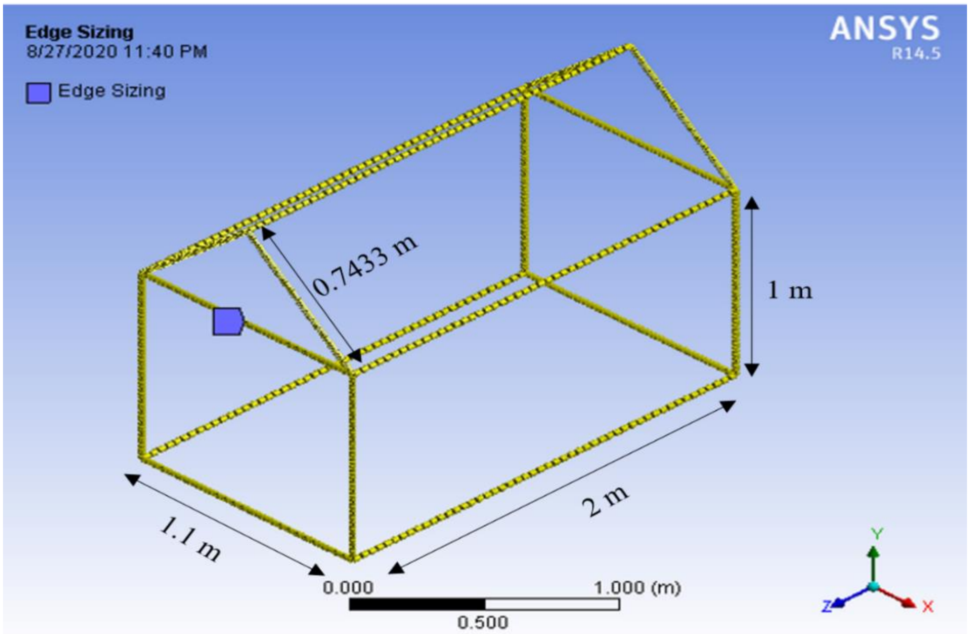
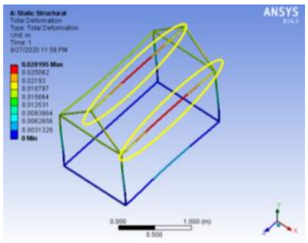
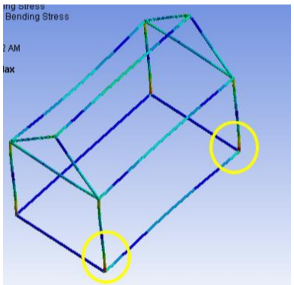


Figure 8: The frame of the 2nd alternative solution

Table 13 shows the results of alternative solution 2.

Table 13: Alternative solution 2 results

Alternative Solution 2			
Frame Material	Aluminum Schedule 40	**Insulation Thickness [cm]**	0.5
Maximum Deflection [mm]	28.2		
Maximum Deflection Location		**Inside Surface Temp. in Summer [°C]**	33
Max. combined Stress [MPa]	88	**Heat flow in Summer [w]**	491
		Inside Surface Temp. in Winter [°C]	8
Max. combined Stress Location		**Heat flow in Winter [w]**	-417.5
Factor of Safety	3.14		

As it is noticed from Table 13, the magnitude of maximum combined stress equals 88×10^6 Pa, which is occurs at the corners. Comparing with the yield stress, the combined stress is smaller than the yield stress. The factor of safety equals 3.14, therefore, the structure is overdesign. Also, the maximum deformation occurs in the roof, and it equals 0.028 m. This value of deformation is better than the deformation happened using PVC schedule 40. This frame may be used for areas where the wind speed is higher than 50 m/s. In addition, the internal surface temperature in summer equals 33 °C with a total value of heat gain equals 491 w. In addition, the inside surface temperature in winter equals 8°C with total heat loses equals 417.5 w. Also, the shape of the tent is uncomfortable, since the person will feel in difficulty to enter and leave the tent due to the horizontal pipes located at height equals 1 m in the front and back sides of the tent where the portable doors are located. Therefore, this alternative solution is not efficient enough.

Alternative solution 3

In this solution PVC pipe schedule 80 is used for the frame with standard 26.67 and 18.34 mm outer and inner diameters, appendix B, foam mat for the floor, Clear PVC fabric for the window and Polyester Velcro for the opening and closing door and window. The cover made of three layers Mylar, Cellulose and Lexi cotton. Figure 9 shows the frame shape with the dimensions for this alternative solution.

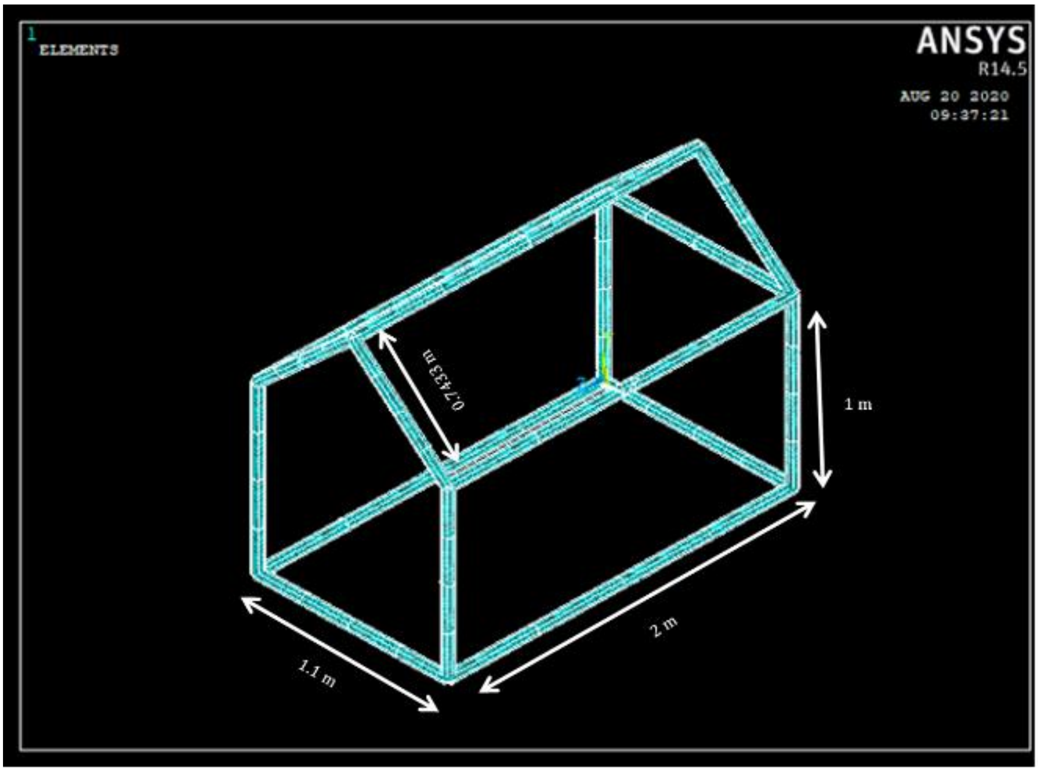
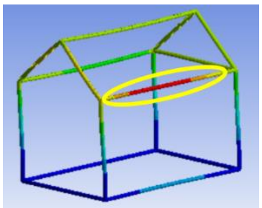
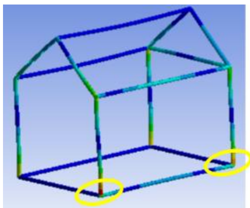


Figure 9: Frame shape with dimensions for the third alternative solution

The frame shape of this alternative solution is similar to the previous alternative except that the front horizontal pipe in the upper side of the front, which equals 1 is removed in order to make the entering and leaving of the tent easily. On the other hand, the horizontal pipe in the back side of the tent is kept in order to enhance the strength of the frame.

Table 14 represents the results of the third alternative solution.

Table 14: Alternative solution three results

<table>
<tr><th colspan="4">Alternative Solution 3</th></tr>
<tr><td>Frame Material</td><td>PVC Pipe Schedule 80</td><td rowspan="2">Insulation Thickness [cm]</td><td rowspan="2">1.5</td></tr>
<tr><td>Maximum Deflection [mm]</td><td rowspan="1">282.3</td></tr>
<tr><td>Maximum Deflection Location</td><td></td><td rowspan="2">Inside Surface Temp. in Summer [°C]</td><td rowspan="2">29</td></tr>
<tr><td rowspan="3">Maximum combined Stress [MPa]</td><td rowspan="3">69</td></tr>
<tr><td>Heat flow in Summer [w]</td><td>350</td></tr>
<tr><td>Inside Surface Temp. in Winter [°C]</td><td>11</td></tr>
<tr><td>Max. combined Stress Location</td><td></td><td rowspan="2">Heat flow in winter [w]</td><td rowspan="2">-297.5</td></tr>
<tr><td>Factor of Safety</td><td>0.526</td></tr>
</table>

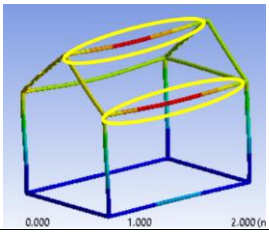
As it is noticed from Table 14, the maximum deformation occurs in the roof, which equals 0.282 m and it is acceptable. The magnitude of maximum combined stress equals 69×10^6 Pa, which occurs at the corners, and comparing with the yield stress, the maximum combined stress is higher than the yield stress. The factor of safety equals 0.526, therefore the structure is not safe, and it will collapse. In addition, the internal surface temperature in summer equals 29℃ with a value of heat flow into the tent equals 350 w. In addition, the inside surface temperature in winter equals 11 ℃ with a value of heat losses from the tent equals 297.5 w. In comparison with the previous alternative solutions, the temperatures in winter and summer are more acceptable that happens because the thickness of the insulation material has been increased. The verification of the floor's material ability in resisting water, which is Inflatable Base, has been done. This material is used in kids' pool or life jackets. Studies are done on this material previously; this material has water-resistant. Inflatable base is an air-supported structure; therefore, it needs a pump to be attached with the packaging. Therefore, this alternative solution is not efficient enough.

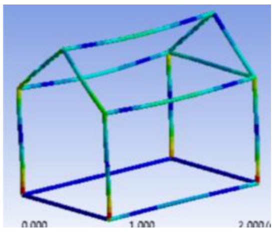
Alternative solution 4

Alternative Solution 4 consists of the following materials for the cover of the tent, which are Mylar, 190T PU Coating Polyester, and Polyester Wool. The material that used for the frame and the structure of the tent is PVC pipe schedule 80 with standard outside diameter equals 42.16 mm and inside diameter equals 31.88 mm. The material that is used for the floor is a Water-resistant Fiber-reinforced Mylar and the material that is used for the window is DuraTop, and the way that is used for opening and closing is Polyester Velcro. The frame shape of this alternative solution is similar to the previous alternative solution.

Table 15 represents the results of alternative solution 4

Table 15: Alternative sulotion 4 results

<table>
<tr><th colspan="4">Alternative Solution 4</th></tr>
<tr><td>Frame Material</td><td>PVC Schedule 80</td><td>Insulation Thickness [cm]</td><td>5</td></tr>
<tr><td>Maximum Deflection [mm]</td><td>96.4</td><td rowspan="2">Inside Surface Temp. in Summer [°C]</td><td rowspan="2">24</td></tr>
<tr><td>Maximum Deflection Location</td><td>
</td></tr>
<tr><td rowspan="3">Max. combined Stress [MPa]</td><td rowspan="3">21</td><td>Heat flow in summer [w]</td><td>155.5</td></tr>
<tr><td>Inside Surface Temp. in Winter [°C]</td><td>14</td></tr>
<tr><td></td><td>-132</td></tr>
</table>

Max. Combined Stress Location		**Heat flow in winter [w]**	
Factor of Safety	2.5		

From Table 15, the maximum deformation equals 0.0964 m. This value of deformation is acceptable since it is low and occurs in the floor due to snow accumulating on the roof. The maximum value of combined stress equals 21x10^7 Pa. Therefore, the factor of safety equals 2.5, since the value of yield strength is higher than the value of maximum combined stress so, the frame is safe from collapsing but the design is overdesign. In comparison with the first two alternatives solution, which made from PVC pipes; the value of deformation of this alternative solution is much lower than the deformation calculated for them. PVC pipe schedule 80 of this alternative solution has higher weight than the PVC pipes in the previous solutions, since this increase the strength of the pipe and make it stronger and that leads to less deformation in order to withstand and to provide a safe tent. Besides, in comparison with the third alternative solution, which made from Aluminum schedule 40; the value of maximum deformation is higher than the value of maximum deformation calculated for Aluminum schedule 40, but it is still low and safe. In addition, this design is overdesign but it gives a low value of deformation pipe schedule 80 provides the needed strength for the frame of the tent and the value of maximum Von-Mises stress is much lower than the yield stress so, there is no need to increase the material in the pipe. Therefore, the best pipe that gives a most efficient performance is PVC schedule 80. As observed from ANSYS results, the internal surface temperature equals 24 ℃ with a total amount of heat flow inside the tent equals 155.5 w. In addition, the inside surface temperature in winter equals 14℃ with a total amount of heat losses equals 132 w. It is concluded from the first and second alternatives solution, the temperature inside the tent in summer is hot and approximately the same for both cases. The internal temperature is too cold in winter in both those alternatives and approximately the same. On the other hand, for the third alternative solution, the thickness of the insulation material has been increased and the result was cooler internal temperature in summer and warmer internal temperature in winter in comparison with the first two alternatives. For this alternative solution, the thickness of the insulation material increases up to 5 cm and the result was an acceptable internal temperature in both summer and winter.

The verification of the ability in resisting water for floor's material, which is Water-resistant Fiber-reinforced Mylar, is important to know. This material is used for the most common camping tent. The material is water-resistance; therefore, the rain and water will not leak inside the tent. In addition, it has a lightweight, high reflectivity, and acceptable size. The material used for the window in this alternative solution is DuraTop. This material has high breathability and UV-protection. Besides, it has a lightweight and acceptable cost. In addition, this material is the standard fabric that is used for all non-printed commercial tents, [13]. Therefore, this alternative solution is efficient enough.

Weighting of the alternative solutions

The comparison between the alternative solutions is shown in Table 16.

Table 16: Weighting of the alternative solutions

	Alternative Solution 1	**Alternative Solution 2**	**Alternative Solution 3**	**Alternative Solution 4**
Low Cost	5	5	4	4
Acceptable Internal Temperature	2	2	3	5
Strong Frame	2	3	5	5
Total Score	9	10	12	14

Therefore, the best alternative solution is alternative solution 4.

Design Description/Statement of Work (SOW)

After rough analysis, the best alternative solution is alternative solution 4. The statement of work will be discussed for this alternative design in this section.

Size and Shape

Table 17 shows the standard size of camping tent.

Table 17: the standard size of camping tent [14]

Rated Capacity	Tent Floor Area	Comfortable Capacity	Floor Area Per Person
4-person	60 to 70 square feet	an adult couple	30 square feet for each adult
6-person	90 to 100 square feet	a family of 4	25 square feet for each adult & 20 square feet for each child
8-person	120 to 130 square feet	a family of 6	25 square feet for each adult & 17.5 square feet for each child

Since this tent will be used only for two adults and one child according to the answers of the survey that is done for refugees in Urfa city; the standard size of camping tent will not be used for the 4 seasons tent. The size and dimensions of the frame tent are shown in Figure 10.

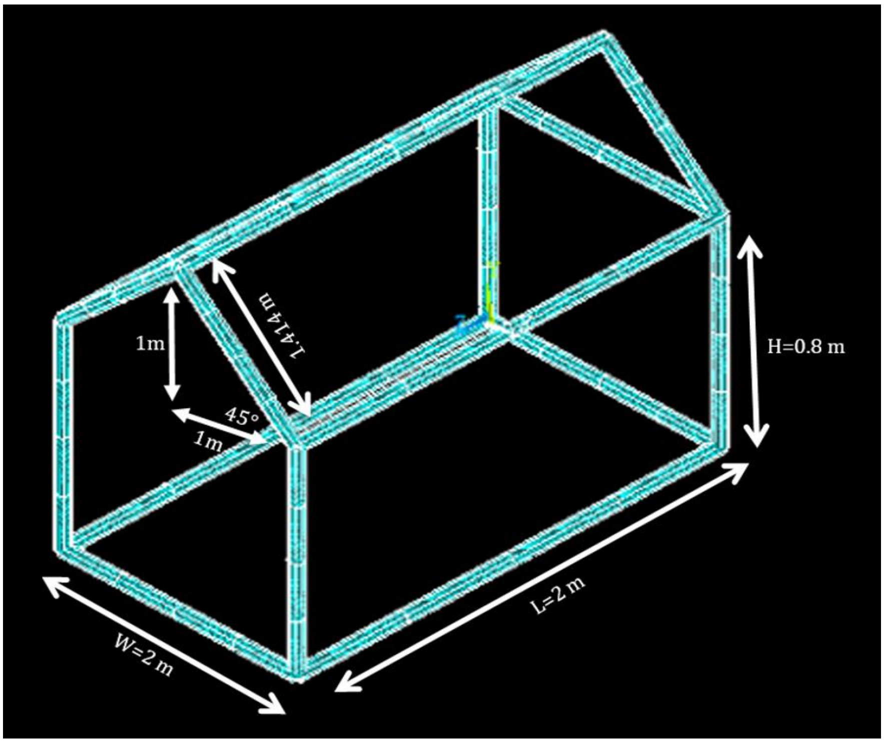


Figure 10: The size and dimensions of the tent

The length [L] of the tent is chosen to be 2 m depends on the standard height of males that equals 1.7 m and for female that equals 1.6 m, and depends on the standard size of the sleeping bag. Therefore, 2 m length will be comfortable for both males and females especially at night when they are sleep. The width [w] is taken to be 2m depending on the standard size of sleeping bag since two sleeping bags will be used and the width of each one equals 80 cm [15], so the 2-meter width would be comfortable enough. The tent peak, which is the tallest point inside the tent body, equals 1.8 m people will be able to stop with their feet, dress up and get around inside of the tent, where the sidewall height equals 0.8 m. The desired slope is calculated to be $\sqrt{2}$ m. The triangular roof shape is chosen because this shape is helpful in reducing the amount of snow that is accumulating on the roof of the tent in winter. The sleeping capacity of this tent is 2 adults and one child.

The Frame

PVC pipe schedule 80 with standard inside diameter equals 31.877 mm and standard outside diameter equals 42.164 mm, is the used material for the frame, this type of pipe has a lightweight in comparison between other types of pipes such as Aluminum and steel. The weight issue has a forceful role in this design, since the overall weight of this tent should be acceptable, portable, and handled by one person. In addition, the total weight of PVC pipes is calculated to be 15.77 Kg which is acceptable. Besides, this pipe is fracture resistance, non-toxic, flame resistance, and safe material. In addition, it has a smooth surface that helps in reducing fluid friction and resistance to flow [16].

Stability

In order to provide more stability to the structure, some weight is added at the corners of the tent. This move is used to enhance the strength of the frame and to stabilize it on the ground, Figure 11.

Figure 11: Stabilizing bag

In 4 season's tent, four small bags will be attached with the packaging. These bags can be filled with sand, rocks, or any heavy stuffs. The bags must be fixed at the lower corners of the frame. Polyester Velcro used to support the bags at the corners.

Structural Modeling

ANSYS workbench program has been used in order to study the frame by assuming that PVC pipe is a beam with circular cross section. Type of forces that affected this frame in summer are due to the frame's weight and wind load. On the other hand, there is an extra force in winter, which is due to snow accumulated on the roof. Nevertheless, the moving air, which is the wind that has a dynamic energy, stopped by a surface; this amount of dynamic energy transformed into dynamic pressure. This amount of dynamic pressure should be taken into consideration in order to test the strength of the frame. The amount of this dynamic pressure depends on the velocity and density of the air. The value of velocity taken in order to calculate the dynamic pressure equals 50 m/s which is approximately double the maximum speed reaches in Urfa, which is the worst-case scenario. In addition, this amount of dynamic pressure is affected on the right side of the tent, since, the wind load is assumed to be from the right side to the left side. The magnitude of dynamic pressure equals 109.35 Pa which is constant because the density and velocity of air are assumed to be constant. In addition, the value of pressure calculated due to snow load equals 137.9 Pa. From structural analysis of the frame, this frame is strong enough and it will not collapse, where the factor of safety is 2.494, and the value of maximum deformation equals 0.0964. The value of factor of safety is high and it is approximately over design, but the value of deformation is acceptable. In addition, if the diameter of the pipe is decreased the design will not be over design but the value of deformation will be too high. Besides, this frame withstands through worst-case scenario so, it will withstand with other scenarios.

The PVC pipes are connected with each other by using some fittings. The material used for the fittings is similar to material used for the frame which is PVC schedule 80.

<u>In summer</u>

According to Urfa weather online, the outside temperature in summer is too high and it reaches 40 ° C. For that reason, people feel too hot and uncomfortable and they need cooler weather for their living place. This tent will be used for homeless and refugee people and a cheap source of cooling is needed for them instead of expensive sources of cooling such as air-conditioning units. For that, special materials are used for the cover of this tent to achieve an acceptable temperature inside the tent. The cover of the tent acts as a composite wall with three materials which are Mylar, polyester wool, and 190T PU coated polyester as shown in the following Figure.

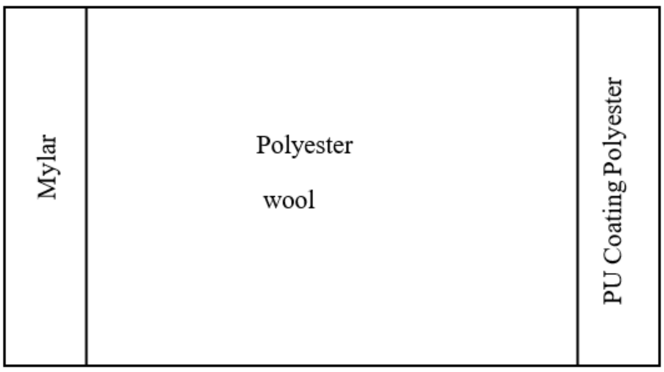


Figure 12: The materials used for the cover of the tent

In summer, the material faced the outside environment is Mylar material, this material reflects approximately 85% - 90% of heat that helps to reduce the amount of heat from the sun due to radiation to reach the inside environment and help to keep the inside weather cool, and this material has a light color that makes it a good reflector and bad absorber. In addition, Mylar is waterproof material and as known, Turkey is a rainy country because of that a waterproof material is chosen to prevent the water to leak inside the tent. Also, according to code NFPA 1, Fire Code, advances fire and life safety for the public and first responders as well as property protection this tent should be fire-resistant and Mylar material is fire resistant. Besides, Mylar has UV-protection, so the cover of the tent will not damage due to sun rays. After Mylar, a polyester wool material is located. As said before, Mylar will reflect only 85% of heat so some of the heat will keep transfer and make its way inside the tent. Polyester wool is an insulation material which is a bad conductor that slows the transfer of heat and keeps heat out during the summer. Polyester wool is not only insulating the heat but it is also insulating the sound that makes people who live inside the tent to feel comfortable and to sleep well especially at night and to insulate the noise from the outside environment. After the insulation material, 190T PU (Polyurethane) coated polyester is coming the reason behind coated the polyester with the PU coating that the polyester is not waterproof but after adding this coating it becomes waterproof. The 190T counts of the number of threads per square inch of fabric. Most of camping tent nowadays made from that fabric that’s because of its properties. Also, PU coated polyester is waterproof and has high breathability because of micro porous that enhance its breathability. As known, moisture can be occurred inside the tent from the human body or from the outside environment which can lead to condensation in the tent’s wall. One person can produce up to 1-pint moisture per night which equals 473.176 ml [17]. Subsequently, this amount of moisture dropping inside the tent and maybe a source of condensation. As known, breathability is the ability of a fabric to allow moisture vapor to be transmitted through the material that can reduce the amount of condensation, especially at night. Also, micro porous are a very tiny porous that prevents water liquid to go through it and that makes it waterproof while allowing the moisture which has very small molecules to go through it and that makes this fabric breathable and waterproof [18].

In addition, PU coating polyester has a dark colour that’s makes it a good absorber which can absorb some of the heat generated inside the tent. After reflected 85% of outside heat in the first layer and insulated some of that heat in the 2nd layer, it is approximately a small amount of heat will reach the inside environment of the tent. Subsequently, the temperature inside the tent will lower than the outside temperature.

In designing, we must take into consideration the heat that is generated from human body, from where that heat comes and its quantity. It is assumed that two adult person and one child will be inside the tent. As known, the energy generated by a person's metabolism depends on a person's activity. By assuming, the person is seated with light activity and according to ASHRE handout this person will generate 1 met which equals 58.2 W/m^2. According to ASHRE Handbook, Fundamentals volume, the average adult is assumed to have an effective surface area for heat transfer of 1.82 m^2 and therefore, this person will generate approximately 106 W. By taking the energy generated from the human body into consideration, the amount of this energy generated is transferred inside the tent. First, this amount of heat is absorbed from the inside surrounding air which has a cooler temperature in comparison with the human body temperature due to convection heat transfer, as known the heat transfers from higher to lower temperature. After that, the amount of heat transfers due to convection keeps transfer until sticks with the third layer of the composite wall which is 190T PU coated polyester and the type of heat transfer will be changed from convection into conduction, then it transfers due to conduction in the rest layers of the composite wall and keeps transfer to leave the tent or this amount of heat may leave the tent through the windows and doors in the tent.

In order to know if the design works or not, the inside temperature of the tent is calculated during the day and during the night. At the beginning of the sun rise, the outside temperature is increased and in the same manner, the inside temperature is increased, and the aim of this study is measuring the difference between the inside and outside temperature and to have an inside temperature cooler than the outside temperature. Therefore, the analysis is started from the sunrise at 6:50 a.m., where the outside temperature equals 23˚C and by assuming that the temperature inside the tent at that time equals 19˚C, the variation of the temperature inside the tent is studied as the outside temperature changed with time. It is concluded from the result at Appendix J, after half hour the temperature increase at a rate of 0.8 and it reached 19.8 $°C$ with an outside temperature equals 26 $°C$, and after two hours it reached 24.8 $°C$ with an outside temperature equals 31 $°C$. Subsequently, at the maximum outside temperature which equals 40 $°C$ that occurs at 4:50 PM, the inside temperature equals 33.8 $°C$, and this is the maximum inside temperature reaches inside the tent. After 4:50 PM, the outside temperature is started to drop and so on the inside temperature. It concluded from the analysis; the inside temperature is cooler than the outside temperatures in approximately 6 ° C. Besides, during the night from 12:00 a.m. into the sunrise at 6:50 a.m. the whole windows and doors are closed to get privacy during the sleeping period except the upper windows in the roof are opened to get ventilation and fresh air, while for the rest of the day the lower and upper windows are opened to get more ventilation.

In winter

The cover of this tent is reversible that can be used on both sides that's because the conditions, concept, and needed in summer are different than what is needed in winter. In winter, the material faced the inside environment is Mylar, the material in the middle is polyester wool and the last material which faced the outside environment is 190T PU coated polyester.

According to Urfa weather online the minimum temperature reaches there equals ˚0 C which is cold. Besides, according to the answers of the surveys, refugee people who lived in Urfa suffering from extreme cold in winter and they need a source of heating to protect them from the extreme cold. Since the aims of this tent are to have low cost, low weight, and acceptable size, the heater or other sources of heat will not be used. The main source of heat will be the human body, as mentioned before that the amount of heat generated by one adult person equals 106 W. So, how this amount of heat will benefit and how it will be used as a source of heating?

When the heat is generated from the human body it transfers by convection until it reaches the first layer of the composite wall which is Mylar material, and as mentioned before this material acts as a good reflector that reflects 85%-90% of the heat generated by the human body and prevents the waste of that energy. Therefore, this amount of energy will provide warm weather inside the tent. Besides, Mylar is a breathable material that will help the person who lives inside the tent to feel comfortable and to prevent the condensation to occur on the wall of the tent as mentioned before. The polyester wool comes after the Mylar material, this polyester has a thermal conductivity value equals 0.0359 w/m. k which makes it a perfect insulator. 15% of the heat generated from the human body keeps transfer due to conduction until reach the insulation material. Therefore, this insulation material will decrease the amount of heat losses from the human body to the outside environment. Since the heat generated from human body is the main source of heating in this tent the insulation material safes this heat from being waste. As known, most of the heat is loses through the composite wall and window but this amount of losses can be reduced because of Mylar and polyester wool insulation.

Most modern buildings are using insulation in their wall to provide a warm place in winter and to prevent heat losses as shown in Figure 13.

Figure 13: Using of insulation material in modern building [19]

The last material in that composite wall is 190T PU coated polyester. This material has a dark color which makes it a good absorber that can absorb heat from the outside environment and will provide privacy for people inside the tent. In addition, this material is waterproof that prevents the rain and snow to leak inside the tent. This material is not fire-resistant but according to code NFPA of fire, it should be fire-resistant. A thermal barrier is a material applied for flammable materials to make them fire-resistant. Therefore, the thermal barrier will be applied for 190T PU coated polyester to make it un flammable and it concluded that this thermal barrier is safe to use for polyester since it will not change polyester's properties so, it's safe for 190T PU coated polyester. Subsequently, the overall cover of the tent is waterproof and fire-resistant on both its sides, so it's safe and comfortable to use this tent as a home. Also, the materials used for the cover of the tent are polyester fabrics and they will not shrink and become smaller in size because of the change of weather from hot to cold temperatures. So, this cover will withstand and has an acceptable lifespan.

The inside temperature of the tent is calculated during the day and during the night in winter. At the beginning of the sun set, the outside temperature is started to decrease and in the same manner, the inside temperature is decreased, and the aim of this study is measuring the difference between the inside and outside temperature and to have an inside temperature warmer than the outside temperature. Therefore, the analysis is started from the sunset at 5:10 p.m., where the outside temperature equals 8˚C and by assuming that the temperature inside the tent at that time equals 18˚C, the variation of the temperature inside the tent is studied as the outside temperature changed with time. It is concluded from the result at Appendix K, after forty minutes the temperature decreases at a rate of 5 degree and it reached 13.2 ° C with an outside temperature equals 7 ° C, and after two hours it reached 10.2 ° C with an outside temperature equals 4 ° C . Subsequently, at the minimum outside temperature which equals 0 ° C that occurs at 11:50 PM, the inside temperature equals 6.2 °C, and this is the minimum temperature reaches inside the tent. After 11:50 PM, the outside temperature is started to increase and in the same manner, the inside temperature increases. It concluded from the analysis; the inside temperature is wormer than the outside temperatures in approximately 6 ° C.

The floor

The material used for the floor is water-resistant fiber-reinforced Mylar which is waterproof, reflective, flame resistance, and breathable material. According to Urfa weather online, the maximum rainfall amount equals 264.3 mm recorder in December 2019 and the maximum snow amount equals 18 cm reaches in February 2020 Appendix B.

The maximum rainfall amount and snow amount should be taken into consideration to design the floor shape of this tent. The floor is designed as a bathtub to prevent the rain and snow from leaking inside the tent and the height of the corners of this bathtub equals 300 mm which is higher than the maximum amount of rainfall and snowfall which is the worst-case scenario. Figure 14 shows the bathtub design for the floor.

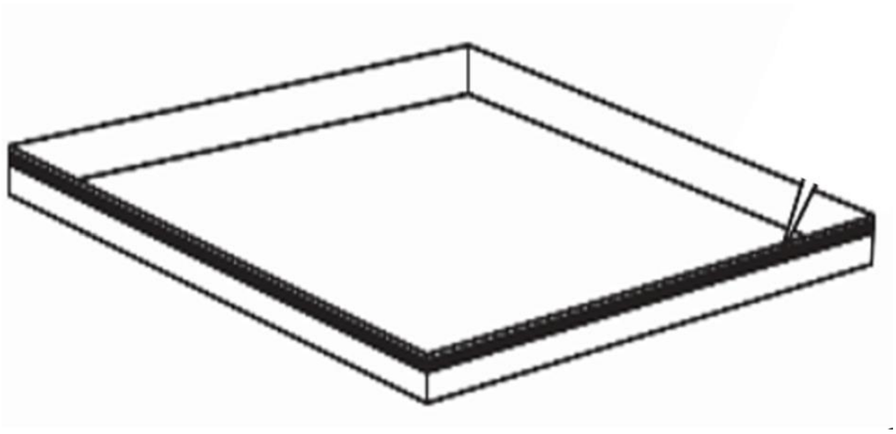


Figure 14: Bathtub design for the floor

The area of the floor equals 4 m^2. Sleeping directly above this bathtub is uncomfortable for that a sleeping bag is used at night to get a good and comfortable sleeping. Figure 15 shows the standard size of the sleeping bag according to CRITERION.

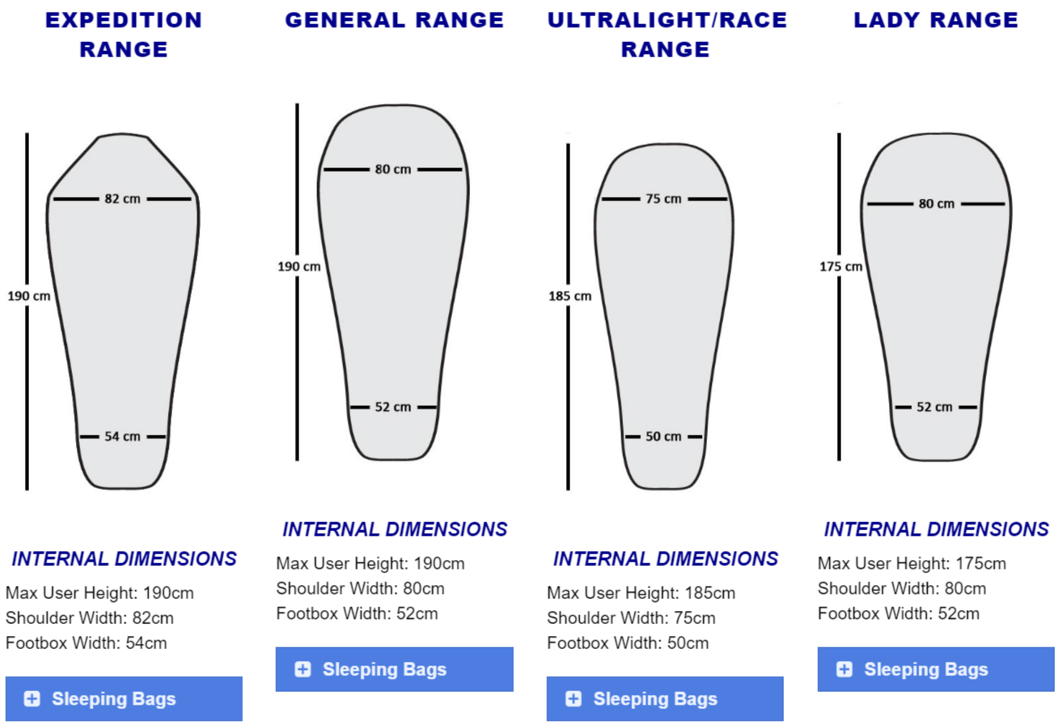


Figure 15: Standard size of the sleeping bag according to CRITERION

The ultra-light/race range is chosen because it fits with the floor's size of the tent.

Doors and window

There will be two removable doors in the front and back of the tent that will make the build of the tent easier. The front door consists of two pieces connected by polyester Velcro that makes the entering and leaving of the tent easier, while the back door consists only of one piece. The area of each door equals 2.6 m^2 Figure 16 shows the shape and the dimensions of the door.

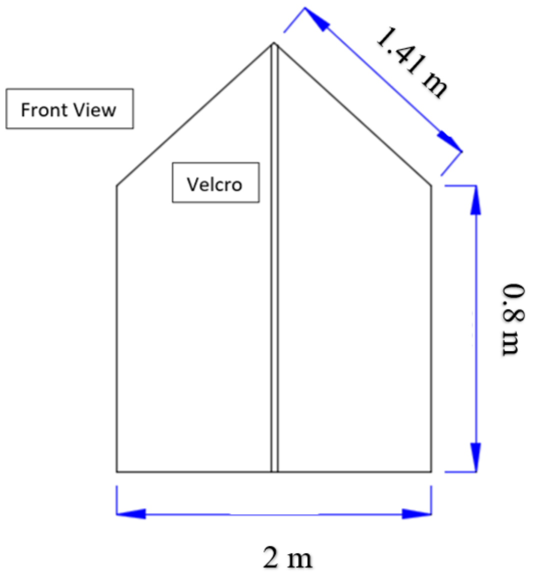


Figure 16: The shape and the dimensions of the door

The back door is similar to front door except that the front door consists of two pieces connected by polyester Velcro, while the back door consists of only one piece. The materials used for the doors are similar to the materials used for the cover of the tent which consists of three layers of materials. In addition, those doors will give a chance for people who lived inside the tent to get more ventilation by opening one of those doors or both of them. Also, according to the survey did for refugee people it concluded that they spent 7-10 hours inside the tent so, when they are outside the tent, they may open both of those doors to replace the old air inside the tent with fresh air. Those doors will be connected with the cover of the tent by using polyester Velcro. The lifespan of polyester Velcro is 3,500 openings and closings which is good and this type of connection is better, faster, and easier than zipper [20]. Also, it is better than nylon Velcro because the life span of polyester Velcro is higher than the lifespan of nylon

Velcro. There will be two large windows and four small windows inside this tent to provide ventilation when both doors are closed.

Ventilation

If the ventilation inside any building was poor this will affect the indoor air quality, healthy of the environment, and thermal comfort which will reduce the performance of that building. Therefore, ventilation is needed in this tent in order to get good indoor air quality and a healthier environment. Since this tent will be used for refugee people, natural ventilation will be used instead of mechanical ventilation. The sources of natural ventilation are wind and temperature differences. The fresh air enters this tent through the windows and two removable doors. Creating air flow and circulation through the windows and removable doors in the tent is the most effective way to increase the amount of ventilation and to reduce the amount of condensation.

The natural ventilation due to wind is called cross ventilation, this ventilation is achieved by adding two windows in two sides of the building as shown in the following Figure.

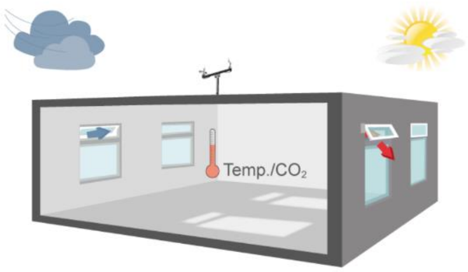


Figure 17: Windows for cross ventilation [21]

This type of ventilation is achieved in four season's tent by closing the two uppers windows and opening the two lower windows. This type of ventilation depends on the pressure variation, one of these windows facing the wind so it has the higher pressure in comparison with the window in the other side. Therefore, this variation of pressure between the two windows creates a current flow of air and give a chance of old air to be replaced by fresh air. This type of ventilation gives a perfect performance when the wind speed is high enough to achieve pressure differences. In the other hand, it does not work so well on days where it is hot and the wind is still. The calculation of cross ventilation is shown in appendix I with an average value equal $6.761\ cfm$ which is close to recommended required ventilation per human occupant.

The other type of natural ventilation which is due to temperature difference is called stack ventilation, this type of ventilation needed two windows one in the lower side and one in the upper side as shown in the following Figure.

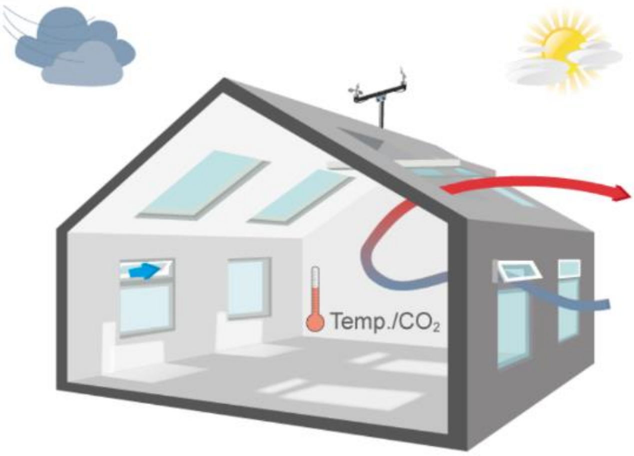


Figure 18:Stack ventilation [22]

This type of ventilation is achieved in four seasons tent by opening both the lower and upper windows and it mostly used in winter and cold weather. The cold air is entering through the lower window, and since the hot air has higher density than the cold water, it will rise and leave the tent through the upper window at the roof (thermal buoyancy) as shown in the following Figure.

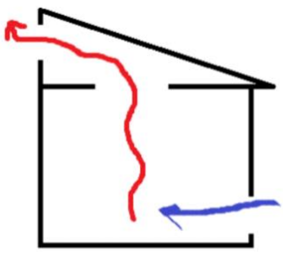


Figure 19: Stack effect [23]

Subsequently, the old air will be replaced by cold air. As the difference in height between the lower and upper windows increase the efficient of this process increases.

To check if there is condensation inside the tent or not, the dew point temperature should be measured. In winter, the relative humidity is too high and it varies from 50% to 100%. Since there is no heater, the relative humidity inside the tent equals the outside relative humidity. By assuming, the pressure equals the atm pressure, the dewpoint temperature is calculated from psychometric chart during the day and night. It concluded from appendix K; the values of dew point temperatures are approximately near the values of inside temperature. In summer, the inside relative humidity varies from 11% to 60%. It concluded from appendix J; the values of dew point temperatures are far away from the values of inside temperature. Therefore, the condensation will not occur inside the tent in summer. According to the answers of surveys, the most common problems in the current tent are leaking of rain and snow inside the tent, hot environment inside the tent in summer, extreme cold inside the tent in winter, doesn't have enough sleeping bag, flammable tent, not enough ventilation and a small tent. This tent will be warmer than the outside environment in winter and cool in summer due to special materials used for the cover of this tent. Also, it will be waterproof since the materials used for the floor and for the cover of the tent are waterproof. In addition, the overall tent is fire resistance since some materials that have been used to build this tent are fire resistance, and the others which are flammable, a thermal barrier is added for them to make them fire-resistant. Also, two sleeping bags will be provided for each tent. Enough ventilation and fresh air will be available inside the tent due to removable doors and windows. Also, the tent is breathable and as known this can reduce the amount of condensation especially at night when the temperature is drop. In addition, if the tent is not breathable and if there is no enough ventilation in the sleeping area the condensation will build up in the wall of the tent and the sleeping area will be wet. Therefore, this tent will solve the most common problems in the current tents and it will provide a comfortable place to live in.

Assembled

All the components needed to build the tent are provided in the package which is fabric bag. The following Figure shows the components inside the fabric bag.

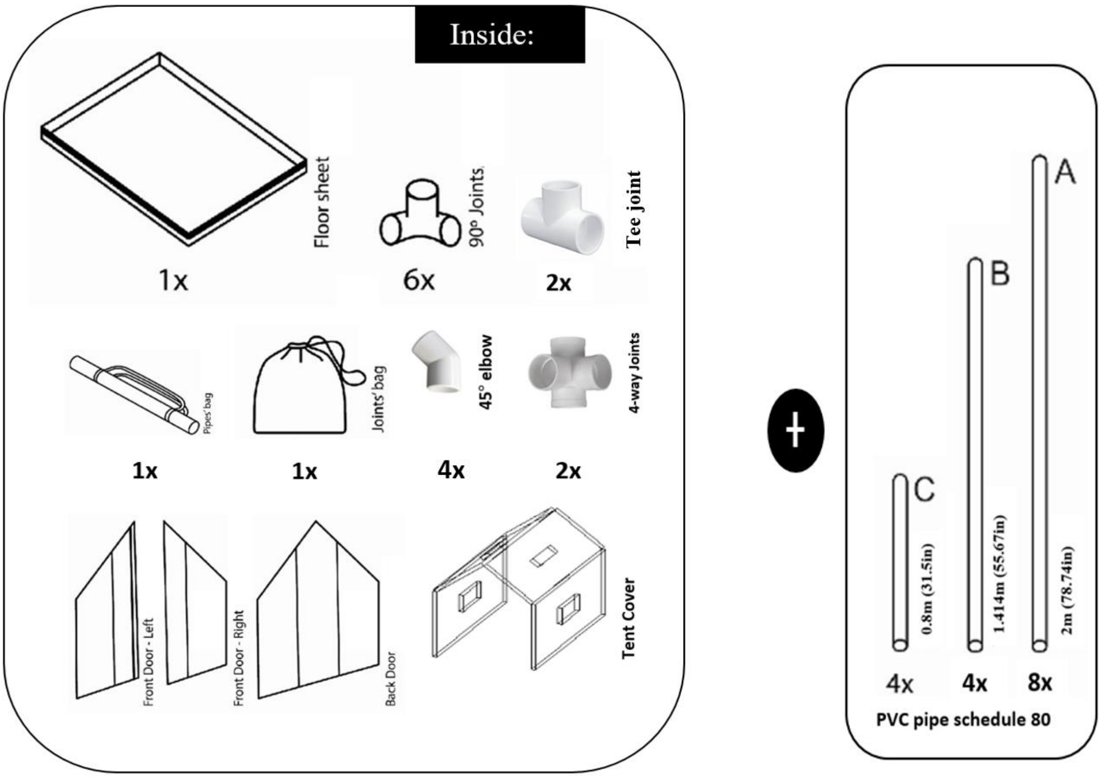


Figure 20: The components inside the fabric bag

First, the bath tub floor sheet is opened and placed on the floor, Figure 21.

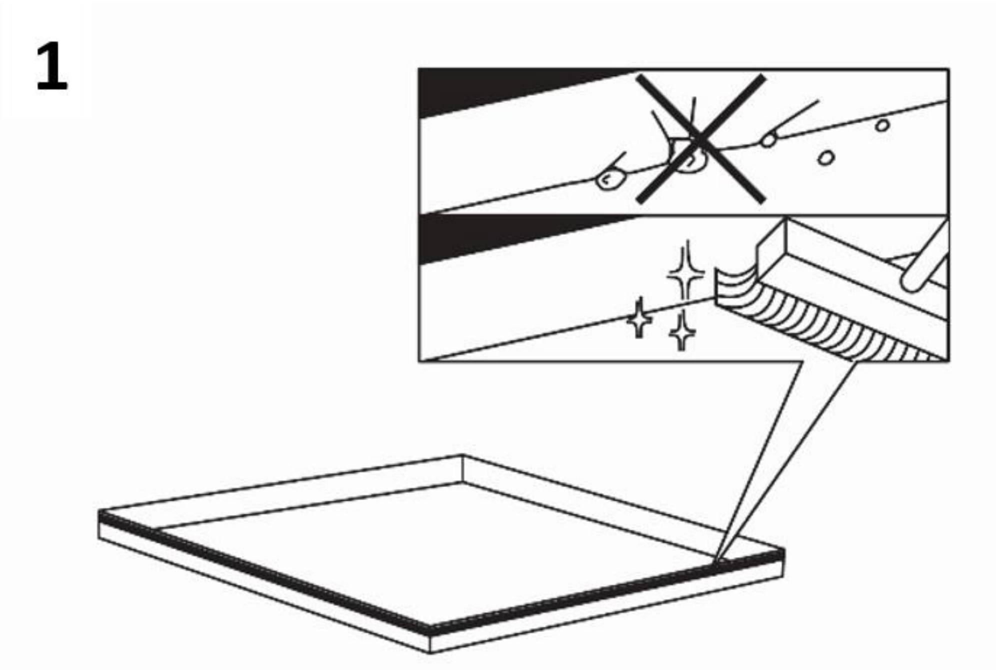


Figure 21: First step of the assembled

The 90° joints are placed in the four inside corners of the bath tub floor sheet Figure 22. The four 90° joints are connected with the four A pipes horizontally on the floor, and four C pipes placed vertically in the four 90° joints in the corners Figure 22.

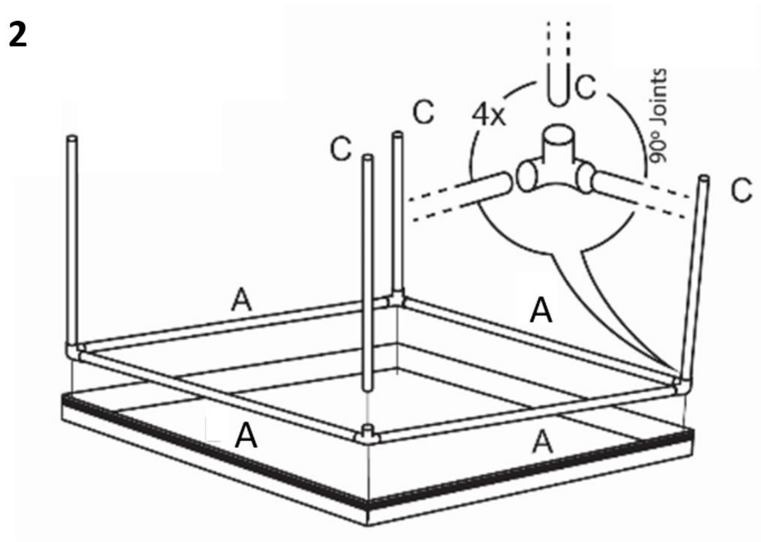


Figure 22: Second step of the assembled

In the front side of the tent, two tee joints are placed on the top of the C pipes and two 45°elbows are placed on the top of the tee joints Figure 23.

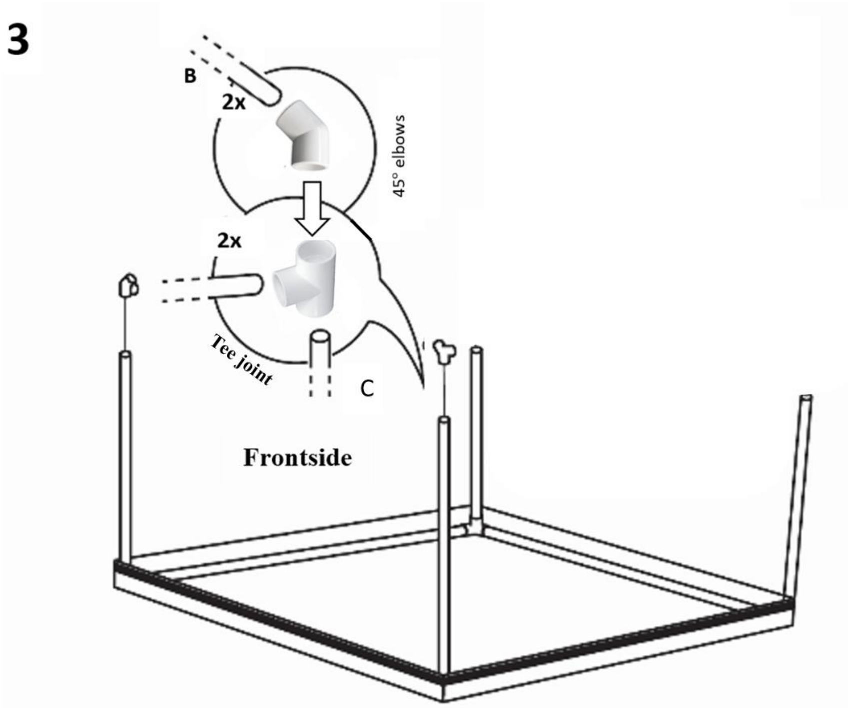


Figure 23: Third step of the assembled

In the backside of the tent, two 4-way joints are placed on the top of the C pipes and two 45°elbows are placed on the top of the 4-way joints Figure 24.

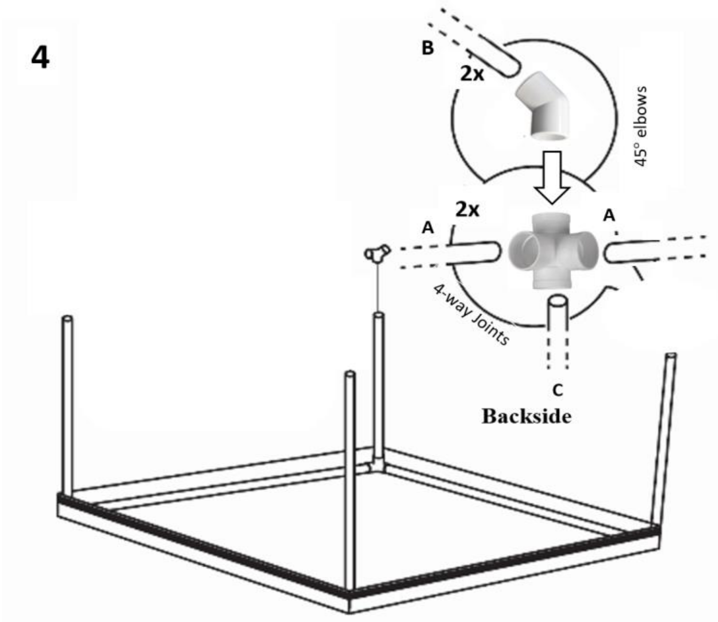


Figure 24: Fourth step of the assembled

In the backside, one A pipe is placed in the middle to connect the two 4-way joints together. On the top of the two 45°elbows, two B pipes are placed and connect by one 90° joint at the peak height of the tent. one A pipe is placed in the 90° joint at the peak height of the tent, at the end of this A pipe another 90° joint is placed. Finally, two B pipes are placed to connect the 90° joint in the front side with the two tee joints, then the frame of the tent is completed Figure 25.

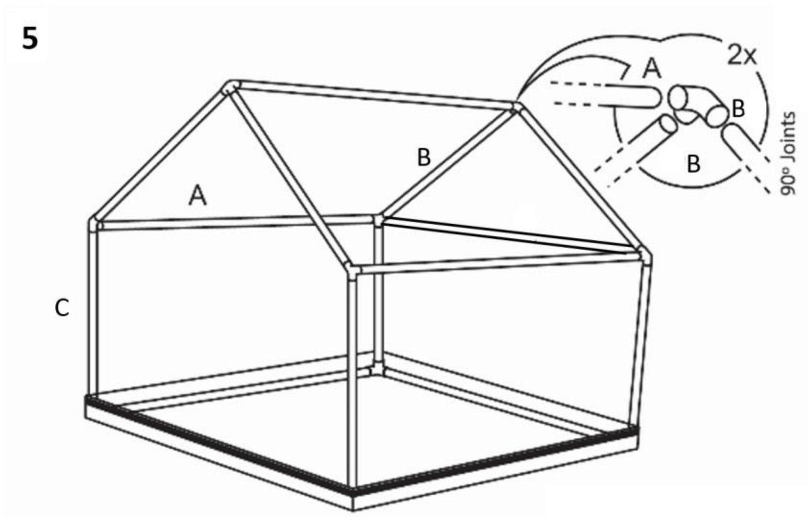


Figure 25: Fifth step of the assembled

The tent cover is opened and in summer, the mylar side face the outside environment, and in winter, the mylar side is faced the inside environment. The cover of the tent is connected with bath tub floor sheet sides by the Velcro Figure 26.

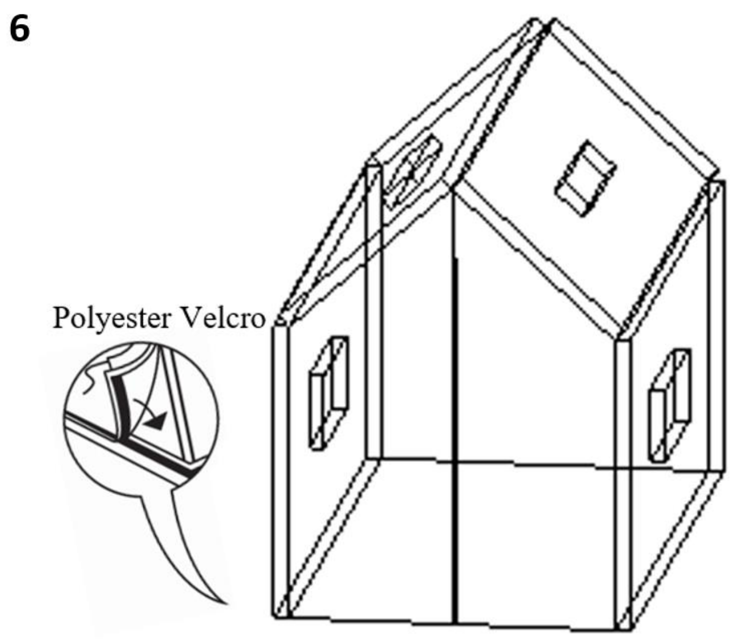


Figure 26: Sixth step of the assembled

The back door is connected to the tent cover and floor of the tent by the Velcro. The front door consists of two pieces right and left, the left side is placed first and connected to the tent cover and floor by the Velcro, then the right side of the door is placed.

Virtual Prototype/ Simulation Model Description

Cad model:

The solid works and Ansys workbench are used in order to have a 3D model of the tent. In this model, the human body is assumed to be a cylinder inside the tent with a temperature equals 36.5 ° C , Figure 27.

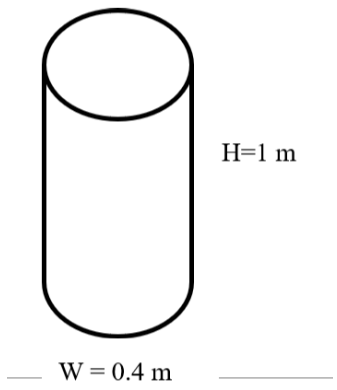


Figure 27: Human body as cylinder.

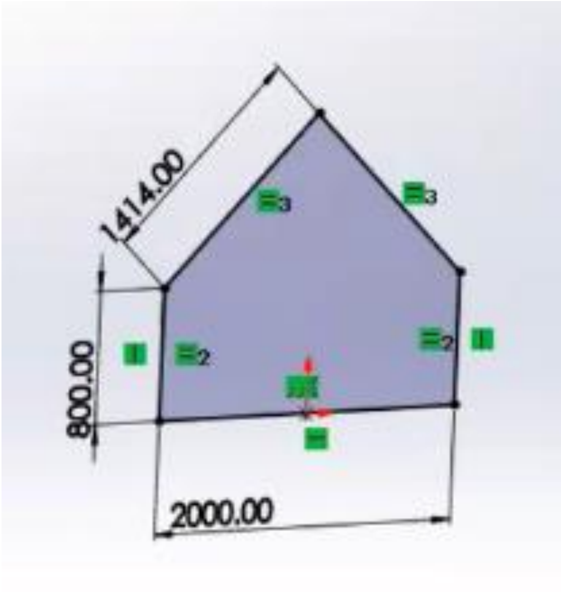


Figure 28:Dimensions of the tent in mm

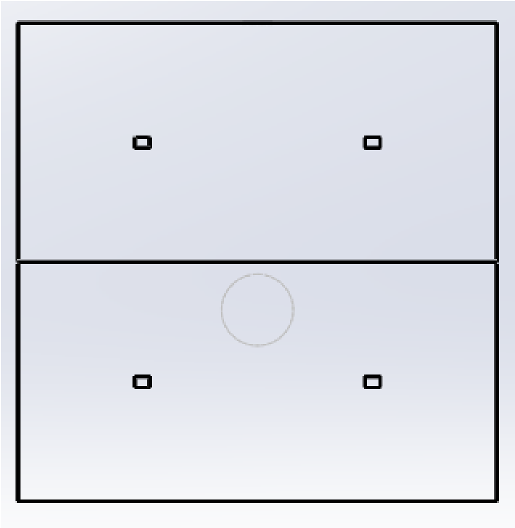


Figure 29: Top view of the tent

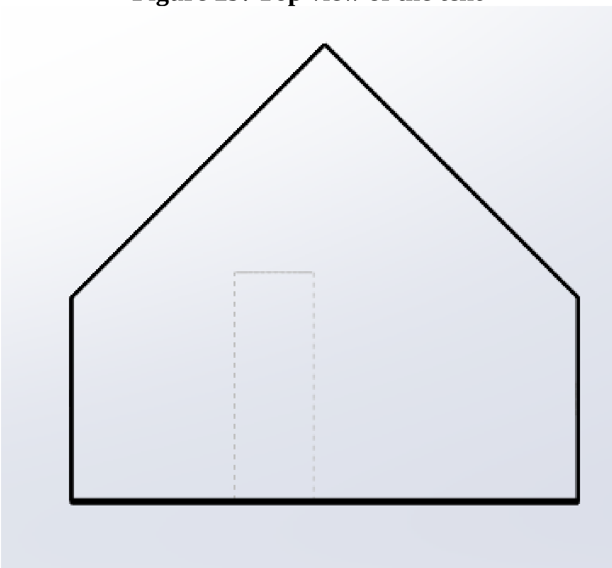


Figure 30: Back view of the tent

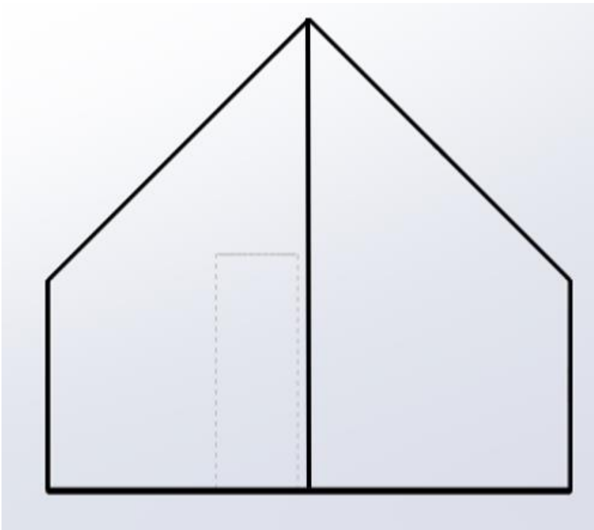


Figure 31: Front view of the tent

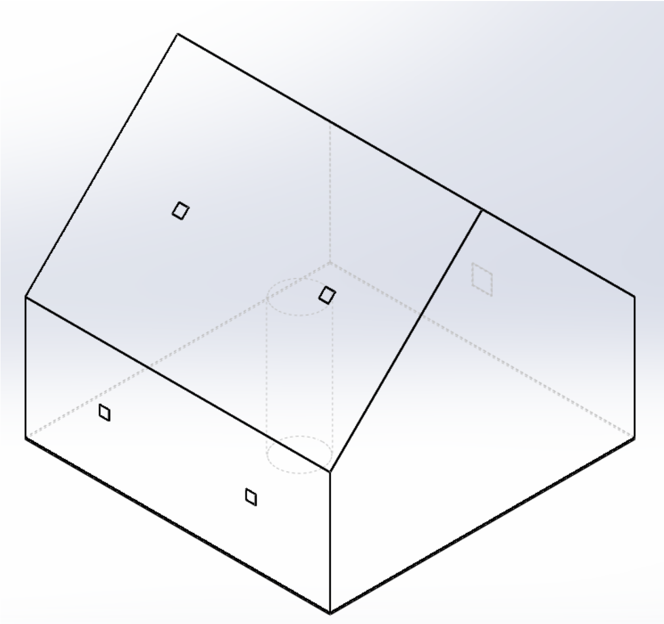


Figure 32: Isometric view of the tent

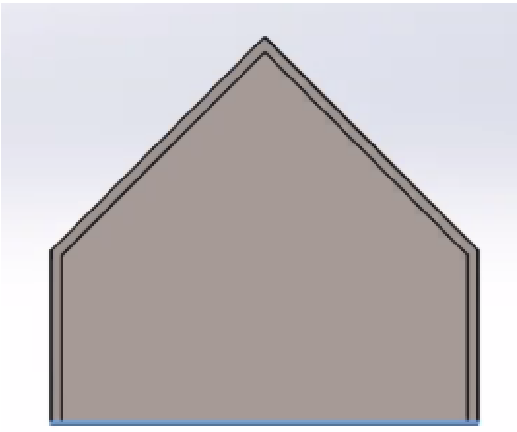


Figure 33:Layers of the cover of the tent

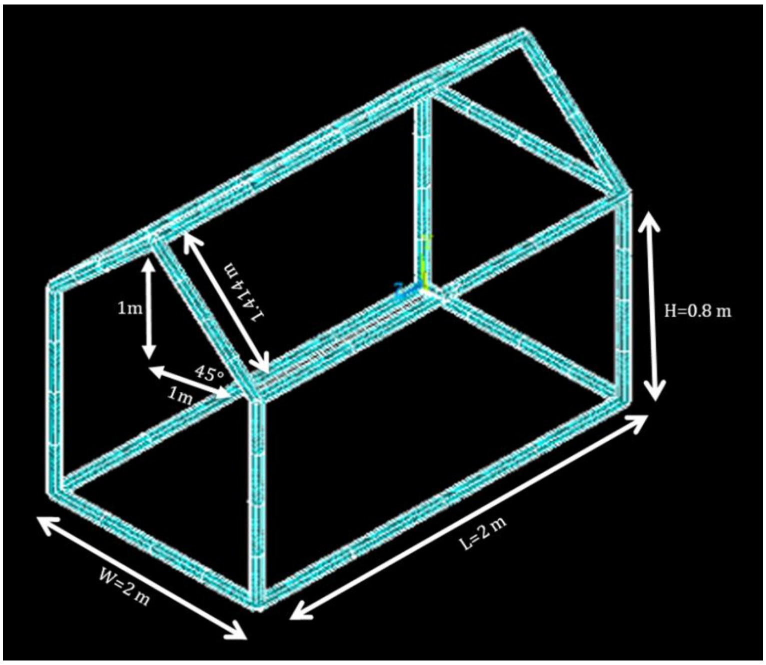


Figure 34: Frame structure with the dimensions

The elbows used for the frame are shown in the assembled section.

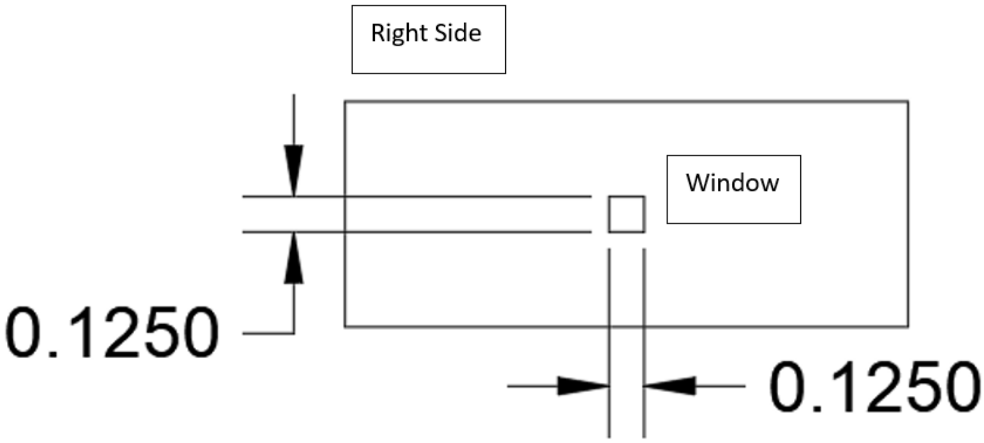


Figure 35: Dimensions of the window in the right side

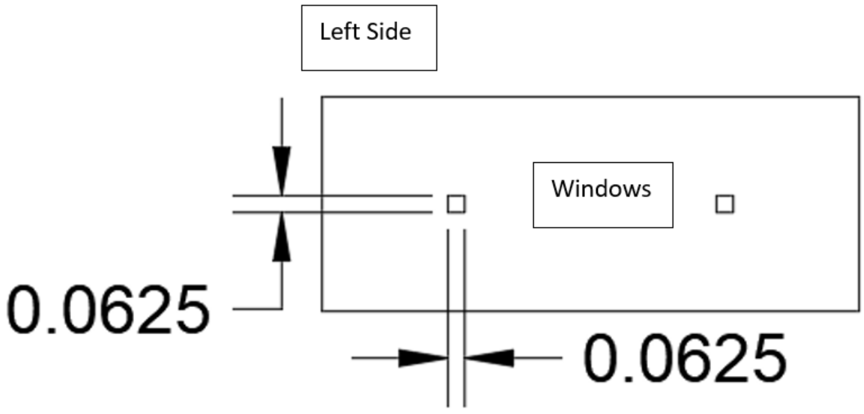


Figure 36: Dimensions of the window in the left side

The upper four windows in the tent have the same dimensions of the windows in the left side.

Perspective test models

Two types of simulation are done in this study, one for the structure and one for the thermal analysis.

The structure:

The structural analysis is done by using Ansys workbench. In order to study the structure, the loads are added in the frame, and the results were as follows.

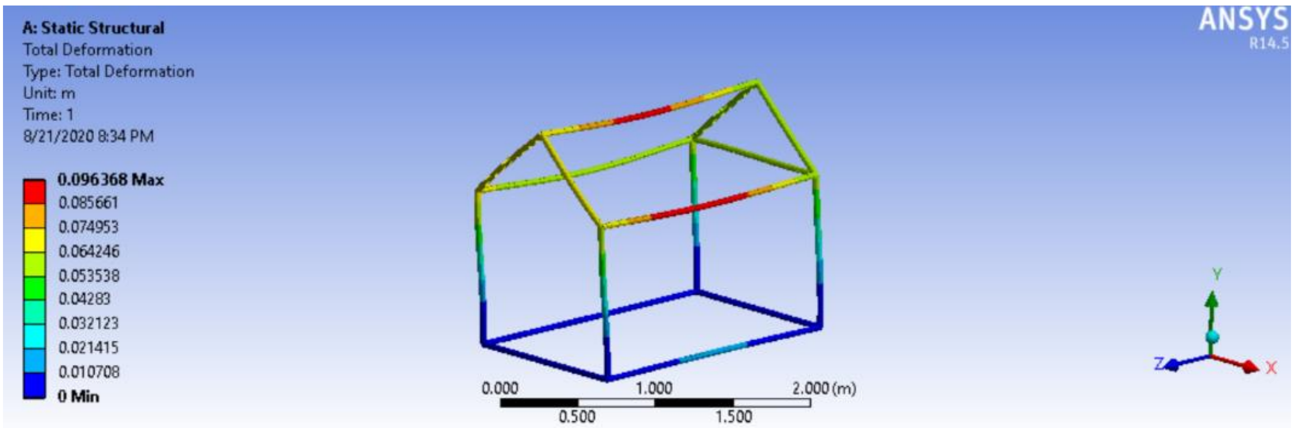


Figure 37: Deformation of the design

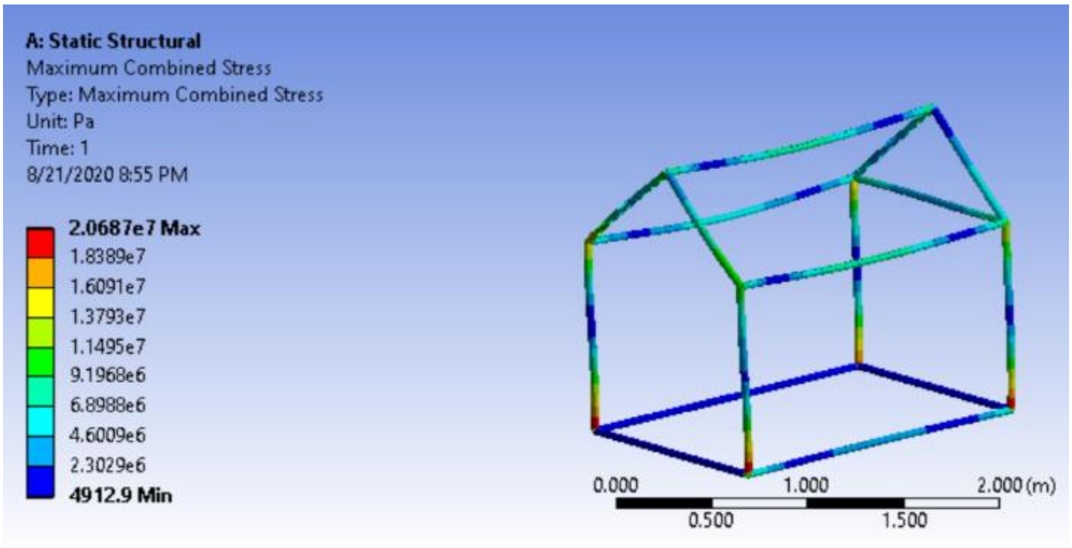


Figure 38: Combined stress of the design

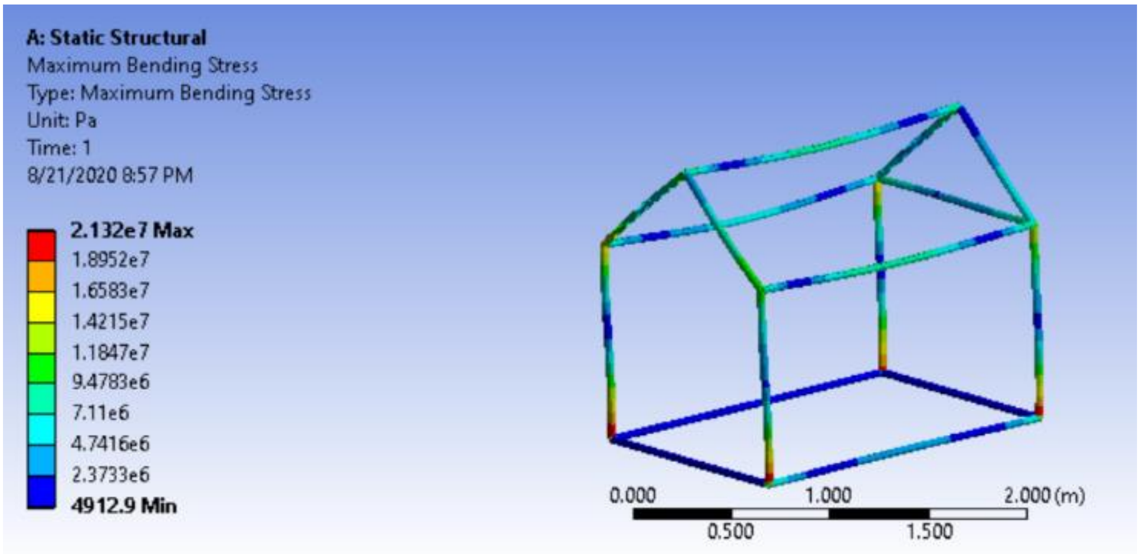


Figure 39: Bending stress of the design

It is concluded from the previous analysis that the frame is safe and it will not collapse.

The thermal analysis:

The thermal analysis for the tent is done in summer and winter in solid works. The following Figures show the simulation and temperature distribution of the tent at the highest temperature in summer.

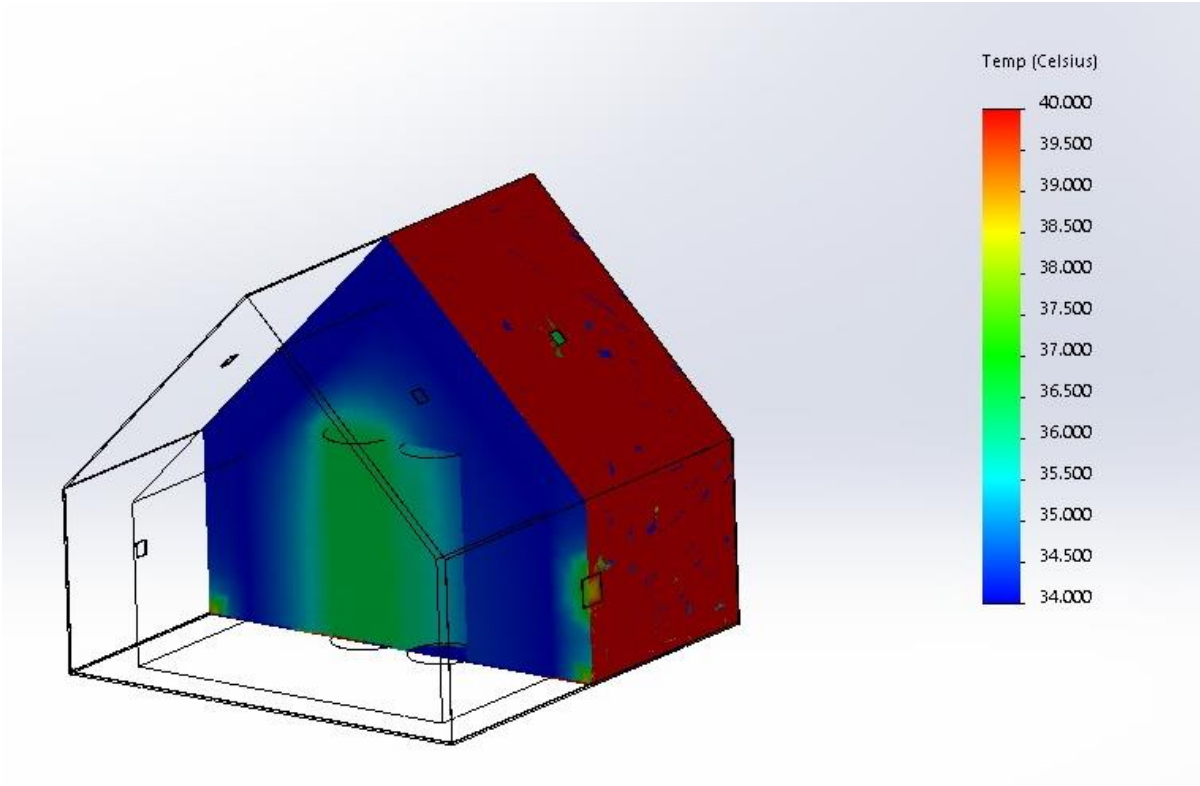


Figure 40: 3D simulation of the tent in summer

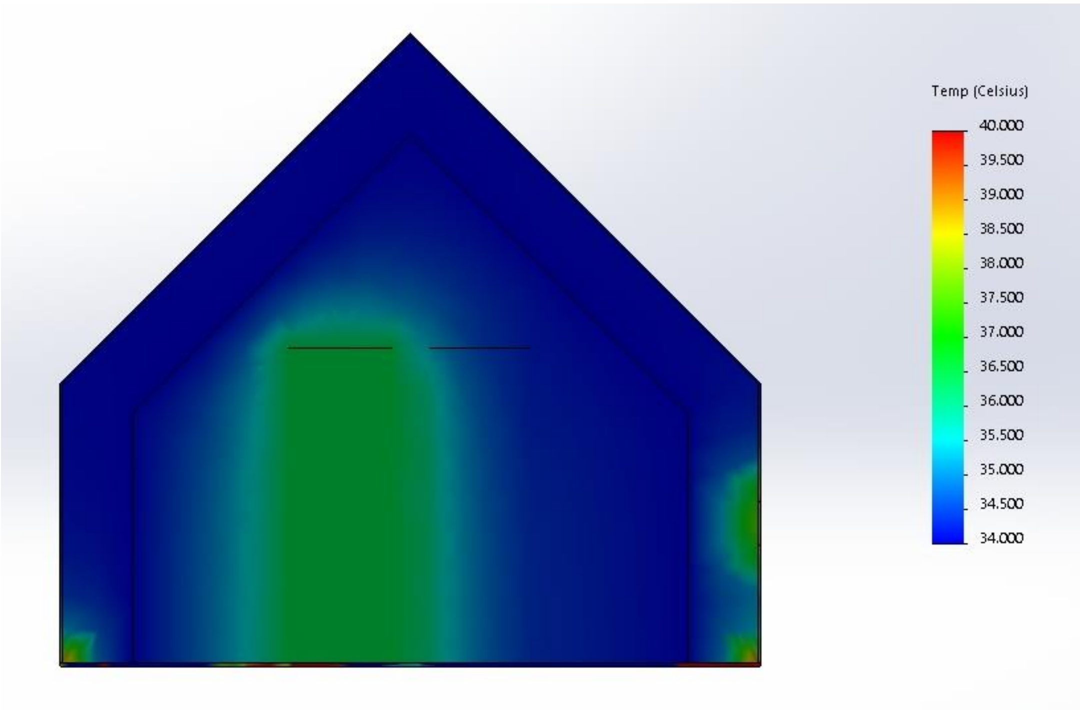


Figure 41: 2D simulation of the tent in summer

It is concluded from the thermal analysis of the tent in summer, the inside temperature equals approximately 34 $° C$ when the outside temperature equals 40 $° C$. This value of inside temperature is compared with the hand calculated value of at the same time, which equals 33.8 $° C$.

The following Figure shows the simulation and temperature distribution of the tent at a randomly moment when the outside temperature equals 8 $° C$ in winter.

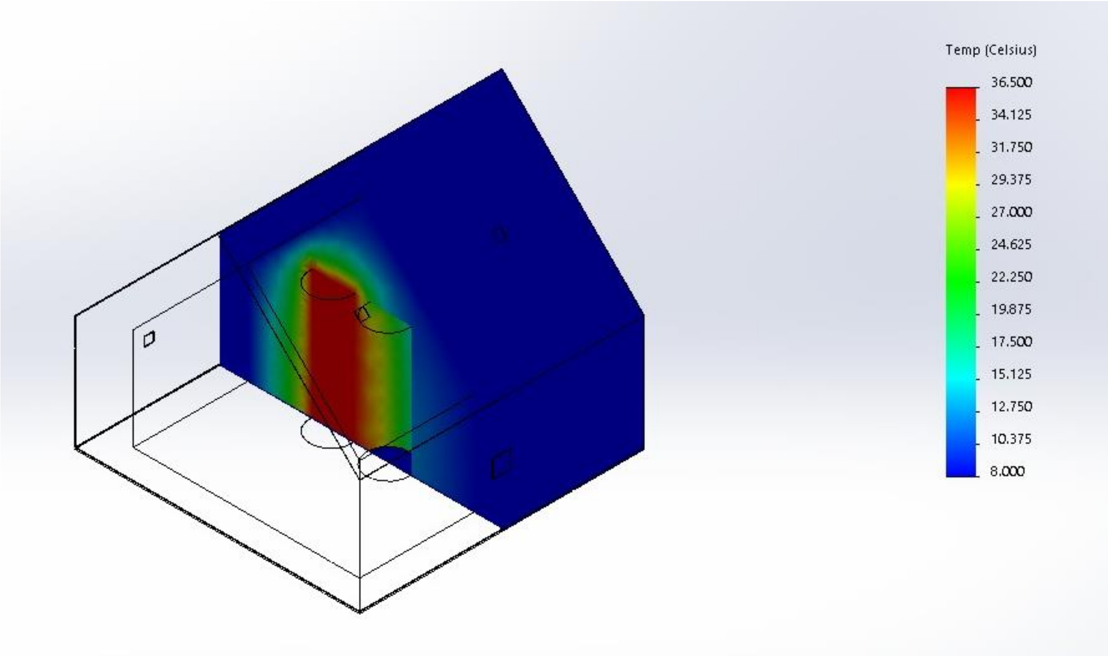


Figure 42: 3D simulation of the tent in winter

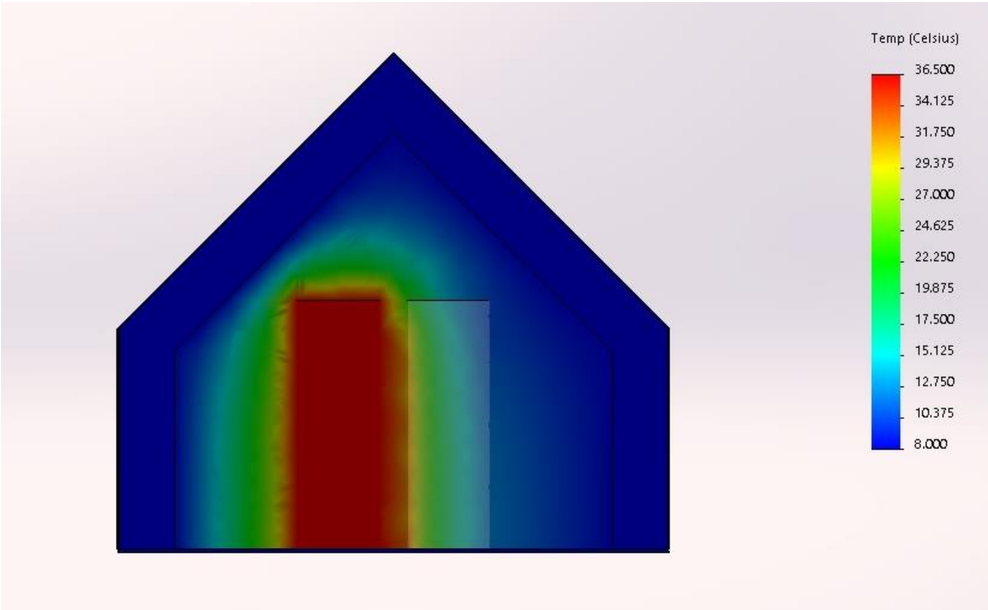


Figure 43: 2D simulation of the tent in winter

It is concluded from the thermal analysis of the tent in winter, the inside temperature equals approximately 15 $° C$ when the outside temperature equals 8 $° C$. This value of inside temperature is compared with the hand calculated value at the same time, which equals 14.2 $° C$.

This system is transient, therefore, it follows the following equation

$$E_{in} - E_{out} + E_{gen} = \rho V C_p \frac{dT}{dt} \quad (1)$$

$$E_g - [h(T - T_\infty) + \varepsilon\sigma(T^4 - T_{sur}^4)]A + q"A = \rho V c \frac{dT}{dt} \quad (2)$$

Equation 2, is a nonlinear, first order, nonhomogeneous, and ordinary differential equation.

In order to simplify the system, the lamped capacitance method is used for the analysis after obtaining the value of Biot number. Since, the value of Biot number is less than 0.1, the lamped capacitance method is used. Besides, the radiation is assumed to be negligible and there is no heat flux.

$$\frac{T - T_\infty}{T_i - T_\infty} = \exp(-at) + \frac{b/a}{T_i - T_\infty}[1 - \exp(-at)] \quad (3)$$

The details equations and assumptions are shown in appendix F, and the sample calculations are shown in appendix I. In addition, the result for both summer and winter are shown in the appendixes J and K.

<u>Design Testing</u>

The testing of the design is done by solving numerical equations and solid works program to find the inside temperature in summer and winter. The results from the numerical solutions are shown in the following Figure.

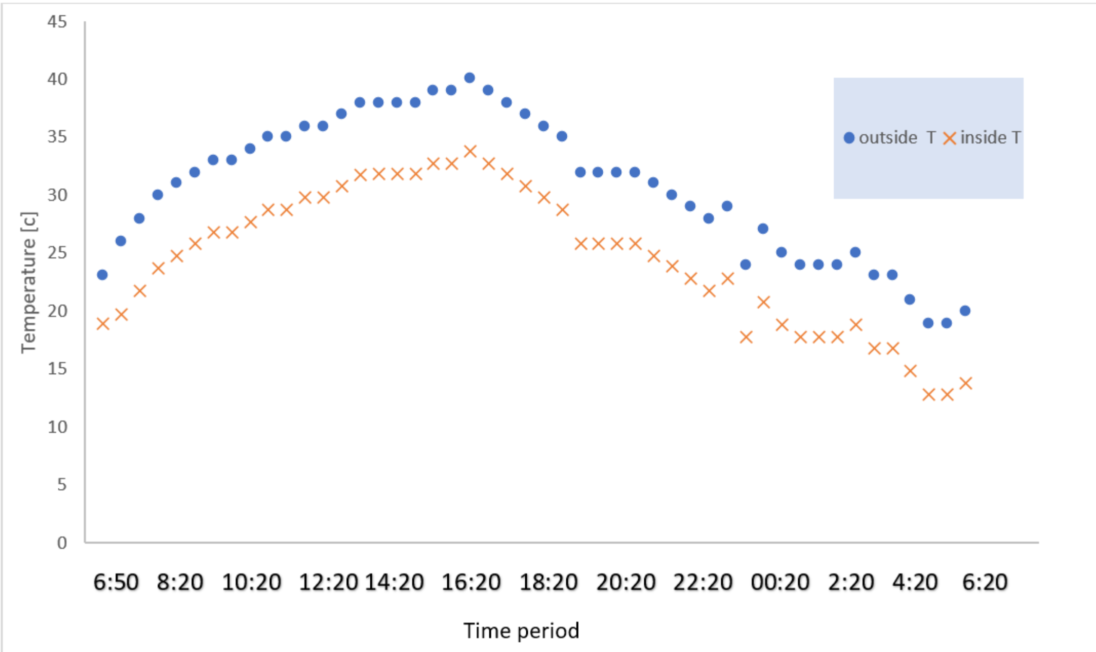


Figure 44: Transient study of temperature in Summer

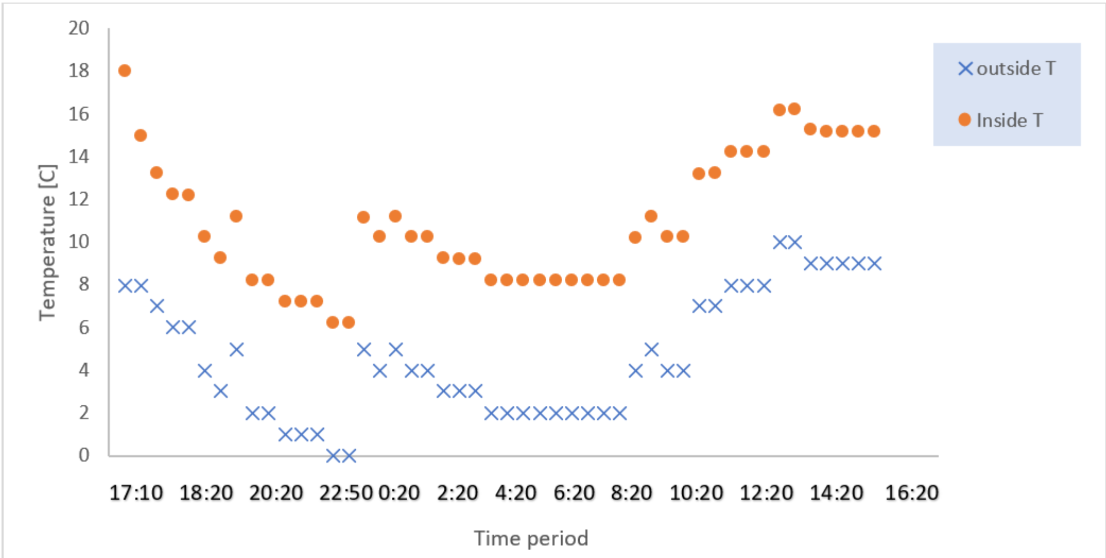


Figure 45: Transient study of temperature in Winter

As concluded from the previous Figures, the inside temperature in summer is approximately cooler than the outside temperature in sex degrees. In addition, the temperature inside the tent is approximately warmer than the outside temperature in 6 degrees in winter. Also, the values of inside temperature that calculated numerically approximately equal the values of inside temperature calculated from solid works. The following figures shows the data of inside temperature and dew point temperature.

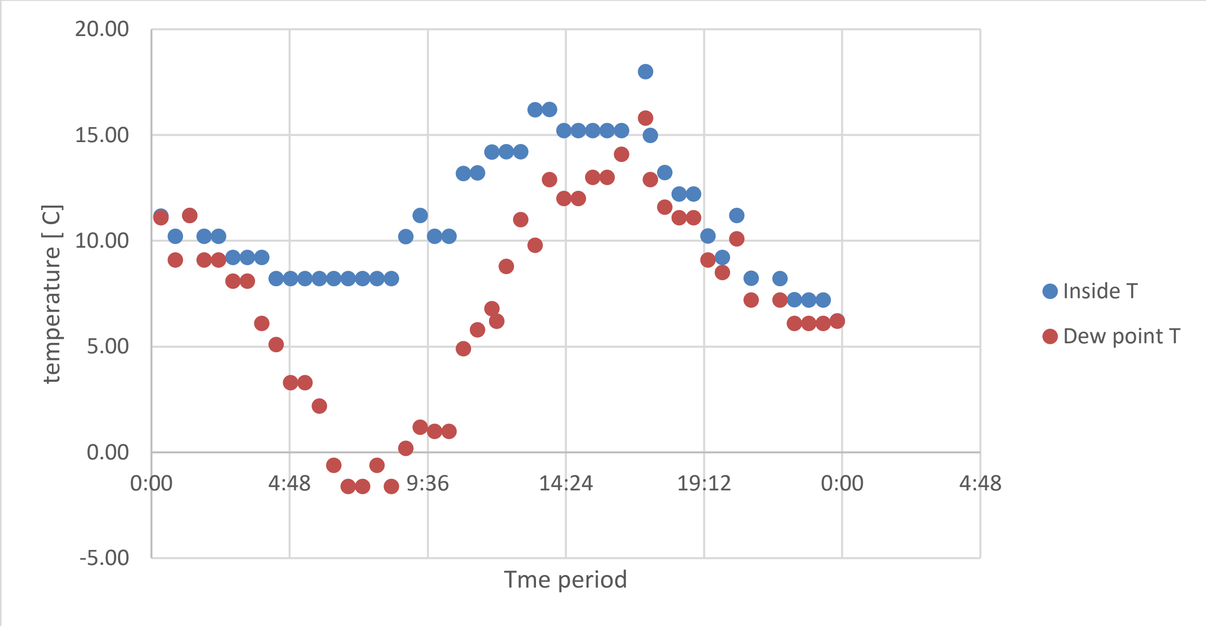


Figure 46: Inside temperature and dew point temperature in winter

It is concluded from the previous Figure, the value of inside temperature in winter is approximately near the value of dew point temperature because of the high value of relative humidity in winter.

The following figures shows the data of inside temperature and dew point temperature in winter.

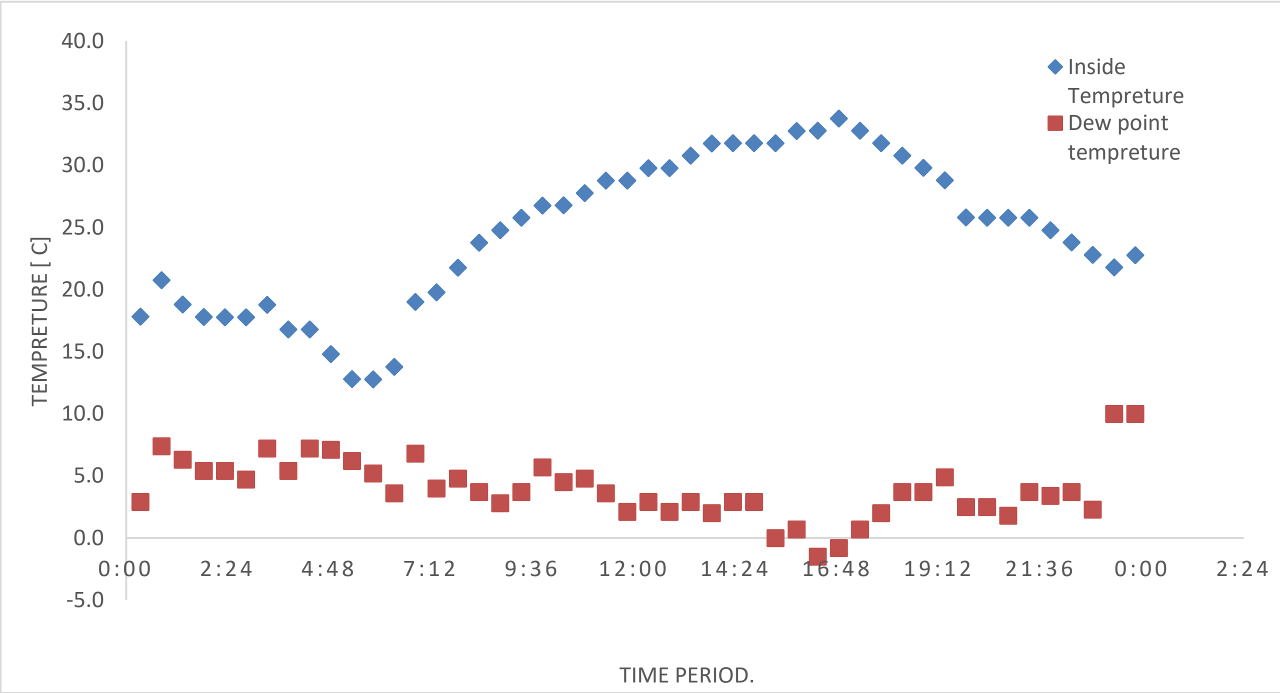


Figure 47: Inside temperature and dew point temperature in summer

It is concluded from the previous Figure, the value of inside temperature in summer is far away from the value of dew point temperature, therefore the condensation will not occur inside the tent in summer Also, the testing of the frame is done by using Ansys workbench and it is concluded that the frame is strong and will not collapse.

<u>Behavior with environment/Safety</u>

This product is safe from snow, rain, and fire. In addition, the project has a factor of safety equals 2.5, it will not collapse, and it withstands with wind speed equals 50 kmph.

It is an important thing to design a tent with materials that do not harm the environment (Environmentally friendly). Since, the most materials used to build this tent are polyester such as polyester wool, Polyester Velcro, 190T PU coated polyester and Mylar, and as known, the polyesters are not biodegradable therefore they are bad for the environment. Also, the production of polyester uses bad and harmful chemicals that cause pollution and damage the environment. A good property for Mylar that it can be recycled by several processes. In addition, the 190T PU coated is damaged the environment because the process of past the PU coating has very high levels of the toxic solvent DMF (dimethyl form amide) and this solvent becomes greenhouse gas that damages the environment. PVC pipes and fittings have a high corrosion resistance, therefore is has a long-life span. Safety, recyclability, and environmental performance are properties of PVC pipes. It consists of low carbon plastic. It has a low manufacturing cost due to low energy used and few resources needed to produce it. Also, it has a smooth finish surface. PVC pipes can recycle for several times without changing in its properties. On the other hand, the polyesters are 100% recyclables which is a good thing. In addition, the polyesters can be manufactured from recycled plastics that means no need to produce polyesters by using harmful chemicals. Besides, Mylar material can be recycled with other polyester risen materials. Figure 46 shows the process of recycling polyesters. Therefore, if the polyesters used in this tent made from recycled plastics the overall materials will be environment friendly.

Figure 48: The process for recycling the polyesters [24]

Economic Study

In real life, when someone asked about a design, he asked about its cost. 4 seasons tent is a product that designed for homeless and refugees. In order to help them, this product must be as cheap as possible with highly efficient process. In this section, an imaginary path is planned and followed to have an overall view of the revenue.

The path studied 1 year from the production of 4 seasons tent, with assumption of 50 quantities of this product is produced monthly, or 600 yearly. Each quantity has price equals 175 KD, where it costs 164.65 KD. This amount of cost includes shipping cost, manufacturing cost (processes), packaging costs, and all components cost, where the details are shown in appendix H. The marketing has zero cost since the investors are charity organizations, and this product is provided for refugees and homeless.

Nevertheless, it has maintenance free since most of the materials can be replaced or thrown away for recycling.

The profit can be found as follows:

Net cash flow (profit) = cash inflows – cash outflows

NCF = 175 – 164.65 = 10.35 KD

If 4 seasons tent is produced 600 times per year, the total outcome for this year is 98,718 KD, and the total income is 105,000 KD. Therefore, the gross profit is 6,282 KD for this year.

Conclusion and recommendation

After the recent disscustion, it is concluded that these results are based on assumptions and simplifications, and the real prototype is needed to have the experimental results which are the actual behavior of the tent. From the numerical method and simulations, this tent will produce a temprature difference between inside it and outside by 6 degrees, which is one of the goals in this design. In winter, the air inside the tent will be humid due to high relative humidity, since the dew point is close to the inside temprature and relative humidity up to 100%. To solve this problem the natural ventilation is not sufficient in this case, a small fan or heater is recommended using natural source of energy. This source of energ can be used for lighting or USB charger. This four season's tent had been designed to fit two adults and one child, but from the survey answers, it has been noticed that there is a need to make two connected tents for one family, they will have more privacy. If there are children, they will be next to their parents. The connected tents could be of the same size connected with a Velcro door. There is an idea also to make a W.C for each tent since those tents are designed to be a home for refugee so they will stay inside it for a long time. The analyses should be improved, real data must be recorded from experimental test of the prototype. A real and detailed economic study must be done before the production process.

This product can serve for the workers in sites, camping, or trips. For these cases it can be available with more efficient materials such as Aluminum for stracture

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We are extremely grateful to our parents for their love, prayers, caring, understanding and sacrifices for educating.

Appendixes

Appendix A (Surveys)

Two surveys are done to have a sense of how many families are there. In addition to know the acceptable budget and the responses.

Survey for Charity Organizations

We are interested in understanding how the refugees people live in Turkey (Urfa), what the problems they are suffering from are and how we can help them to improve their home 'tent'.

اننا مهتمون في معرفة كيفية معيشة اللاجئين في تركيا (اورفا)، ما هي المشاكل التي يعانون منها، وكيف بإمكاننا مساعدتهم في تحسين مسكنهم (الخيمة)

1. How many families are there?

1. كم عدد الأسر هناك؟

1) 20-40
2) 40-60
3) 60-80
4) Less than 20 (أقل من 20)
5) Higher than 80.(أكثر من 80)

2. How many children are there?

كم عدد الأطفال هناك؟

1) 20-40
2) 40-60
3) 60-80
4) Less than 20 (أقل من 20)
5) Higher than 80. (أكثر من 80)

3. What is the number of persons in each family?

كم عدد أفراد الأسرة الواحدة؟

1) 2-4
2) 4-7
3) 7-10

4.What is the level your organization operate in?

ما هو المستوى الذي تعمل به منظمتكم؟

1) International. (دولي)
2) National. (وطني)
3) Local (محلي)
4) From the refugee community (من مجتمع النازحين)

5. What is your organization name?

ما أسم منظمتكم؟

6. How this organization helps the refugee people?

كيف تساعد هذه المنظمة اللاجئين؟

1) Feed (طعام)
2) residence 'home'(مسكن)
3) Health and medical care.(رعاية صحية)
4) Education.(تعليم)

7. Do you think that the current tents are perfect and comfortable for the refugees?

هل تعتقد بأن الخيام الحالية مناسبة ومريحة للاجئين؟

1) Yes (نعم)
2) No (لا)

8. What are the important needs in the tents, in your opinion?

من رأيك، ما هي أهم الاحتياجات التي قد تتوفر في الخيمة؟

9. What do you think is the accepted cost for the tent?

ما هو السعر المقبول للخيمة الواحدة؟

1) 100-150KD
2) 150-300KD
3) Above 300 KD (أكثر من 300)

10. What are the most common problems in the current tents?

ما هي المشكلات الموجودة في الخيمة الحالية؟

10. Please write any extra comment.

من فضلك اكتب أي تعليق إضافي

Survey for Refugees in UFRA

We are interested in understanding how the refugees people live in Turkey (Urfa), what the problems they are suffering from are and how we can help them to improve their home 'tent'.

اننا مهتمون في معرفة كيفية معيشة اللاجئين في تركيا (اورفا)، ما هي المشاكل التي يعانون منها، وكيف بإمكاننا مساعدتهم في تحسين مسكنهم (الخيمة).

1. Do you think that your current living place is comfortable?

هل تعتقد بأن مكان إقامتك الحالية مناسبة ومريحة؟

1) Yes (نعم)
2) No (لا)

2. What do you think is missing in your place to be comfortable?

ماذا تعتقد هو الشي الناقص في مكان معيشتك ليكون مناسب؟

3. If you had a place to live in, what would you like it to be in the first place?

من منظورك، ما هي الميزة الأساسية التي يتوجب أن تتواجد في مكان معيشتك؟

1) Warm in winter (دافئ في الشتاء)
2) Cool in summer (بارد في الصيف)
3) Wide (واسع)
4) Rain resistance (ضد الأمطار الغزيرة)

4. If you have a tent, will you like it to be enough for:

إذا امتلكت خيمة، كم عدد الأفراد المناسب تواجدهم فيها؟

1) Two (اثنان)
2) Three (ثلاثة)
3) Four (أربعة)
4) More than four (أكثر من أربعة)

5. What do you think is more important to be inside your tent?

ما هو الشيء الأكثر أهمية الذي تود إضافته إلى خيمتك؟

1) Lights (إضاءة)
2) USB charger (شاحن للهاتف)
3) Others, write them down: (أخرى، اذكرها)

6. How many hours are spent inside the tent?

كم من الساعات تمضيها داخل الخيمة؟

1) Less than 7 hr (أقل من)
2) 7 – 10 hr
3) 10 – 14 hr
4) Above 14 hr (أكثر من)

7. What are the most common problems in the current tent?

ما هي المشاكل التي تواجهها في خيمتك الحالية؟

8. Please write any extra comment.

من فضلك اكتب أي تعليق إضافي.

<u>The results of the first survey, which is for the refugees, are as following:</u>

- First question: Do you think that your current living place is comfortable?

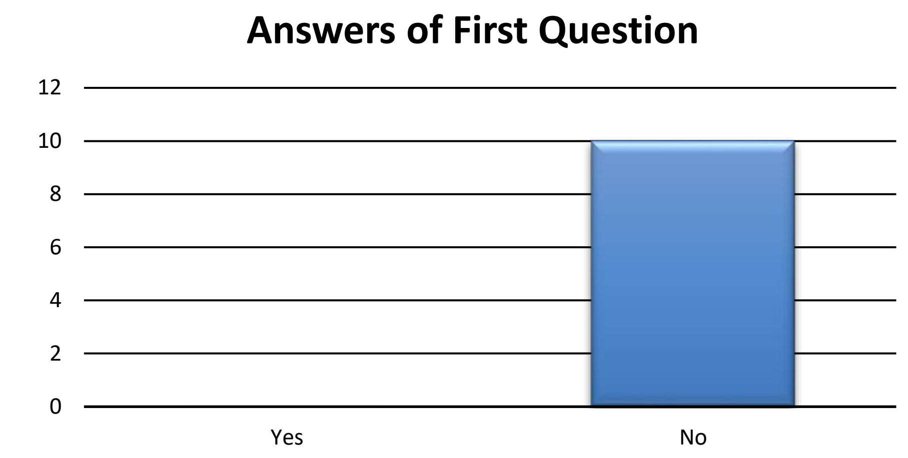


Figure 49: Answers of the first question in first survey

- Second question: What do you think is missing in your place to be comfortable?
    - Provide a source of clean water.
    - Provide a comfortable place to live in.
    - Provide more than one tent for each family.
    - Improve the current tents.
    - Nothing.
    - Provide a source of energy.

- Third question: If you had a place to live in, what would you like it to be in the first place?

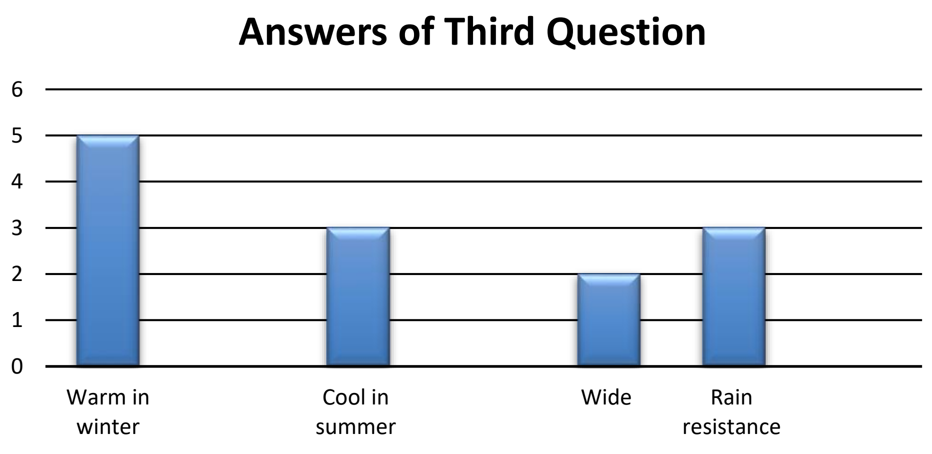


Figure 50: Answers of third question in first survey

- Fourth question: If you have a tent, will you like it to be enough for:

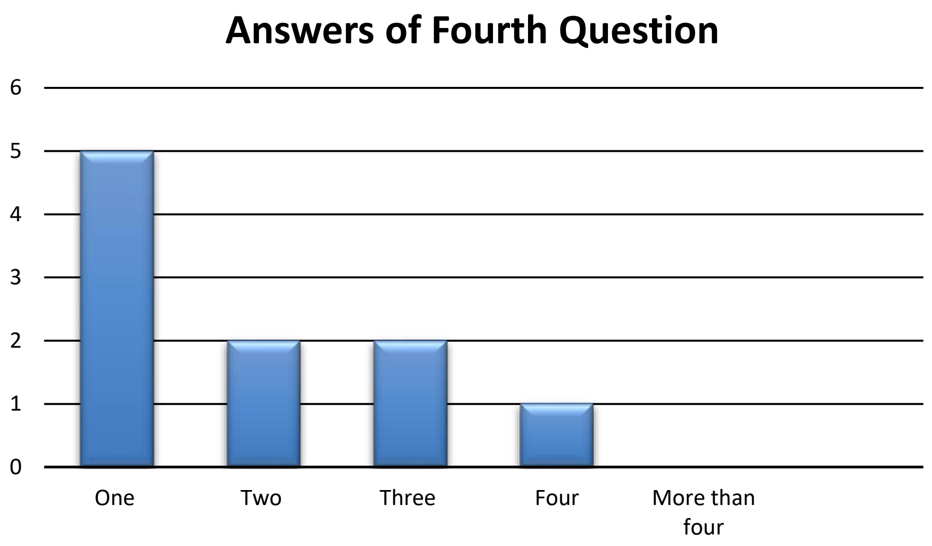


Figure 51: Answers of fourth question in first survey

- Fifth question: What do you think is more important to be inside your tent?

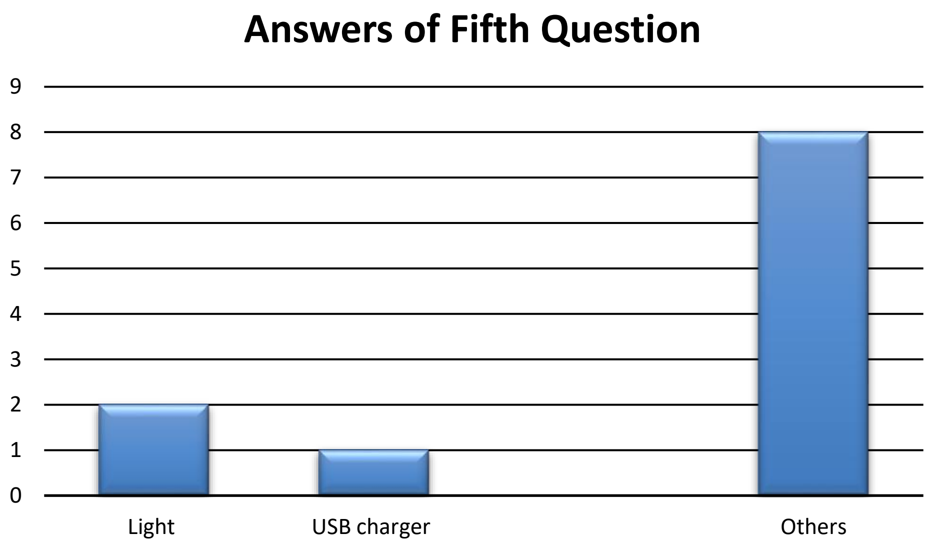


Figure 52: Answers of fifth question in first survey

- The other answers included:
  - Large tent.
  - Increase the lighting inside the tent.
  - Provide a source of heating.
  - Provide a source of energy.
  - Provide a toilet.
  - Provide a source of water.
  - Heating devices.

- Sixth question: How many hours are spent inside the tent?

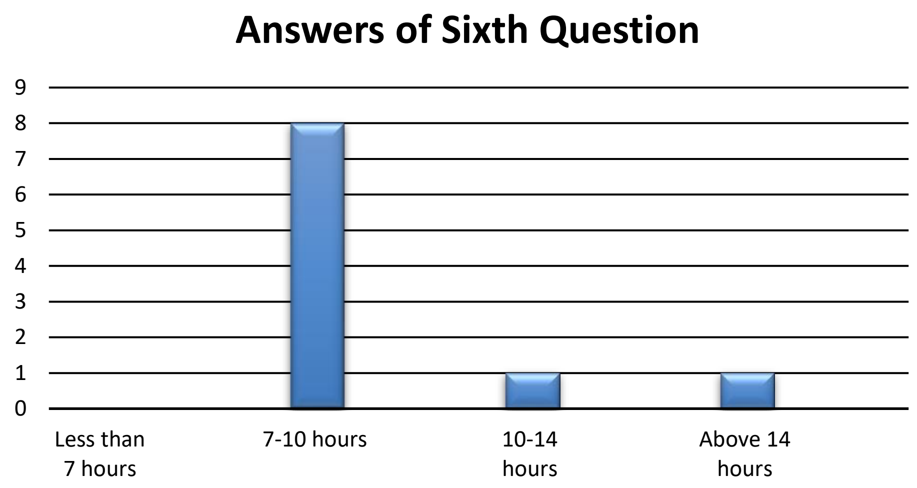


Figure 53: Answers of sixth question in first survey

- Seventh question: What are the most common problems in the current tent?
  - Leaking of water inside the tent.
  - Insects.
  - Cold weather in winter.
  - Lacking off a source of clean water.
  - Old and uncomfortable tent.
  - Small tent.

- Eighth question: Please write any extra comment:
  - We wish that we had a warmer, safer, and better place to live in.
  - More caring from charity organizations.

<u>The results of the second survey, which is for the charity organizations, are as following:</u>

- First question: How many families are there?

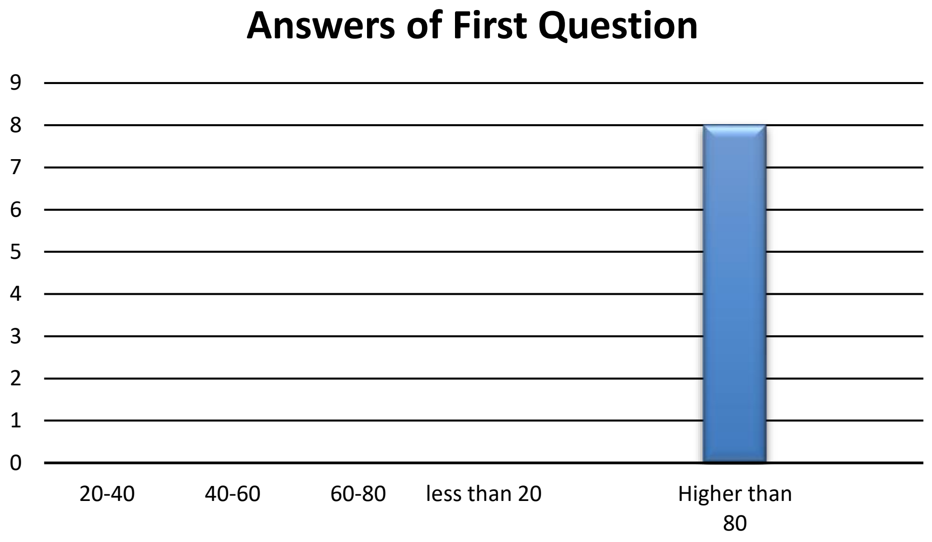


Figure 54: Answers of first question in second survey

- Second question: How many children are there?

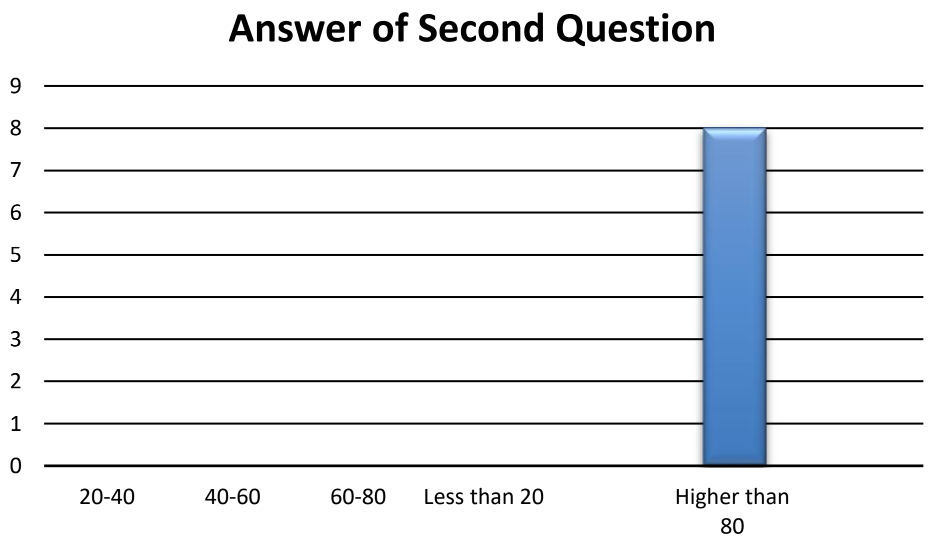


Figure 55: Answers of second question in second survey

- Third question: what is the number of persons in each family?

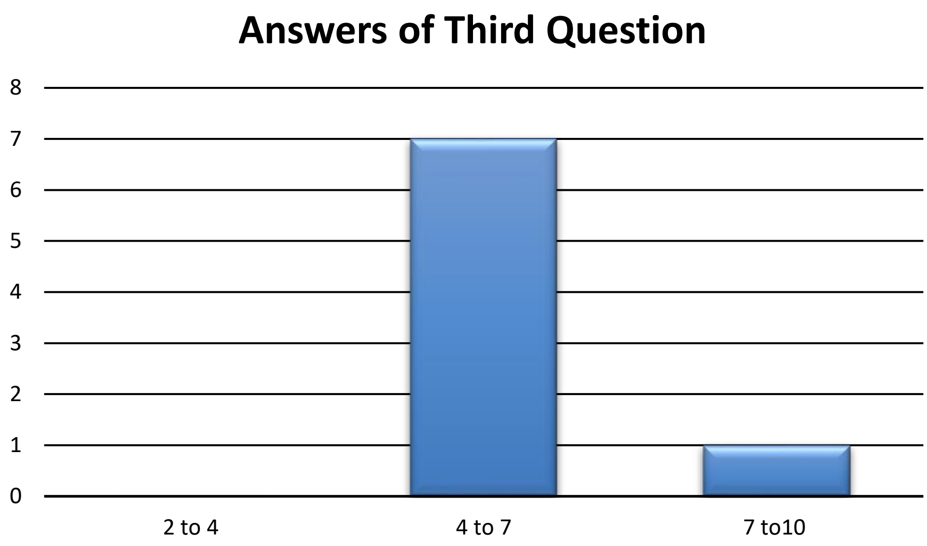


Figure 56: Answers of third question in second survey

- Fourth question: What is the level your organization operate in?

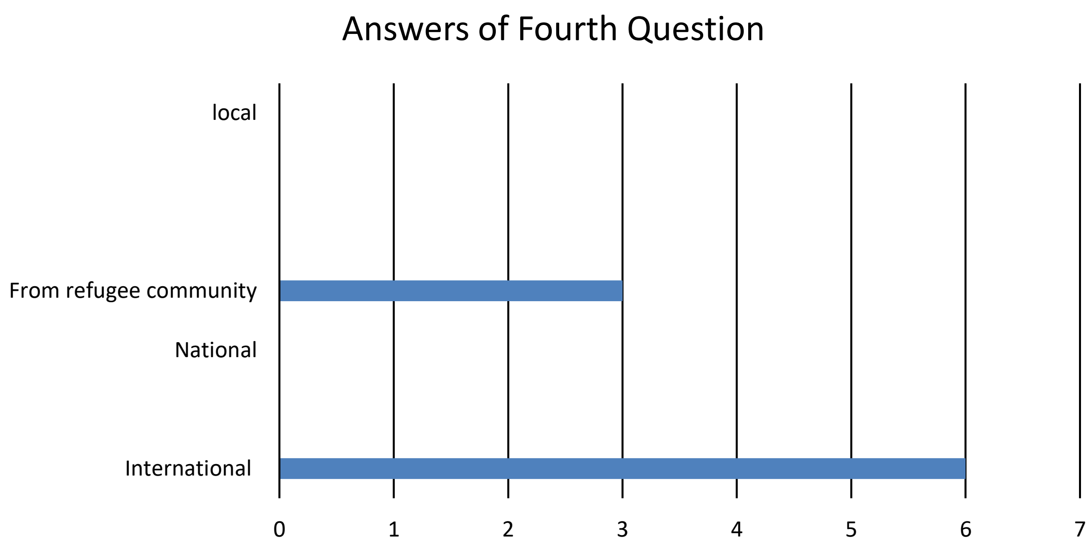


Figure 57: Answers of fourth question in second survey

- Fifth question: what is your organization name?
  - Tarahem Charity Organization.

- Sixth question: How this organization helps the refugee people?

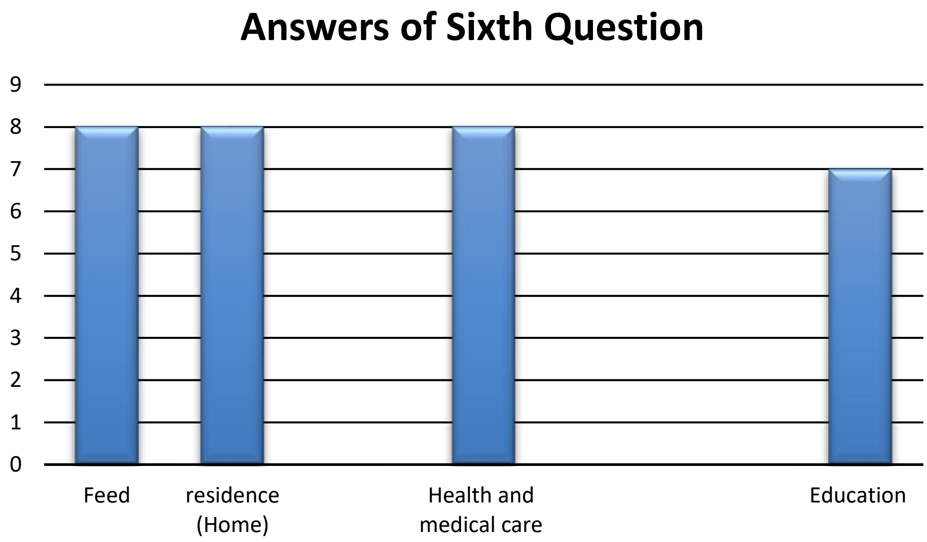


Figure 58: Answers of sixth question in second survey

- Seventh question: Do you think that the current tents are perfect and comfortable for the refugees?

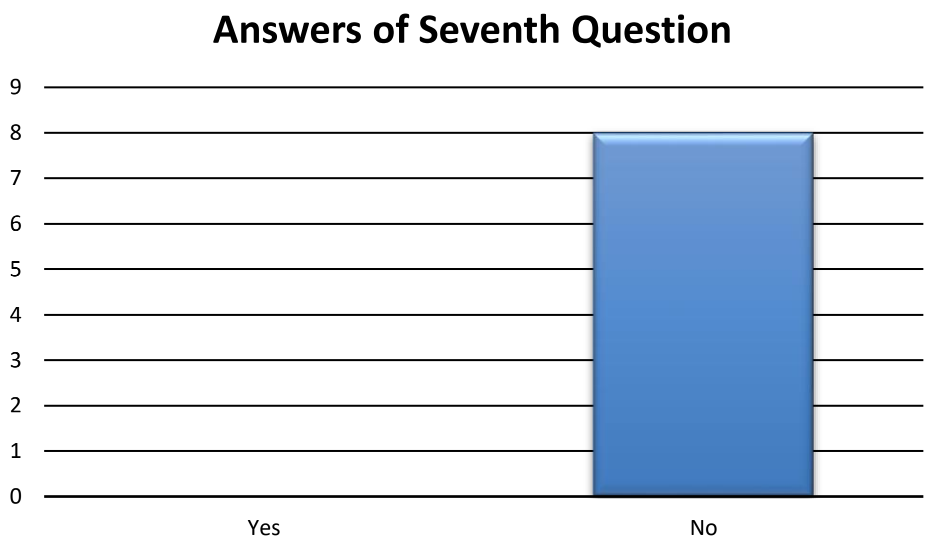


Figure 59: Answers of seventh question in second survey

- Eighth question: What are the important needs in the tents, in your opinion?
  - Source of electricity.
  - Source of heating.

- Prevent water from leaking inside the tent.
- Lacking off enough ventilation inside the tent.
- Need bigger tents.
- Cooler environment in summer.
- Sleeping bags.
- The tent should be fire resistance.

- Ninth question: What do you think is the accepted cost for the tent?

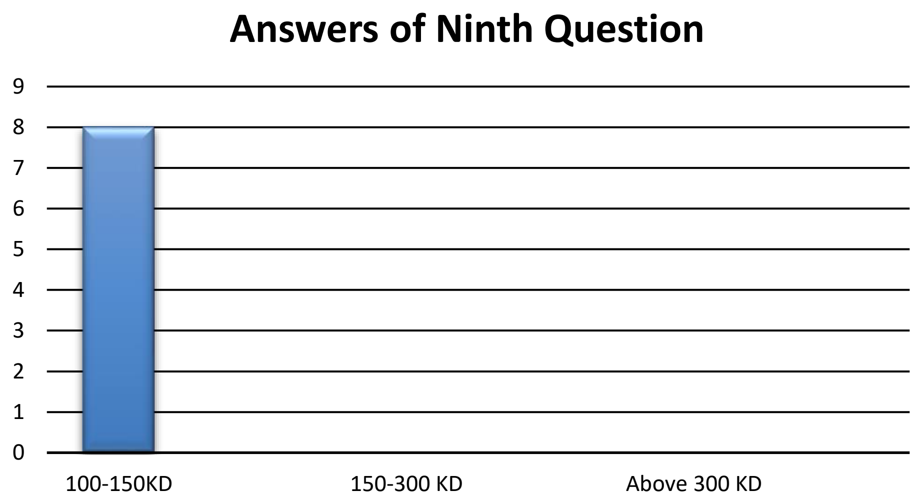


Figure 60: Answers of ninth question in second survey

- Tenth question: What are the most common problems in the current tents?
    - Lacking off a source of clean water.
    - Lacing off a source of heating.
    - Lacking off a source of electricity.
    - Leaking of water from the roof.

- Eleventh question: Please write any extra comment.
    - This organization has many ideas to help the refugees and one of these ideas is to provide a better place (Tents) for them that includes all comfort needs.

Appendix B (Pipes standard and properties)

Schedule 40 PVC Pipe Dimensions

Nom. Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nominal Wt./Ft.	Maximum W.P. PSI*
1/8	0.405	0.249	0.068	0.051	810
1/4	0.540	0.344	0.088	0.086	780
3/8	0.675	0.473	0.091	0.115	620
1/2	0.840	0.602	0.109	0.170	600
3/4	1.050	0.804	0.113	0.226	480
1	1.315	1.029	0.133	0.333	450
1-1/4	1.660	1.360	0.140	0.450	370
1-1/2	1.900	1.590	0.145	0.537	330
2	2.375	2.047	0.154	0.720	280
2-1/2	2.875	2.445	0.203	1.136	300
3	3.500	3.042	0.216	1.488	260
3-1/2	4.000	3.521	0.226	1.789	240
4	4.500	3.998	0.237	2.118	220
5	5.563	5.016	0.258	2.874	190
6	6.625	6.031	0.280	3.733	180
8	8.625	7.942	0.322	5.619	160
10	10.750	9.976	0.365	7.966	140
12	12.750	11.889	0.406	10.534	130
14	14.000	13.073	0.437	12.462	130
16	16.000	14.940	0.500	16.286	130
18	18.000	16.809	0.562	20.587	130
20	20.000	18.743	0.593	24.183	120
24	24.000	22.544	0.687	33.652	120

Figure 61: Standard sizes and diameters of PVC pipes schedule 40

Schedule 80 PVC Pipe Dimensions

Nominal Pipe Size (in)	O.D.	Average I.D.	Min. Wall	Nominal Wt./ft.	Maximum W.P. PSI*
1/8	0.405	0.195	0.095	0.068	1230
1/4	0.540	0.282	0.119	0.115	1130
3/8	0.675	0.403	0.126	0.158	920
1/2	0.840	0.526	0.147	0.232	850
3/4	1.050	0.722	0.154	0.314	690
1	1.315	0.936	0.179	0.461	630
1-1/4	1.660	1.255	0.191	0.638	520
1-1/2	1.900	1.476	0.200	0.773	470
2	2.375	1.913	0.218	1.070	400
2-1/2	2.875	2.29	0.276	1.632	420
3	3.500	2.864	0.300	2.186	370
4	4.500	3.786	0.337	3.196	320
6	6.625	5.709	0.432	6.102	280
8	8.625	7.565	0.500	9.269	250
10	10.750	9.493	0.593	13.744	230
12	12.750	11.294	0.687	18.909	230
14	14.000	12.41	0.750	22.681	220
16	16.000	14.213	0.843	29.162	220
18	18.000	16.014	0.937	36.487	220
20	20.000	17.814	1.031	44.648	220
24	24.000	21.418	1.218	63.341	210

Figure 62: Standard size and diameters of PVC pipes schedule 80

Nominal	Aluminum Schedule 40			Aluminum Schedule 80		
Pipe Size	Diameter (ins)		Thickness	Diameter (ins)		Thickness
(ins)	Outside	Inside	(ins)	Outside	Inside	(ins)
0.38	0.675	0.493	0.091	0.675	0.423	0.126
0.50	0.840	0.622	0.109	0.840	0.546	0.147
0.75	1.050	0.824	0.133	1.050	0.742	0.154
1.00	1.315	1.049	0.133	1.315	0.957	0.179
1.25	1.660	1.380	0.140	1.660	1.278	0.191
1.50	1.900	1.610	0.145	1.900	1.500	0.200
2.00	2.375	2.067	0.154	2.375	1.939	0.218
2.50	2.875	2.469	0.203	2.875	2.325	0.276
3.00	3.500	3.068	0.216	3.500	2.900	0.300
3.50	4.000	3.548	0.226	4.000	3.364	0.318
4.00	4.500	4.026	0.237	4.500	3.826	0.337
5.00	5.563	5.047	0.258	5.563	4.813	0.375
6.00	6.625	6.065	0.280	6.625	5.761	0.432
8.00	8.625	7.981	0.322	8.625	7.625	0.500
10.00	10.750	10.020	0.365	10.750	9.750	0.500
12.00	12.750	12.000	0.375	12.750	11.750	0.500

Figure 63: Standard size and diameters of Aluminum pipe

Table 18: General properties of rigid PVC [31]

Property	Value
Density	1380 kg/m³
Young's modulus	2900-3300 MPa
Tensile strength	50-80 MPa
Elongation @ break	20-40%
Impact strenght	2-5 kJ/m²
Glass temperature	87 °C
Melting point	212 °C
Vicat temperature	85 °C
Heat transfer coefficient	0.16 W/m.K
Linear expansion coefficient	8.10^{-5} /K
Specific heat	0.9 kJ/(kg·K)
Water absorption	0.04-0.4

Table 19: Physical Properties of PVC & CPVC Pipe [32]

GENERAL	PVC Value	CPVC Value	Test Method
Cell Classification	12454	23447	ASTM D 1784
Maximum Service Temp.	140°F	200°F	
Color	White, Dark Gray	Medium Gray	
Specific Gravity, (g/cu.cm @ 73°F)	1.41	1.51	ASTM D 792
Water Absorption % increase 24 hrs @ 25°C	0.05	0.03	ASTM D 570
Hardness, Rockwell	110 - 120	117 - 119	ASTM D 785
Poisson's Ratio @ 73°F	0.410	0.370	
MECHANICAL			
Tensile Strength, psi @ 73°F	7,450	7,900	ASTM D 638
Tensile Modulus of Elasticity, psi @ 73°F	420,000	426,000	ASTM D 638
Flexural Strength, psi @ 73°F	14,450	15,000	ASTM D 790
Flexural Modulus, psi @ 73°F	360,000	360,000	ASTM D 790
Compressive Strength, psi @ 73°F	9,600	10,000	ASTM D 695
Izod Impact, notched, ft-lb/in @ 73°F	0.75	2.9	ASTM D 256
THERMAL			
Coefficient of Linear Expansion (in/in/°F)	2.9×10^{-5}	3.2×10^{-5}	ASTM D 696
Coefficient of Thermal Conductivity			ASTM C 177
Calories • cm/second • cm2 • °C	3.5×10^{-4}	3.27×10^{-4}	
BTU • inches/hour • Ft.2 • °F	1.02	0.95	
Watt/m/K	0.147	0.137	
Heat Deflection Temperature			
Under Load (264 psi, annealed)	170	235	ASTM D 648
ELECTRICAL			
Dielectric Strength, volts/mil	1,413	1,250	ASTM D 149
Dielectric Constant, 60Hz, 30°F	3.70	3.70	ASTM D 150
Volume Resistivity, ohm/cm @ 95°C	1.2 x 1012	3.4 x 1012	ASTM D 257
Spears® PVC & CPVC Pipe is non-electrolytic			
FIRE PERFORMANCE			
Flammability Rating	V-0	V-0, 5VB, 5VA	UL-94
Flame Spread Index	<10	<10	
Flame Spread	0-25	<25	ULC
Smoke Generation	80-225	<50	ULC
Flash Ignition Temp.	730°F	900°F	
Average Time of Burning (sec.)	<5	<5	ASTM D 635
Average Extent of Burning (mm)	<10	<10	

Burning Rate (in/min)	Self Extinguishing	Self Extinguishing	
Softening Starts (approx.)	250°F	295°F	
Material Becomes Viscous	350°F	395°F	
Material Carbonizes	425°F	450°F	
Limiting Oxygen Index (LOI)	43	60	ASTM D 2863

NOTE: The physical properties shown above are considered general for PVC and CPVC. Contact Spears® Technical Services for additional information if necessary.

To purchase PVC or CPVC pipe and fittings call Commercial Industrial Supply at: **866-777-8001**

Table 20:Properties of Aluminum pipe [33]

Physical Properties	Metric	English	Comments
Density	2.7 g/cc	0.0975 lb/in³	AA; Typical
Mechanical Properties			
Hardness, Brinell	95	95	AA; Typical; 500 g load; 10 mm ball
Hardness, Knoop	120	120	Converted from Brinell Hardness Value
Hardness, Rockwell A	40	40	Converted from Brinell Hardness Value
Hardness, Rockwell B	60	60	Converted from Brinell Hardness Value
Hardness, Vickers	107	107	Converted from Brinell Hardness Value
Ultimate Tensile Strength	310 MPa	45000 psi	AA; Typical
Tensile Yield Strength	276 MPa	40000 psi	AA; Typical
Elongation at Break	12 %	12 %	AA; Typical; 1/16 in. (1.6 mm) Thickness
Elongation at Break	17 %	17 %	AA; Typical; 1/2 in. (12.7 mm) Diameter
Modulus of Elasticity	68.9 GPa	10000 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Notched Tensile Strength	324 MPa	47000 psi	2.5 cm width x 0.16 cm thick side-notched specimen, K_t = 17.
Ultimate Bearing Strength	607 MPa	88000 psi	Edge distance/pin diameter = 2.0

Bearing Yield Strength	386 MPa	56000 psi	Edge distance/pin diameter = 2.0
Poisson's Ratio	0.33	0.33	Estimated from trends in similar Al alloys.
Fatigue Strength	96.5 MPa	14000 psi	AA; 500,000,000 cycles completely reversed stress; RR Moore machine/specimen
Fracture Toughness	29 MPa-m½	26.4 ksi-in½	K_{IC}; TL orientation.
Machinability	50 %	50 %	0-100 Scale of Aluminum Alloys
Shear Modulus	26 GPa	3770 ksi	Estimated from similar Al alloys.
Shear Strength	207 MPa	30000 psi	AA; Typical
Electrical Properties			
Electrical Resistivity	3.99e-006 ohm-cm	3.99e-006 ohm-cm	AA; Typical at 68°F
Thermal Properties			
CTE, linear 68°F	23.6 µm/m-°C	13.1 µin/in-°F	AA; Typical; Average over 68-212°F range.
CTE, linear 250°C	25.2 µm/m-°C	14 µin/in-°F	Estimated from trends in similar Al alloys. 20-300°C.
Specific Heat Capacity	0.896 J/g-°C	0.214 BTU/lb-°F	
Thermal Conductivity	167 W/m-K	1160 BTU-in/hr-ft²-°F	AA; Typical at 77°F
Melting Point	582 - 652 °C	1080 - 1205 °F	AA; Typical range based on typical composition for wrought products 1/4 inch thickness or greater; Eutectic melting can be completely eliminated by homogenization.
Solidus	582 °C	1080 °F	AA; Typical
Liquidus	652 °C	1205 °F	AA; Typical
Processing Properties			
Solution Temperature	529 °C	985 °F	
Aging Temperature	160 °C	320 °F	Rolled or drawn products; hold at temperature for 18 hr
Aging Temperature	177 °C	350 °F	Extrusions or forgings; hold at temperature for 8 hr

Appendix C (Urfa Climate):

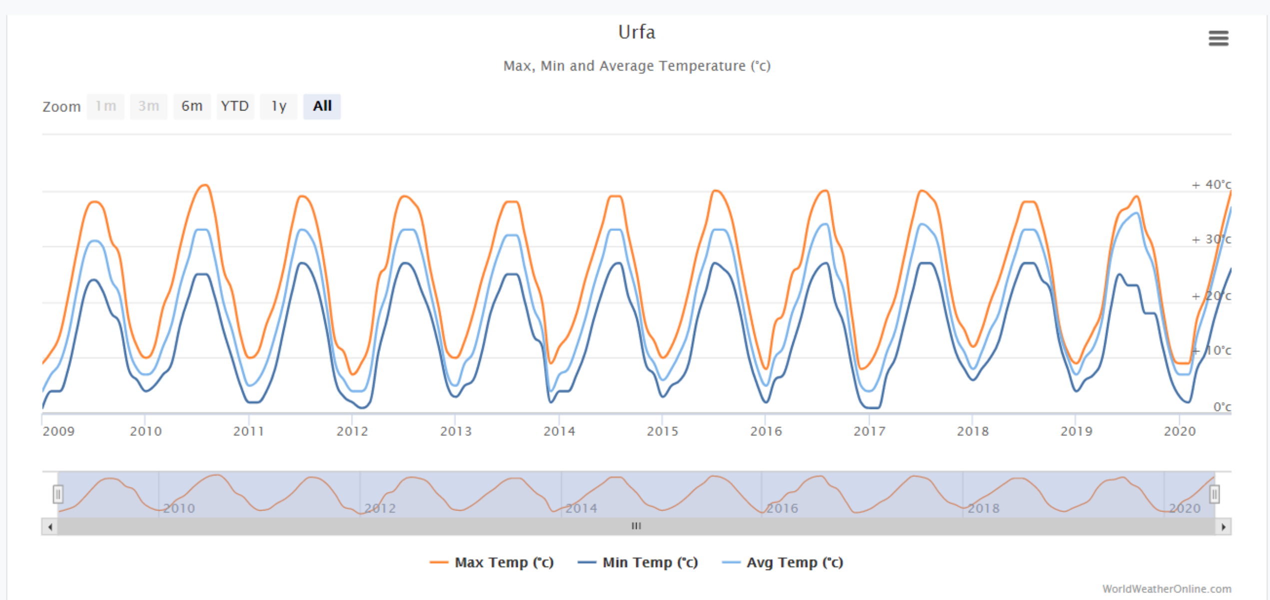


Figure 64: Urfa maximum, minimum and average temperature (C°)

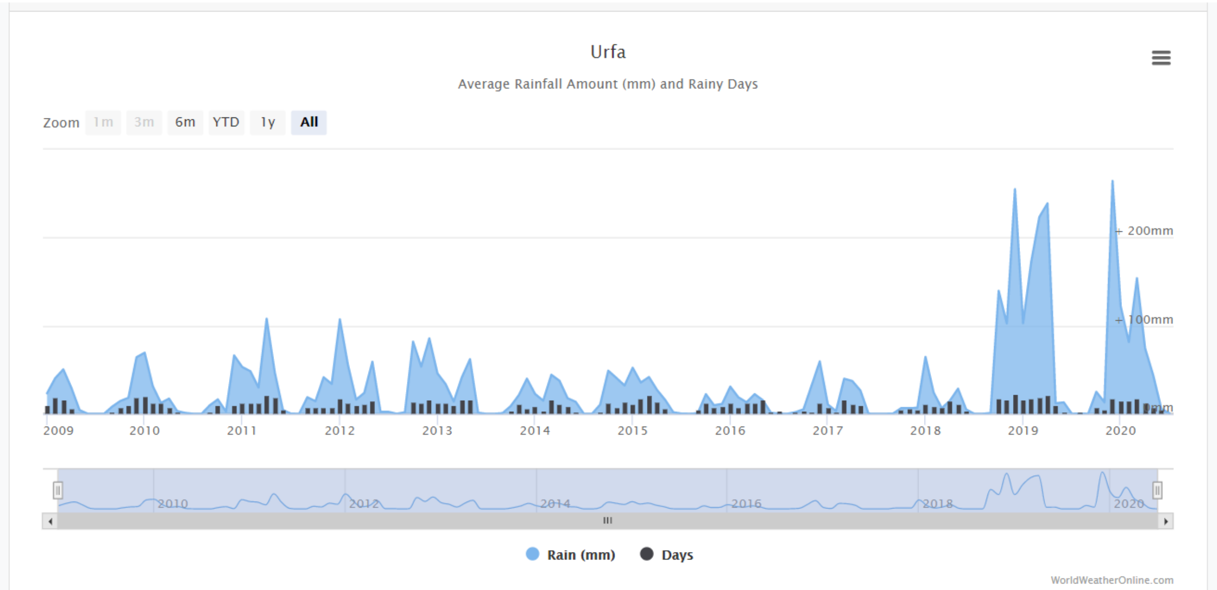


Figure 65: Urfa Rainfall and Rain Days

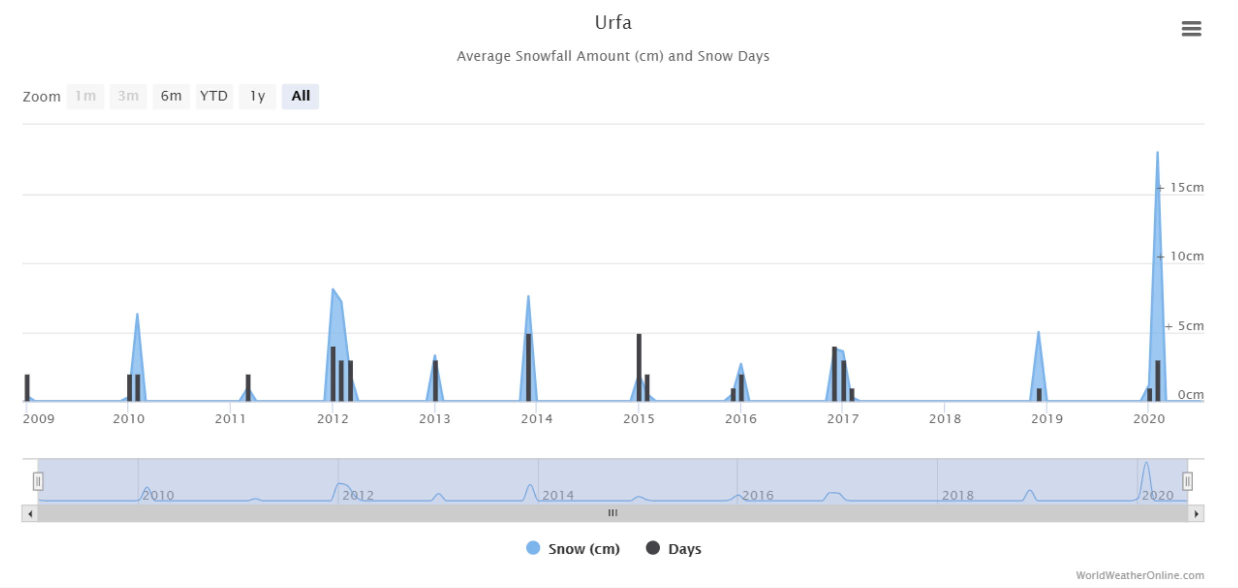


Figure 66: Urfa Snowfall and Snow Days

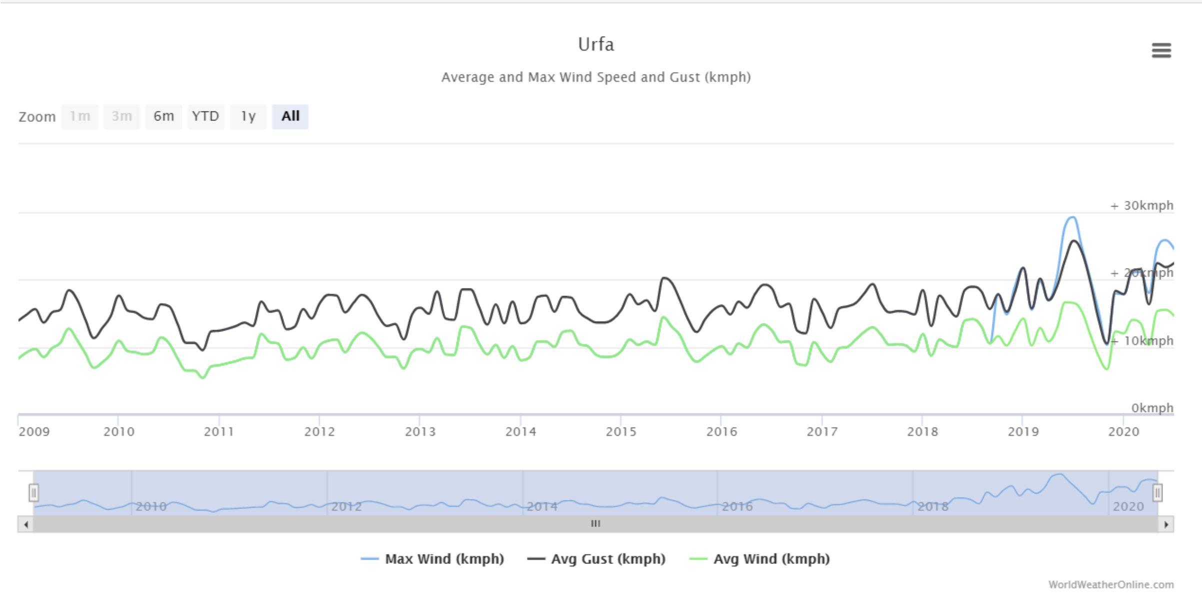


Figure 67: Urfa Max and Average Wind Speed and Wind Gust

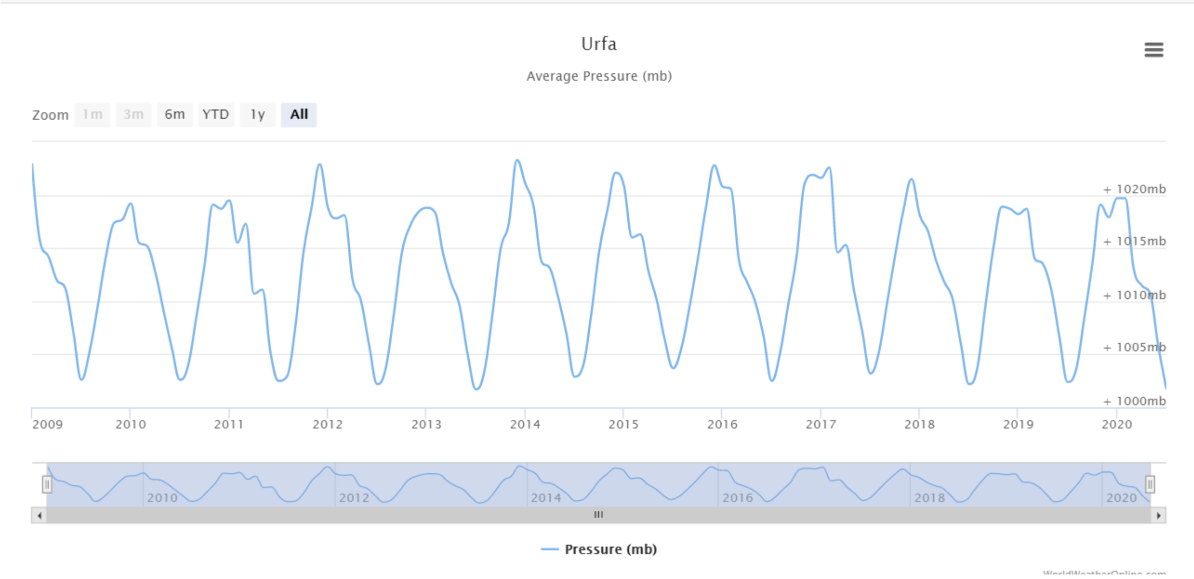


Figure 68: Urfa Pressure

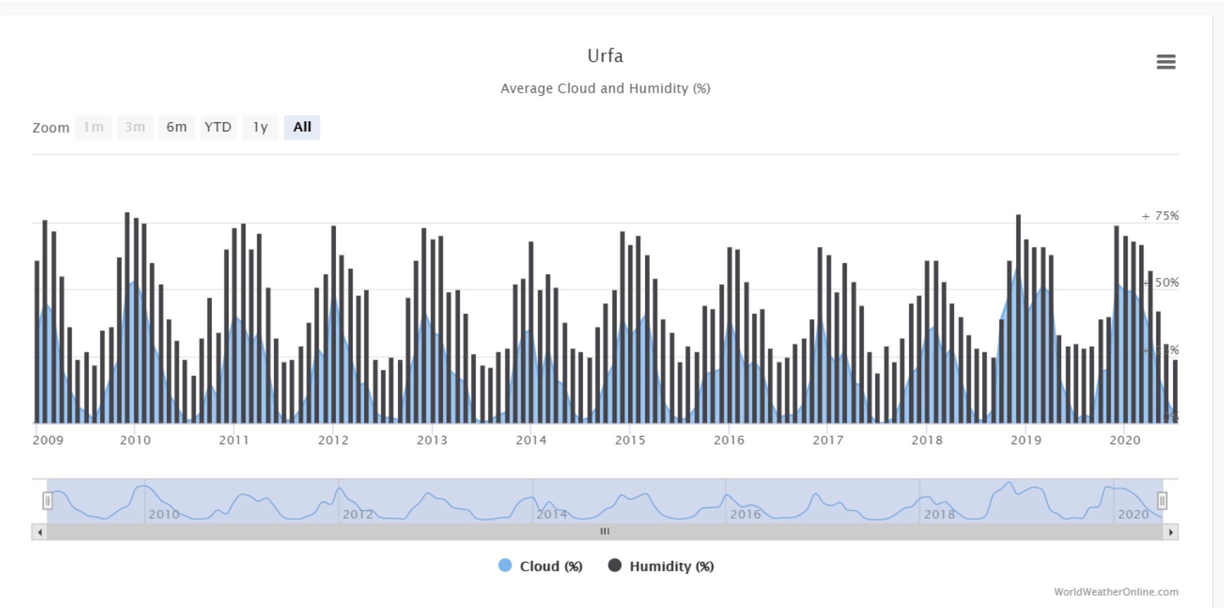


Figure 69: Urfa Cloud and Humidity

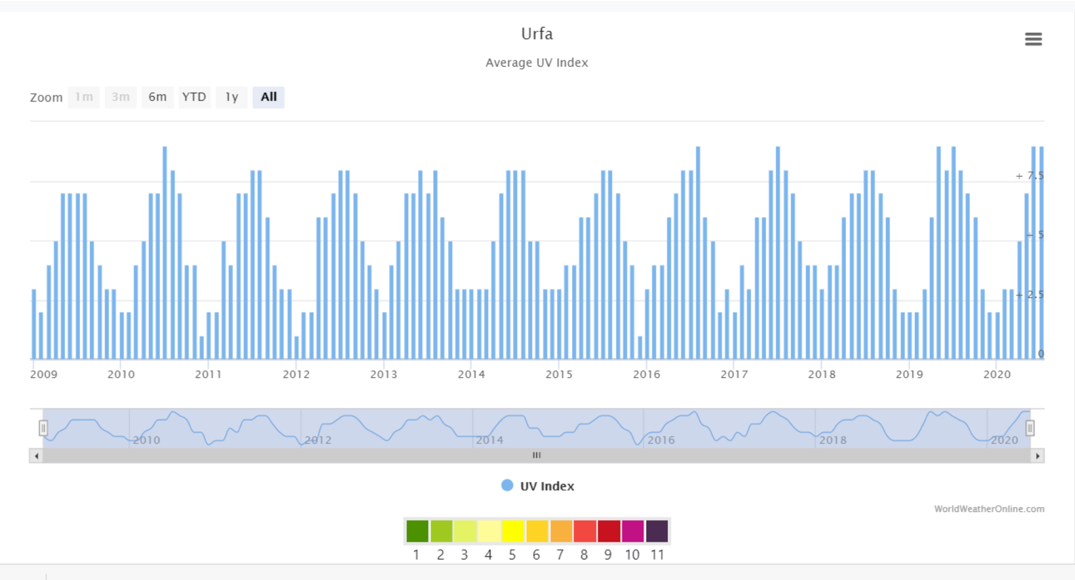


Figure 70: Urfa UV Index

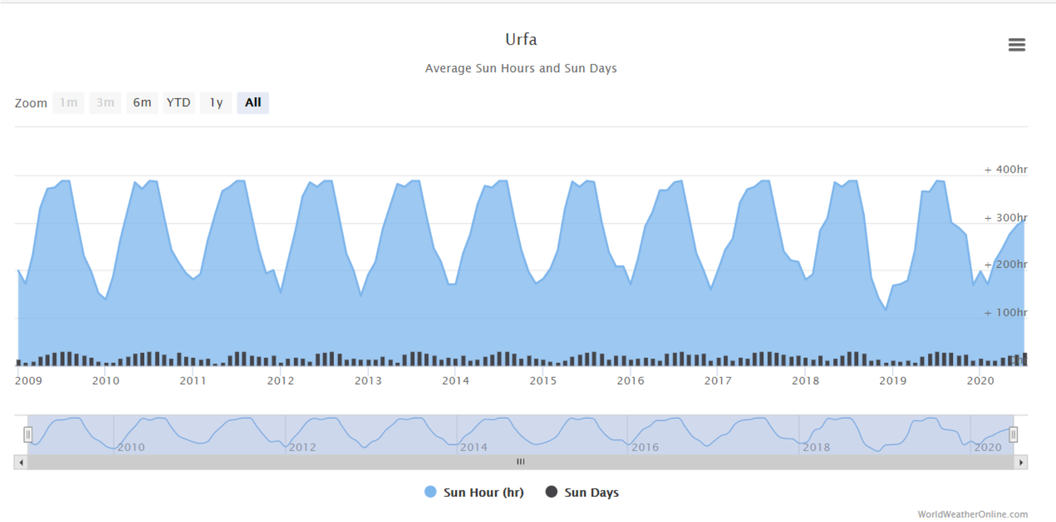


Figure 71: Urfa Sun Hours and Sun Days

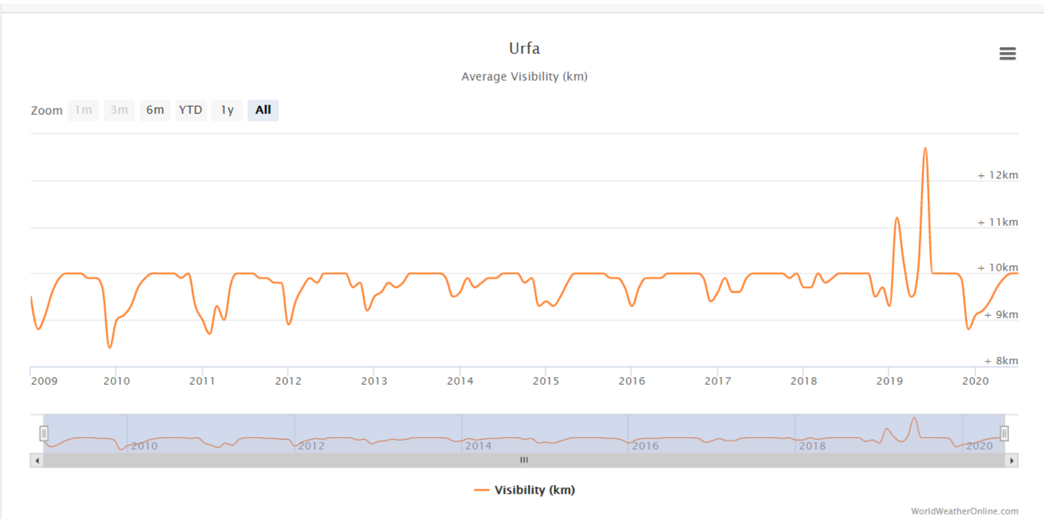


Figure 72: Urfa visibility

There is another reference for Urfa climate with specific information [25]

Appendix D (Frame Analysis)

The frame Analysis is the same for the all alternative solutions. As mentioned, the forces affected in the frame are due to its own weight, wind and snow, the calculations and locations of these loads are discussed in this section.

Calculation of loads affected in the frame of the tent

The ANSYS software is used to study the frame and it is assumed that the frame is fixed in the ground through its corners.

Loads Due to pipe's weight

Since ANSYS software is used, the weight of each beam is added as a standard earth gravity (g = 9.8066 m/s) in negative y axis depends on the density of the pipe used in each alternative.

Loads Due to snow

The maximum snow depth was found in February 2020 which equals to 18 cm. In this area, the temperature distribution in February was found as 9℃ for the maximum temperature and 2℃ for the minimum.
In order to calculate the sow load, snow type, snow depth and roof pitch should be known. Assuming that the snow type in Urfa is fresh snow and the roof pitch is assumed to be 1 as shown in following Figure.

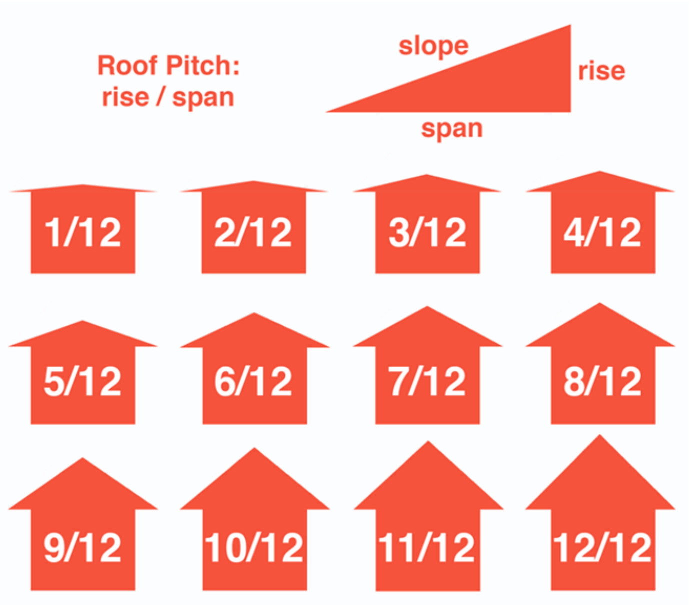


Figure 73: Roof pitch [26]

The snow weight is calculated as follows

$$Snow\ weight = \frac{length\ of\ the\ roof x\ width\ of\ the\ roof}{\cos\ (pitch(°))} xsnow\ load \qquad (4)$$

Where the length of the roof equals 2 m, width of the roof equals 0.7433 m, and snow depth equals 0.18 m.

$$snow\ load\ = thickness\ of\ snow\ *\ density\ of\ snow \qquad (5)$$

Where the density of snow depends on snow type as shown in the following table.

Table 21: Density of snow depends on its type

snow type	density [kg/m³]	density [lbs/cu ft]
Fresh snow	60	3.75
Damp fresh snow	110	6.87
Settled snow	250	15.61
Wind-packed snow	375	23.41
Very wet snow	750	46.82
Ice	917	57.25

$$pich\ angle = \tan^{-1}\frac{rise}{run} \qquad (6)$$

Where the roof pitch is calculated to be 10/12, since the rice of the roof equals the run.

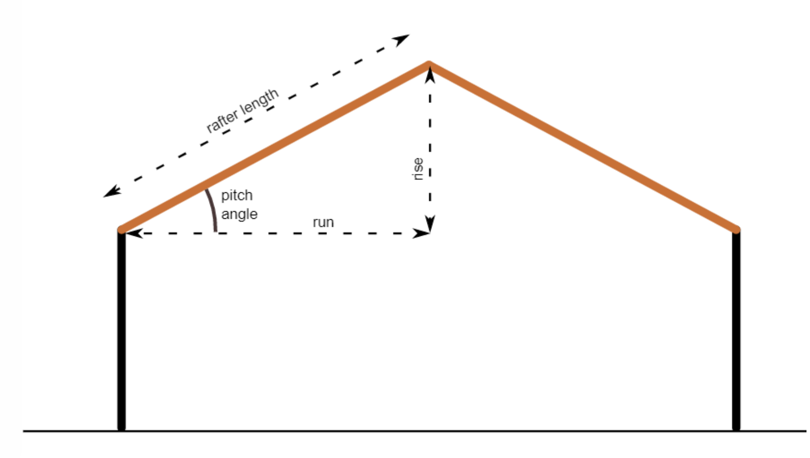


Figure 74: Roof pitch [36]

$$Pitch\ angle = \tan^{-1}\frac{10}{12} = 39.806\,°\,°$$

Since the snow type is assumed to be fresh the density equals 60 kg/m3.

$$snow\ load = 0.18 * 60 = 10.8\ kg/m^2$$

$$Snow\ weight = \frac{2x\ 0.7433}{\cos\,(39.806)} x\ 10.8 = 20.9\ Kg$$

The surface area of the roof equals $2\ x\ 0.7433 = 1.4866\ m^2$

F = mg = 20.9 x 9.81 = 205.029 N

$$P = \frac{F}{A} = \frac{173.5389}{1.4866} = 137.9\ N/m^2$$

The pressure due to snow is applied in vertical direction in the roof in the negative y axis and it is distributed along the beam since the snow comes in vertical direction.

Loads due to wind

The maximum wind speed is recorded in July 2019 to be 29.2×10^3 mph but the wind speed taken in the calculation is $50x10^3$ mph. The created pressure is dynamic pressure due to wind effect.

Where the force due to wind:

$$F_w = P_d A \qquad (7)$$

Where P_d is the dynamic pressure of the wind and A is the surface area:

$$P_d = \frac{1}{2}\rho Vm^2 \qquad (8)$$

Where ρ the density of the air and Vm is is the maximum velocity that leads to maximum dynamic pressure.

The density is assumed to be $\rho = 1.13854\ kg/m^3$.

The maximum velocity in SI unit is $V_{max} = 13.8889\ m/s$.

$$P_d = \frac{1}{2} \times 1.13854 \times (13.8889)^2 = 109.813\ Pa$$

As known the wind load is came from one side of the building which called pressure side into other side of the building which called suction side as shown in the following Figure.

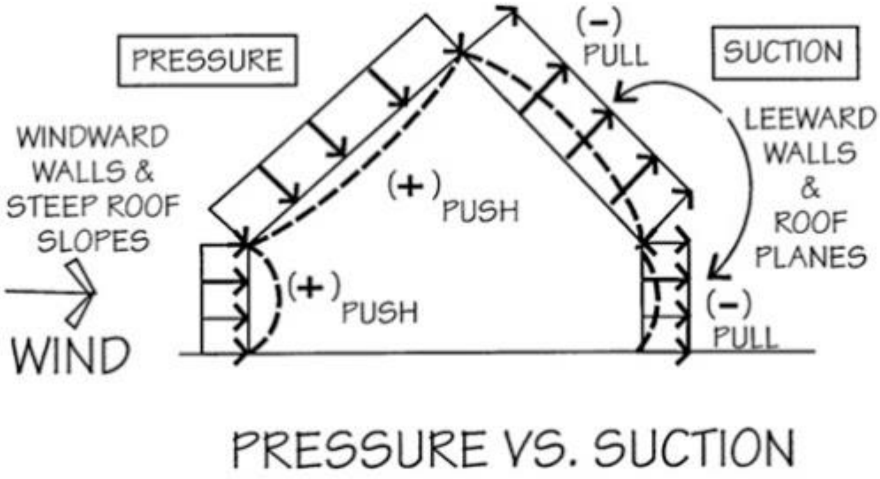


Figure 75: Pushing and pulling due to wind

Its assumed that the direction of wind is from the right to the left side of the tent, so the positive dynamic pressure due to wind load occurred in the right side of the tent (pushing) while the negative dynamic pressure occurred in the left side of the tent (pulling).

The value of dynamic pressure is constant since it is calculated at same density and velocity which equals 109.813 Pa. The direction of wind load in all beams in the right side of the tent from the positive to negative x-axis.

Appendix E (Alternative Solutions Detailed Results)

The approximate inner surface temperature of the tent is calculated from ANSYS program by assuming that the tent is large symmetric model. The properties of air inside the tent are assumed as shown in the following table.

Table 22: Properties of air inside the tent

Density [kg/m3]	Convection coefficient [w/$\boldsymbol{m^2.k}$]	Thermal conductivity [w/m. k]	Cp Specific heat [kJ/kg]
1.184	3	0.02551	1007

The outside temperature in summer is taken to be 41 $°C$ and convection coefficient equals 12 [w/$m^2.k$]. Also, the properties of human body are taken for the skin as shown in the following table.

Table 23: Properties of human skin [27]

Material	Thermal conductivity [w/m. k]	Density [kg/m3]	Modules of elasticity [Mpa]	Specific heat [kJ/kg]
Human skin	0.2	860	0.5	5021

Only the one side of the tent has been studied since the right side is similar to the left side so the results for the both sides are the same. The type of heat transfers are due to convection from outside environment, conduction between the layers of the cover of the tent, and convection inside the tent. The thermal analysis is studied by assuming that the convection inside the tent occurred at temperature equals 20˚C, the result of the approximate inside surface temperature is calculated for each alternative solution in ANSYS. The following Figure shows a simplified diagram of the tent in summer.

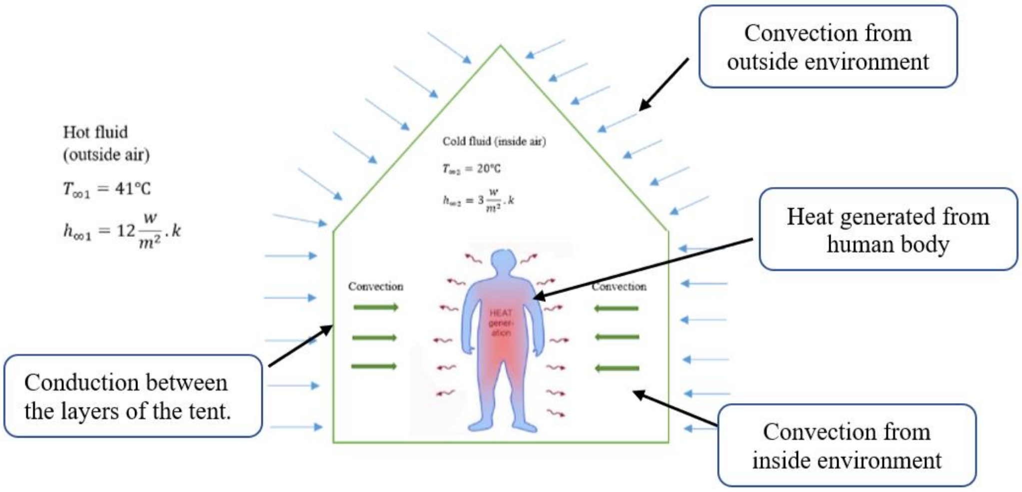


Figure 76: Simplified diagram of the tent in summer

The same analysis will be taken for winter except that the outside temperature equals 1˚C and the convection inside the tent occurred at temperature equals 17˚C. Figure 77 shows a simplified diagram of the tent in winter.

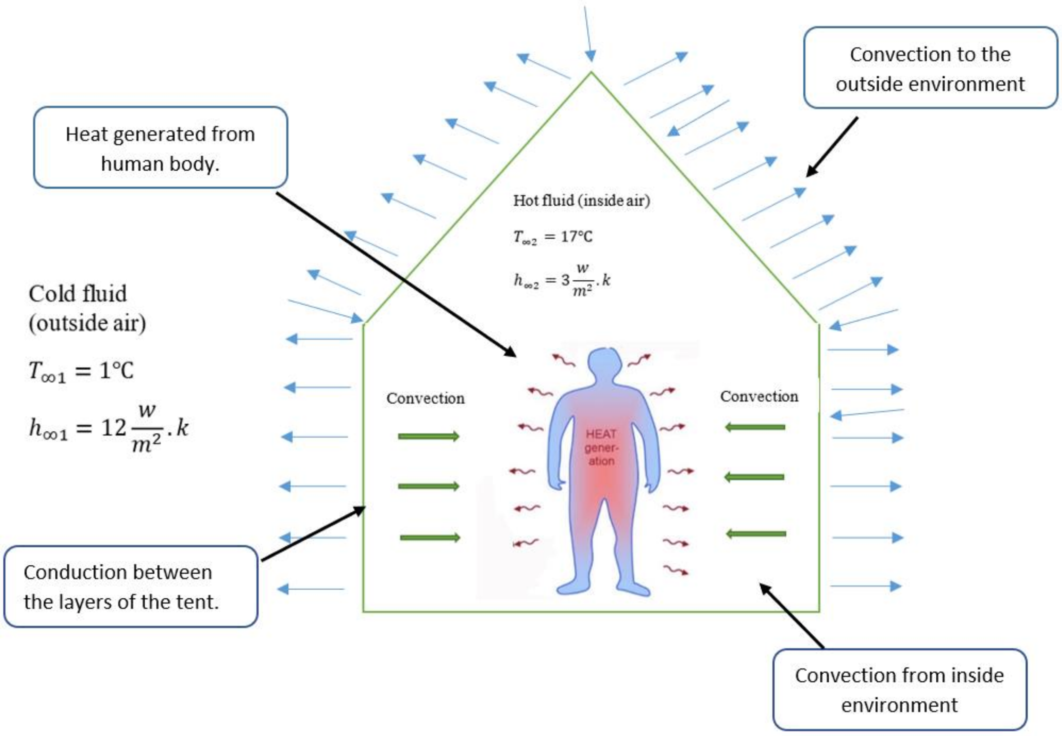


Figure 77: Simplified diagram of the tent in winter

Alternative solution 1

For this alternative solution PVC pipe schedule 40 is used for the structure. Table 24 shows the properties of the PVC pipe schedule 40.

Table 24: Properties of PVC schedule 40

Modules of elasticity E [MPa]	Tensile yield strength S_y [MPa]	Maximum Temperature Limit [°C]	Coefficient of Linear Expansion - α – [$°C^{-1}$]	Poison's Ratio	Density [kg/m³]
55.2	51	65	30×10^{-6}	0.4	1300

The type of PVC pipe schedule 40 used in this alternative solution has a size ¾ and standard diameters (inside diameter = 20.4216 mm and outside diameter = 26.67 mm), Appendix C.

The following tables represents the properties of the materials used for the cover of the tent. Foylon is made of Polyester Fabric and Aluminum, where it has similar characteristics of Mylar. Foylon is considered more rugged and durable than Mylar, in addition to 95% reflectivity. Using Foylon as a heat reflector can increase the ventilation in enclosures. Foylon can be cleaned, positioned, and repositioned easily. In addition, it has tear resistance, which gives it long life span.

Table 25: Properties of Foylon

Material	**Thermal conductivity [W/m.k]**	**Density [kg/m³]**	**Coefficient of Linear Expansion - α – [$°C^{-1}$]**	**Modulus of Elasticity [MPa]**	**Poisson's Ratio**	**Thickness [microns]**
Foylon	0.44	1390	1.7x10^{-5}	4895.278	0.4	15

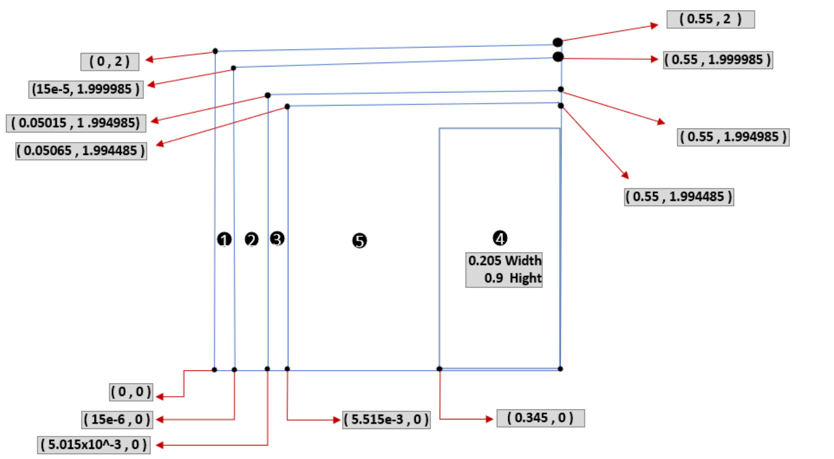
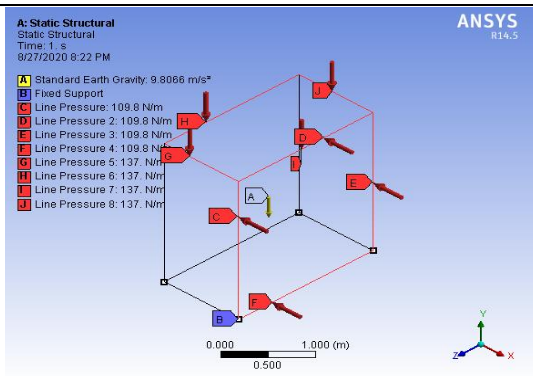
Table 26: Properties of Rockwool

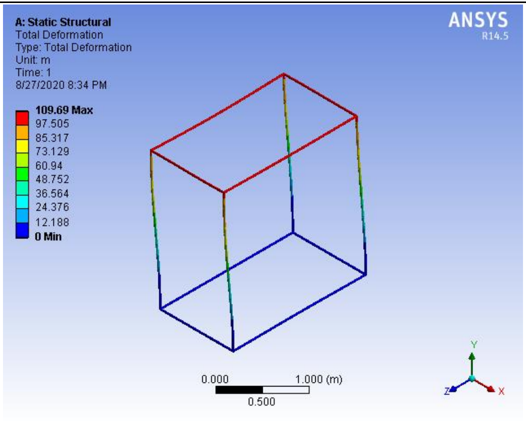
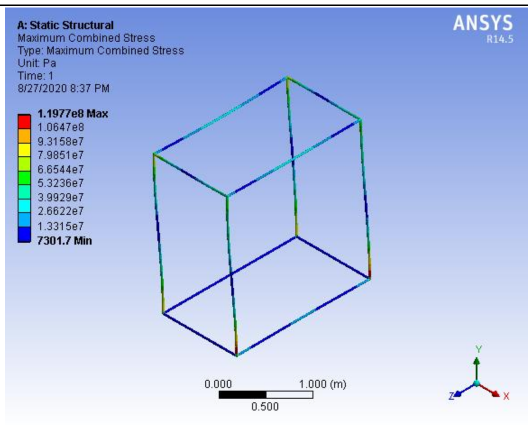
Material	**Thermal conductivity [W/m.k]**	**Density [kg/m³]**	**Modulus of Elasticity [kPa]**	**Poisson's Ratio**	**Thickness [cm]**
Rockwool	0.035	22	100	0.3	0.5

Table 27: Properties of Kevlar

Material	**Thermal conductivity [W/m.k]**	**Density [kg/m^3]**	**Coefficient of Linear Expansion - α – [K^{-1}]**	**Modulus of Elasticity [GPa]**	**Poisson's Ratio**	**Thickness [mm]**
Kevlar	4	1380	-4x10^{-3}	76	0.36	0.5

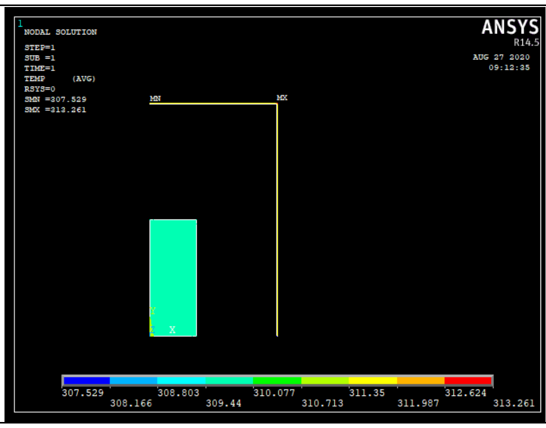
Table 28: Alternative Solution 1 structural analysis

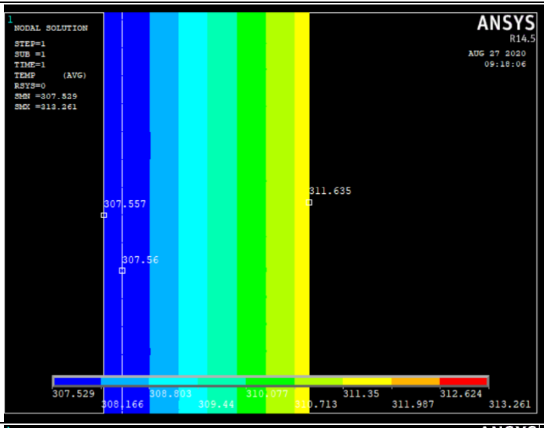
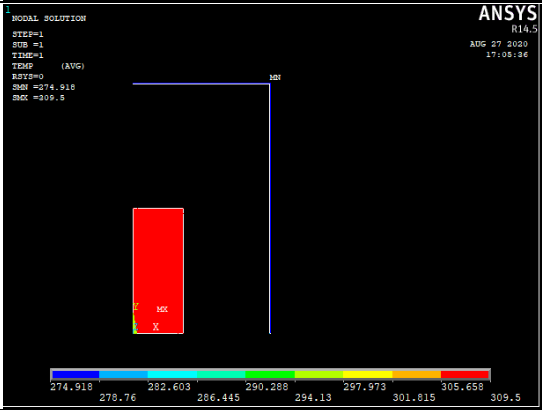
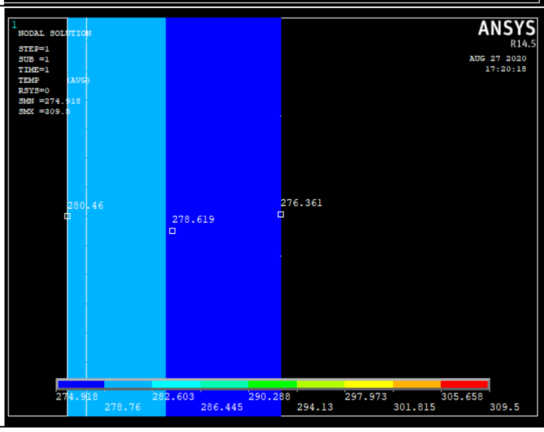
Alternative Solution 1	Dimensions of The Studied Side (left side)	
	Total Loads Affected on The Frame	
	Deformation	

<table>
<tr><td></td><td></td><td>
</td></tr>
<tr><td></td><td>Stress</td><td>
</td></tr>
</table>

Where the total width of the tent equals 1.1 m and the hight equals 1 m. Number 1 in the Dimensions of The Studied Side (left side) in the previous table represents the Foylon material in summer and kevlar in winter, Number 2 represents the reckwool in both summer and winter, Number 3 represents mylar material in winter and kevlar in summer. While, Number 5 represents the air and 5 human body.

Table 29: Alternative Solution 1 thermal analysis

<table>
<tr><td rowspan="2">Alternative Solution 1 (Thermal Analysis)</td><td>Temperature Distribution in Summer</td><td>
</td></tr>
<tr><td>Temperature Between Layers in Summer</td><td></td></tr>
</table>

		
	Temperature Distribution in Winter	
	Temperature Between Layers in Winter	

Alternative solution 2

Aluminum schedule 40 pipe is used with standard size, which is similar to PVC pipe schedule 40 in dimensions; therefore, it has thicker walls than schedule 40. The standard diameters have been taken as 26.67 and 20.9296 mm outer and inner diameters (nominal pipe size $^3/_4$), respectively, Appendix C. Aluminum schedule 80 pipe properties are showing in Table 30.

Table 30: Properties of Aluminum schedule 40 pipe

Modules of elasticity E [GPa]	Tensile yield strength S_y [MPa]	Maximum Temperature Limit [℃]	Coefficient of Linear Expansion - α – [$℃^{-1}$]	Poison's Ratio	Density [kg/m³]
68.9	276	660	23.6×10^{-6}	0.33	2700

The following tables represent the properties of the materials used for the cover of the tent, and the properties of reflective material used in this alternative solution which is Mylar is similar to Foylon properties Table 25.

Table 31: Properties of Cellulose

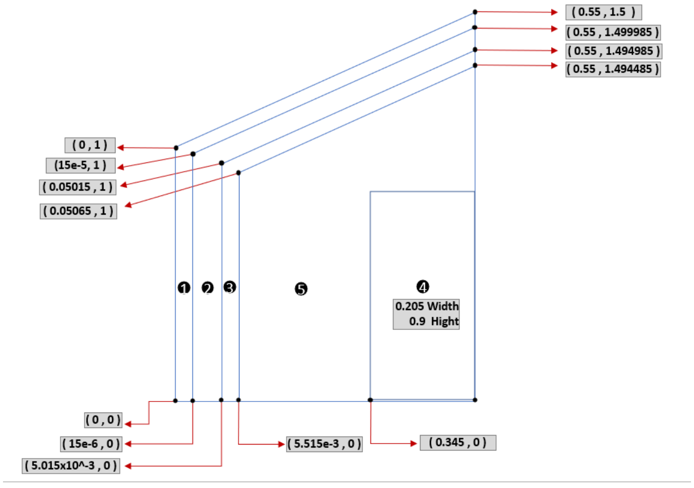
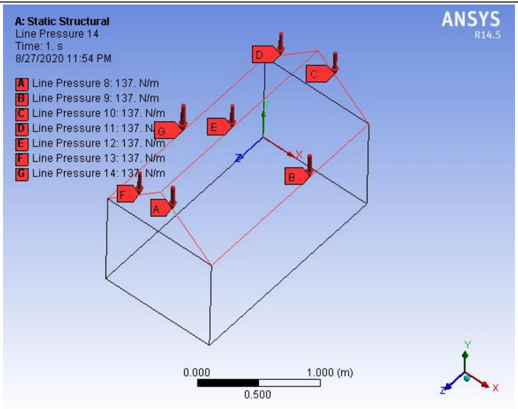
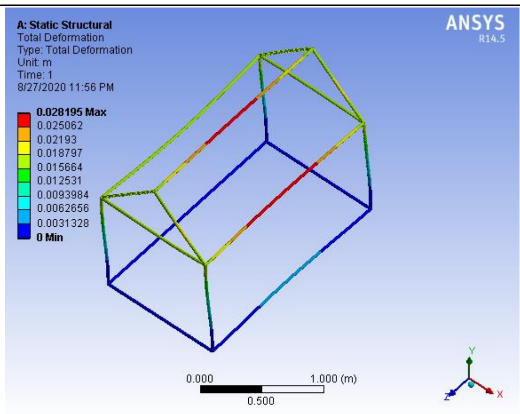
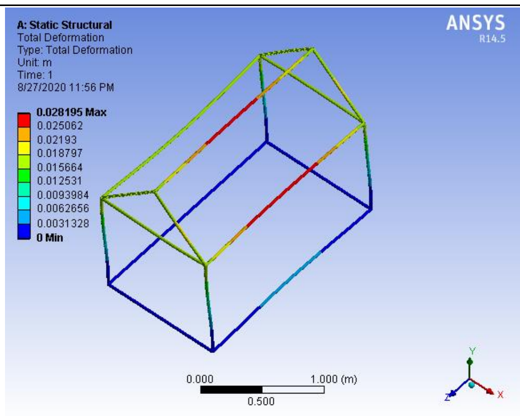
Modulus of elasticity E [GPa]	Tensile yield strength [MPa]	Thermal expansion [ml./g./°C]	Thermal conductivity [W/m.k]	Poisson's Ratio	Density $[kg/m^3]$
20	22.1 - 41.4	ranged from 5.1 to 6.0 × 10^{-4}	0.04	0.3	1.5

Table 32: Properties of Nylon Silicone coating

Material	Thermal conductivity [W/m.k]	Density [kg/m³]	Coefficient of Linear Expansion - α – $[K^{-1}]$	Modulus of Elasticity [GPa]	Poisson's Ratio	Thickness [mm]
Nylon Silicone coating	0.25	2300	300x$\mathbf{10^{-6}}$	2	0.49	0.5

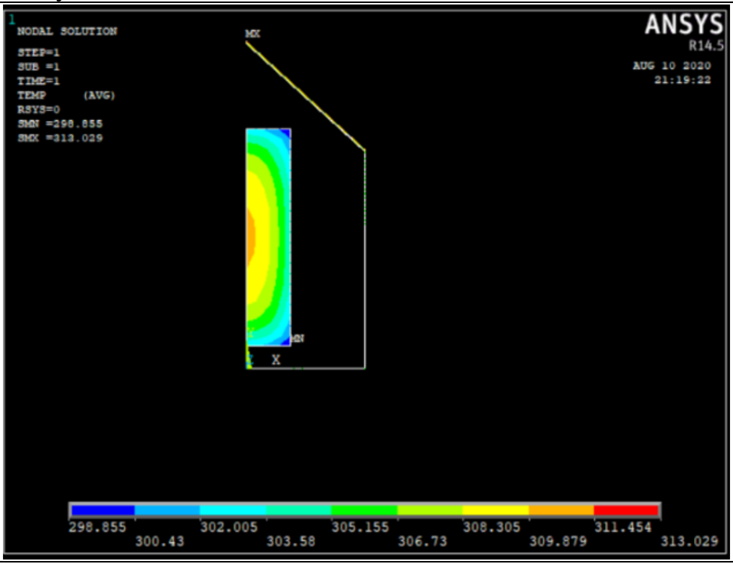
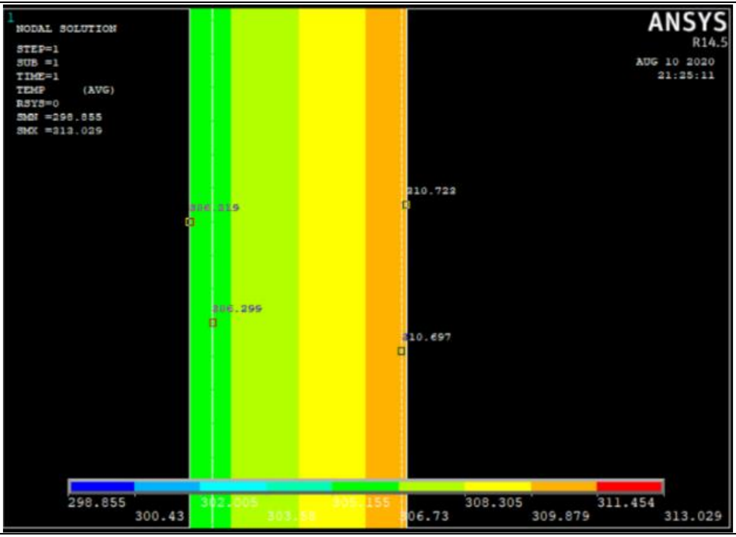
Table 33: Alternative Solution 2 structural analysis

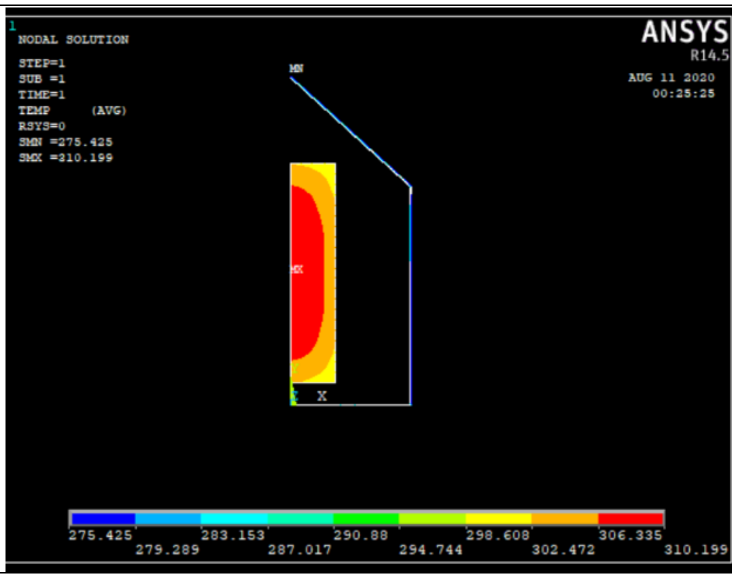
Alternative Solution 2 (Structural Analysis)	Dimensions of The Studied Side (left side)	

<table>
<tr><td></td><td></td><td>
</td></tr>
<tr><td></td><td>Snow Load Affected on The Frame (wind and weight loads are applied)</td><td>
</td></tr>
<tr><td></td><td>Deformation</td><td>
</td></tr>
<tr><td></td><td>Stress</td><td>
</td></tr>
</table>

Where the total width of the tent equals 1.1 m and the hight equals 1.5 m. Number 1 in the dimensions of the studied side (right side) in the previous table represents the mylar material in summer and Nylon Silicone coating in winter, Number 2 represents the Cellulose in both summer and winter, Number 3 represents mylar material in winter and Nylon Silicone coating in summer. While, Number 5 represents the air and 4 human body.

Table 34:Alternative Solution 2 thermal analysis

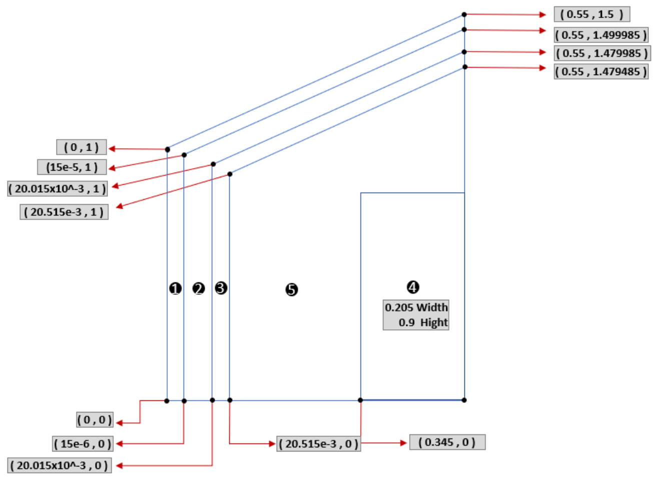
<table>
<tr><td rowspan="3">Alternative Solution 2 (Thermal Analysis)</td><td>Temperature Distribution in Summer</td><td>
</td></tr>
<tr><td>Temperature Between Layers in Summer</td><td>
</td></tr>
<tr><td>Temperature Distribution in Winter</td><td></td></tr>
</table>

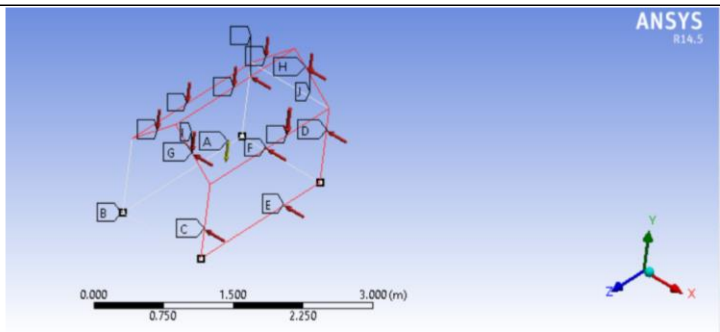
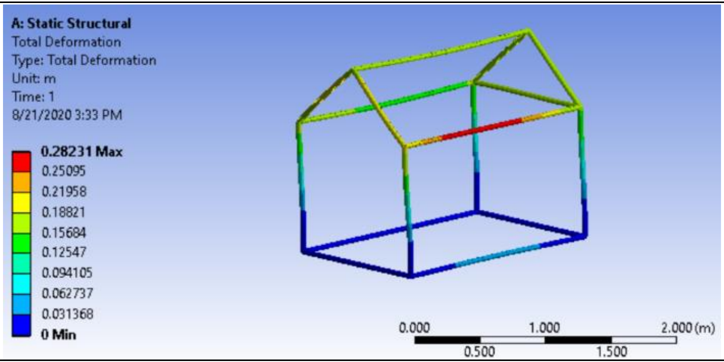
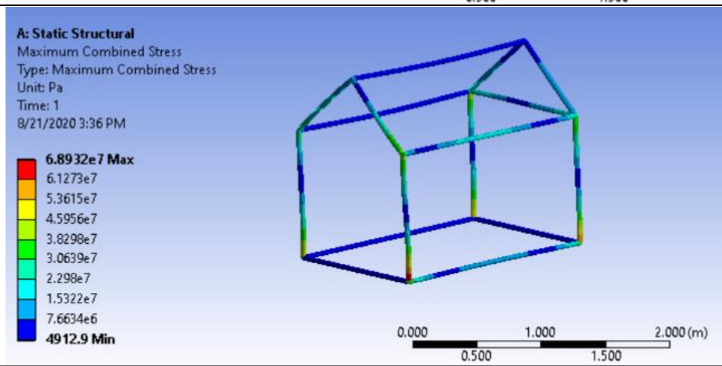
			

Alternative solution 3

The material of the frame is PVC pipe schedule 80 with standard radii; the standard diameters have been taken as 26.67 and 18.3388 mm outer and inner diameters (nominal pipe size $^3/_4$), respectively, Appendix B. PVC pipe schedule 80 has thick walls, so it can withstand higher water pressure than PVC pipe schedule 40. PVC pipe schedule 80 has a slightly higher cost than the other type of PVC pipes [28]. The following Figures shows the location of the loads affected in the frame.

Table 35: Alternative Solution 3 structural analysis

Alternative Solution 3 (Structural Analysis)	Dimensions of The Studied Side (left side)	
	Total Loads Affected on The Frame	

			
	Deformation		
	Stress		

The following tables represent the properties of the materials used for the cover of the tent.

Table 36: Properties of Mylar

Material	Thermal conductivity [W/m.k]	Density [kg/m^3]	Coefficient of Linear Expansion - α – [°C^{-1}]	Modulus of Elasticity [MPa]	Poisson's Ratio	Thickness [microns]
Mylar	0.154	1390	1.7x10^{-5}	4895.278	0.4	15

Table 37: Properties of Cellulose

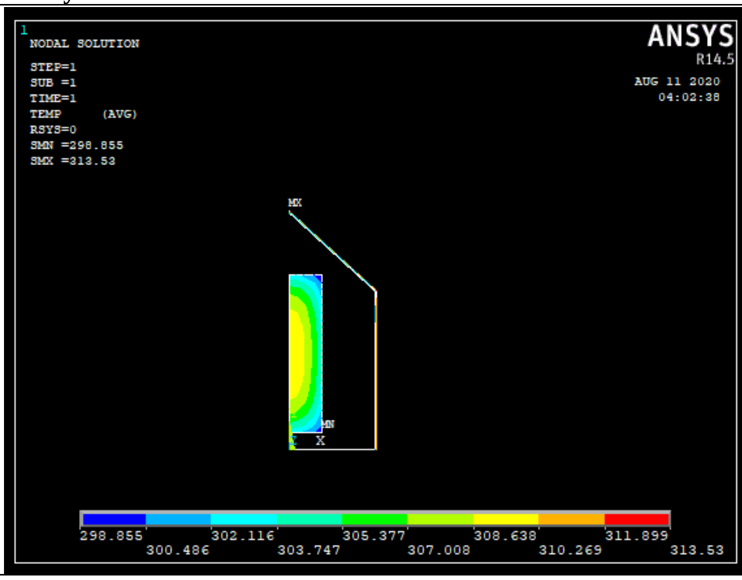
Modulus of elasticity E [GPa]	Tensile yield strength [MPa]	Thermal expansion [ml./g./°C]	Thermal conductivity [W/m.k]	Poisson's Ratio	Density $[kg/m^3]$
20	22.1 - 41.4	ranged from 5.1 to 6.0 × 10^{-4}	0.04	0.3	1.5

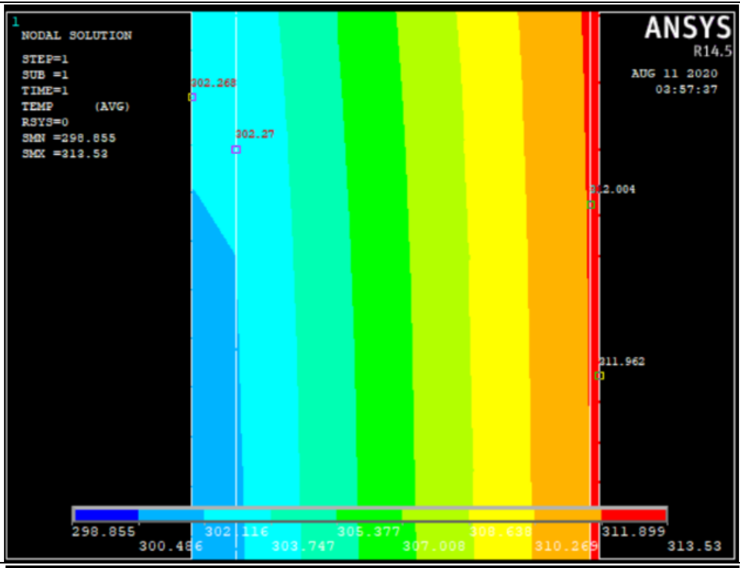
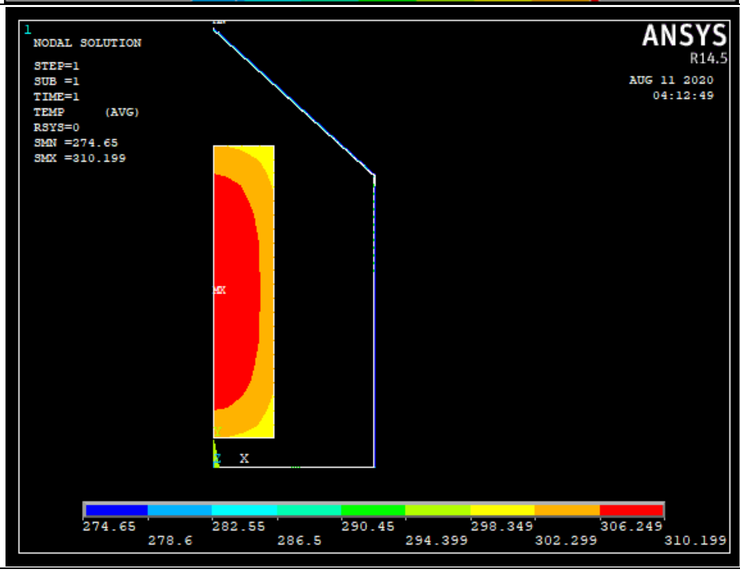
Table 38: Properties of Lexi cotton

Modulus of elasticity E [MPa]	Thickness	Thermal expansion [ml./g./°C]	Thermal conductivity [w/m.k]	Poisson's Ratio	Density $[kg/m^3]$
30	0.5 mm	ranged from 9.56-73.9	0.23	0.3	1.54

Where the total width of the tent equals 1.1 m and the hight equals 1.5 m. Number 1 in the dimensions of the studied side (left side) in the previous table represents the mylar material in summer and Lexi cotton in winter, Number 2 represents Cellulose in both summer and winter, Number 3 represents mylar material in winter and Lexi cotton in summer. While, Number 5 represents the air and 4 human body.

Table 39:Alternative Solution 3 thermal analysis

<table>
<tr><td rowspan="2">Alternative Solution 3 (Thermal Analysis)</td><td>Temperature Distribution in Summer</td><td>
</td></tr>
<tr><td>Temperature Between Layers in Summer</td><td></td></tr>
</table>

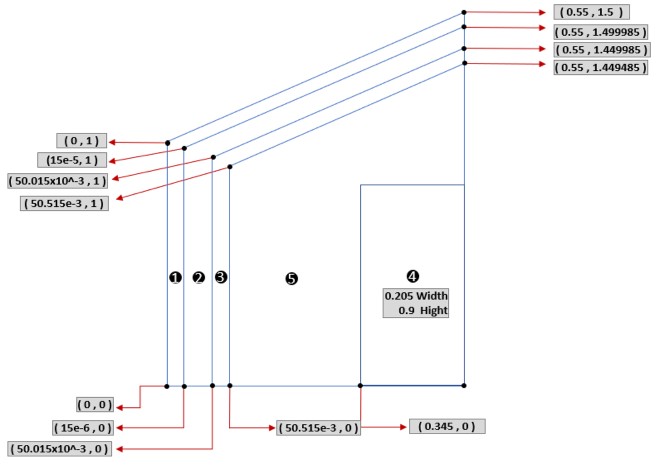
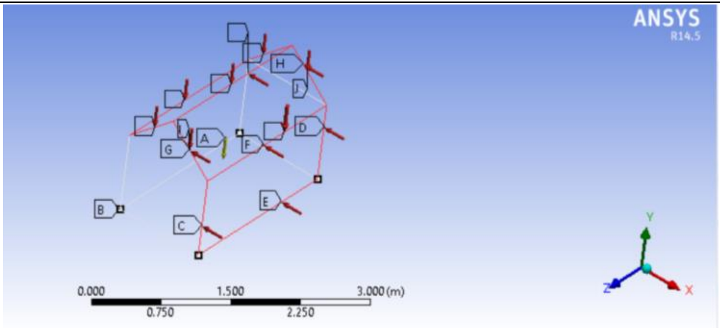
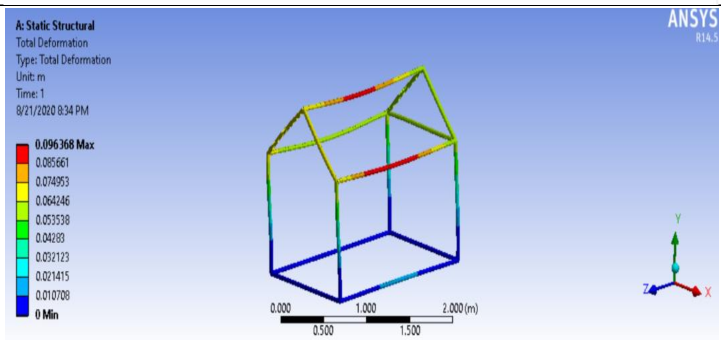
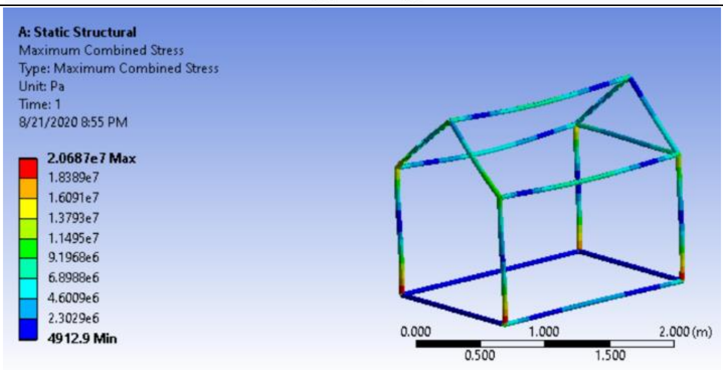
		
	Temperature Distribution in Winter	

Alternative solution 4

The material that used for the frame and the structure of the tent is PVC pipe schedule 80 with standard outside diameter equals 42.164 mm and inside diameter equals 31.877 mm, Appendix C.

Table 40:Alternative Solution 4 structural analysis

Alternative Solution 4 (Structural Analysis)	Dimensions of The Studied Side (left side)	

<table>
<tr><td></td><td></td><td>
</td></tr>
<tr><td></td><td>Total Loads Affected on The Frame</td><td>
</td></tr>
<tr><td></td><td>Deformation</td><td>
</td></tr>
<tr><td></td><td>Stress</td><td>
</td></tr>
</table>

The following tables represents the properties of the materials used for the cover of the tent. The properties of Mylar material represent in the table in the previous alternative solutions.

Table 41: Properties of Polyester Wool

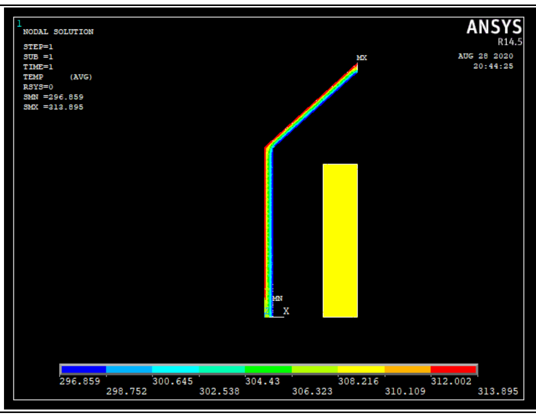
Material	Thermal conductivity [W/m.k]	Density [kg/m^3]	Modulus of Elasticity [Gpa]	Poisson's Ratio	Thickness [cm]
Polyester Wool	0.0359	40	80	0.4	5

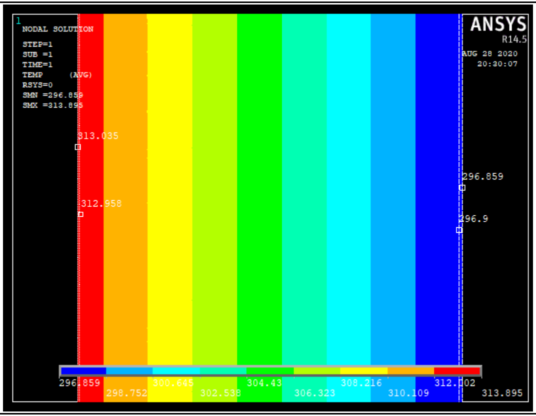
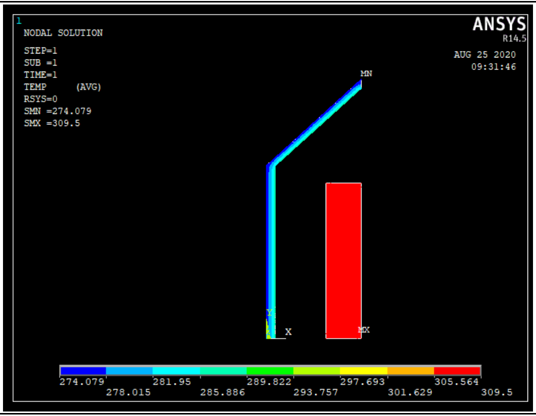
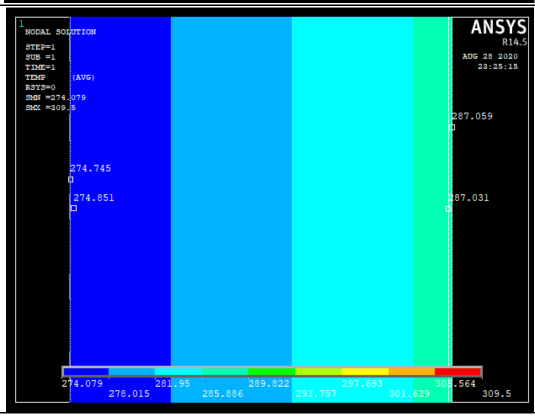
Table 42: Properties of PU Coating Polyester

Material	Thermal conductivity [W/m.k]	Density [kg/m^3]	Coefficient of Linear Expansion - α – [$℃^{-1}$]	Modulus of Elasticity [GPa]	Poisson's Ratio	Thickness [mm]
PU Coating Polyester	0.14	2200	40x10^{-6}	5	0.4	0.5

Where the total width of the tent equals 2 m and the hight equals 1.8 m. Number 1 in the dimensions of the studied side (left side) in the previous table represents the mylar material in summer and PU coating polyester in winter, Number 2 represents polyester wool in both summer and winter, Number 3 represents mylar material in winter and PU coating polyester in summer. While, Number 5 represents the air and 4 human body.

Table 43:Alternative Solution 4 thermal analysis

Alternative Solution 4 (Thermal Analysis)	Temperature Distribution in Summer	
	Temperature Between	

	Layers in Summer		
	Temperature Distribution in Winter		
	Temperature Between Layers in Winter		

Appendix F (analysis for selected design)

Outside flow properties:

The fluid case study is air, since the tent is subjected to quiescent air current; the type of convection from that air is free or natural convection.

Compressibility

In order to know if the flow around the tent is compressible or incompressible the continuity equation has been used as follows

$$\frac{D\rho}{Dt} + \rho\nabla.\vec{U} = 0 \qquad (9)$$

Since the value of density is constant, the first term equals zero ($\frac{D\rho}{Dt} = 0$), therefore, the continuity equation as follows

$$\nabla.\vec{U} = 0$$

And by assuming that the velocity is solenoidal then the flow is incompressible.

Flow Type

In order to know if the free convection boundary layer is laminar or turbulent; A rough analysis is done for the entire tent. Since the tent consists of vertical and inclined plates the analysis is done two times. In addition, in order to know the flow, type the outside temperature, outside wind speed and outside surface temperature must be known.

Vertical plate:

Grashof number for the vertical plate is calculated from the following equation.

$$Gr_l = \frac{g\beta(T_s - T_\infty)l^3}{\nu^2} \qquad (10)$$

Where, Gr_l= Grashof number.

, g = acceleration due to gravity in ($\frac{m}{s^2}$)

, v = Kinematic viscosity of air in ($\frac{m^2}{s}$) at T_f

, T_s= Temperature of outside surface of the tent in (˚C)

, T_∞= Temperature of outside surface of the tent in (˚C)

, $l =$ Length of the plate in (m)

, $\beta = \frac{1}{T_f}$ and T_f is the average temperature between the outside surface temperature and outside temperature $T_f = \frac{T_S + T_\infty}{2}$.

Rayleigh number is calculated from the following equation:

$$Ra_l = Gr_l * Pr \qquad (11)$$

Where, Pr = Prandtl number of air at T_f.

The Nusselt number is calculated from the following equations:

$$\overline{Nu_l} = 0.68 + \frac{0.670 * (Ra_l)\text{^}1/4}{\left[1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right]^{4/9}} \qquad (12)$$

The previous equation is used for the values of Rayleigh number less than 10^9 (Laminar flow).

In addition, a correlation that may be applied over the entire range of Ra has been recommended by Churchill and Chu as follows (Laminar + Turbulent)

$$\overline{Nu_l} = 0.825 + \left(\frac{0.387 * (Ra_l)^\wedge 1/6}{\left[1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right]^{\frac{8}{27}}} \right)^2 \quad (13)$$

The value of convection coefficient is calculated from the following equation:

$$\bar{h} = \frac{\overline{Nu} * k}{l} \quad (14)$$

Where, $\overline{Nu_l}$ = The Nusselt number.

, $\bar{h}$ = convection coefficient in W/m^2.K

, K= Thermal conductivity in W/m.k.

Inclined plate:

Grashof number for the inclined plate is calculated from the following equation.

$$Gr_l = \frac{g * \cos(\theta) * \beta(T_s - T_\infty)l^3}{\nu^2} \quad (15)$$

Where, θ = The angle of the inclined plate.

Rayleigh number is calculated from the following equation:

$$Ra_l = Gr_l * Pr$$

The Nusselt number is calculated from equation number 13 by using Churchill and Chu correlation.

Also, the value of convection coefficient is calculated from equation number 14.

In order to know the properties of air the film coefficient must be found, since the surface temperature is unknown it is assumed at the beginning, then the actual surface temperature is calculated from the total heat flow and composite wall.

Summer (Morning):

The total calculation of heat transfer in the tent in summer is calculated from energy balance equation as follows:

$$E_{in} - E_{out} + E_{gen} = E_{st} \quad (16)$$

Where, E_{in} = the energy entering the tent.

E_{out} = the energy leaving the tent.

E_{gen}= the energy generating inside the tent.

E_{st} = the energy of the system.

The energy entering the tent in summer in the morning are due to convection, radiation from the outside environment, and conduction between the layers of the cover of the tent.

$$E_{in} = q_{convection} + q_{conduction} + q_{radiation}$$
$$= U * A * (\triangle T)$$

Where, U = the total heat transfer coefficient for the convection, conduction and radiation.

$$= \frac{1}{\sum R*A}$$

Where, $\sum R$ = Total thermal Resistance.

$$\sum R = \frac{1}{h_{\infty 1}A} + \frac{L_A}{k_A A} + \frac{L_B}{k_B A} + \frac{L_C}{k_C A} + \left(\frac{1}{\frac{1}{h_{\infty 2}A}} + \frac{1}{\frac{1}{hrA}} \right)^{-1} \quad (17)$$

Where, A = the area of the outside surface of the tent without the floor since the ground is assumed to be adiabatic.

$\triangle T$ = Temperature difference between the contents of the tent and the outside surroundings.

$h_r = \varepsilon * \sigma * (T_s + T_{sur}) * (T_s^2 + T_{sur}^2)$

T_{sur} = temperature of radiation surface which is the surroundings.

Ts = Temperatura of receiving surface which is the surface of the tent.

$\varepsilon = emiisivity\ of\ the\ surface.$

$\sigma = Stefan\ Boltzman\ constant\ which\ equals\ 5.67\text{x}10^{-8} \frac{\text{W}}{\text{m2}} * \text{K4}\ )$

E_{gen} = energy generated from human body in (W).

E_{out} = When the all doors and windows are closed, the energy leaving the tent is assumed to be zero since the floor is assumed to be adiabatic and the openings are closed there is no way to let the heat to leave the tent. Besides, if the doors and windows are open the heat will be transfer during that openings and there will be heat leaving the tent due to convection.

$$E_{st} = \rho * V * C_p \frac{dT}{dt} \quad (18)$$

Where, ρ = density of the air inside the tent in (Kg/m^3).

V = volume of the air inside the tent in (m^3).

C_p = Specific heat of the air inside the tent in (J/Kg).

$\frac{dT}{dt}$ = the change of temperature with respect to time.

Therefore, the total energy balance at the morning is as follows.

$$U * A * (\triangle T) + E_{generation} = \rho * V * C_p * \frac{dT}{dt} \qquad (19)$$

In order to know the temperatures between the layers of the tent another analysis has been done.

This case could be considered as a composite wall, which is consist of four series thermal resistances and two parallel thermal resistances.

$$\sum R = \frac{1}{h_{\infty 1} A} + \frac{L_A}{k_A A} + \frac{L_B}{k_B A} + \frac{L_C}{k_C A} + \left(\frac{1}{\frac{1}{h_{\infty 2} A}} + \frac{1}{\frac{1}{hrA}} \right)^{-1}$$

Using the one-dimensional heat transfer rate:

$$q = \frac{T_{\infty 1} - T_{\infty 2}}{\sum R} = K_A * A * \frac{T_1 - T_2}{L_A} = K_B * A * \frac{T_2 - T_3}{L_B} = K_c * A * \frac{T_3 - T_4}{L_c}$$

Where, q = The total value of heat flow in (W).

, L_A = The thickness of the material that faced the outside environment in summer which is Mylar in (m).

k_A = Thermal conductivity of mylar material in (W/m. K).

L_B = The thickness of the insulation material which is polyester wool in (m).

k_B = Thermal conductivity of polyester wool in (W/m. K).

L_c = The thickness of PU coating polyester material in (m).

k_c = Thermal conductivity of PU coating polyester in (W/m. K).

h_1 = Convection coefficient for the outside environment in (W/m^2. k) .

h_4 = Convection coefficient for the air inside the tent in (W/m^2. k).

$T_{\infty 1}$ = Temperature of the outside environment in (˚C).

$T_{\infty 2}$ = Temperature of the inside environment (˚C).

T_{s1} = The surface temperature that faced the outside environment (˚C).

T_2, T_3 = The temperature between the layers of the tent (˚C).

T_{s4} = The surface temperature that faced the inside environment (˚C).

h_r = Radiation coefficient for the outside environment.

Then the outside surface temperature is calculated and compared with the assumed value. If the value of the assumed one didn't equal the value of the actual one the assumption should be repeated.

Summer (Night):

Similar equations will be used in night except that there will not be any radiation affected on the tent as follows.

$$U * A * (\triangle T) + E_{generation} = \rho * V * \frac{dT}{dt}$$

Besides, the value of total convection coefficient is as follows:

$$U = \left(\frac{1}{h_{\infty 1}} + \frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C} + \frac{1}{h_2}\right)^{-1}$$

In addition, the thermal circuit for the tent in summer in night is as follows.

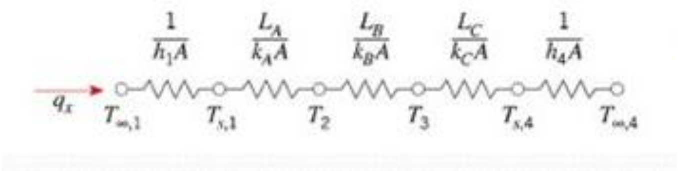


Figure 78: Composite wall thermal resistances

Since, the energy balance equation for the transient response is a function of time and temperature it cannot be solved without knowing one of these parameters, therefore one of them should be known.

Winter (Morning):

The total calculation of heat transfer in the tent in winter is calculated from energy balance equation as follows:

$$E_{in} - E_{out} + E_{gen} = E_{st}$$

E_{gen}= energy generated from human body.

$E_{st} = \rho * V * \frac{dT}{dt}$

Where, ρ = density of the air inside the tent.

V = volume of the air inside the tent.

$\frac{dT}{dt}$ = the change of temperature with respect to time.

$$E_{out} = q_{convection} + q_{conduction} + q_{radiation}$$
$$= U * A * (\triangle T)$$

Therefore, the total energy balance at the morning is as follows.

$$-U * A * (\triangle T) + E_{generation} = \rho * V * \frac{dT}{dt}$$

Winter (Night):

Similar equations will be used in night except that there will not be radiation affected on the tent.

$$-U * A * (\triangle T) + E_{generation} = \rho * V * \frac{dT}{dt}$$

In order to simplify the solution, the lamped capacitance method is used to calculate the approximate inside temperature.

$$E_g - [h(T - T_\infty) + \varepsilon\sigma(T^4 - T_{sur}^4)]A + q"A = \rho V c \frac{dT}{dt} \qquad (20)$$

Equation 20, is a nonlinear, first order, nonhomogeneous, and ordinary differential equation. Before solving in lamped capacitance method, the Biot number is measured and it should be less than 0.1.

$$Bi = \frac{hl_c}{k} \qquad (21)$$

Where Bi = the Biot number.

l_c= characteristic length.

The radiation is assumed to be negligible. In addition, no heat flux, then equation 22 is the result.

$$E_g - [h(T - T_\infty)]A = \rho V c \frac{dT}{dt} \qquad (22)$$

Let $\theta = T - T_\infty, a = \frac{hA}{\rho Vc}$ $, and\ b = \frac{E_g}{\rho Vc}$

Then

$\frac{d\theta}{dt} + a\theta - b = 0$

Then, let $\theta' = \theta - \frac{b}{a}$

$$\frac{d\theta'}{dt} + a\theta' = 0$$

The integration limitation from 0 to t, $\theta_i'\ to\ \theta$

$$\frac{\theta'}{\theta_i'} = \exp(-at)$$

Then

$$\frac{T - T_\infty}{T_i - T_\infty} = \exp(-at) + \frac{b/a}{T_i - T_\infty}[1 - \exp(-at)] \qquad (23)$$

Then the temperature inside the tent is calculated as the outside temperature is changed.

The types of ventilation in this tent are due to natural sources, which are temperature difference and wind. The cross-section ventilation is achieved due to wind and stack effect is achieved due to temperature difference.

Cross Section Ventilation

For cross ventilation, two windows at the center in right left and sides of the tent, with geometries $1/8 \times 1/8$ and $1/16 \times 1/16$, respectively.

Opening area

$A_1 =$ Inlet area from right

$A_2 =$ Outlet area from left

Ventilation due to wind for cross ventilation according to Ainsley method is as follow

$$Q = \sqrt{\frac{C_{p1} - C_{p2}}{\frac{1}{A_1^2 C_{d1}^2} + \frac{1}{A_2^2 C_{d2}^2}}} V \qquad (24)$$

where V is the velocity of the wind, Cp pressure coefficient, Cd discharge coefficient.

The discharge coefficient:

$$C_d = \frac{\dot{m}}{A\sqrt{2\rho \Delta P}} \qquad (25)$$

Where $\dot{m}$ the mass flow rate of air, ρ is density of air and △P pressure drop across constriction (N/m2)

The pressure coefficient

$$C_p = \frac{p - p_\infty}{\frac{1}{2} x \rho_\infty x\, V_\infty^2} \qquad (26)$$

Where P is static pressure at the point at which pressure coefficient is being evaluated, p∞ is free stream pressure and V ∞ is free stream velocity.

Appendix G (Validation of ANSYS answers for the frame)

All the calculations in this section are for the chosen design which is alternative 4.

Deformation

By assuming that the beam is fixed and using supper position for simply supports beam with uniform load case [2]:

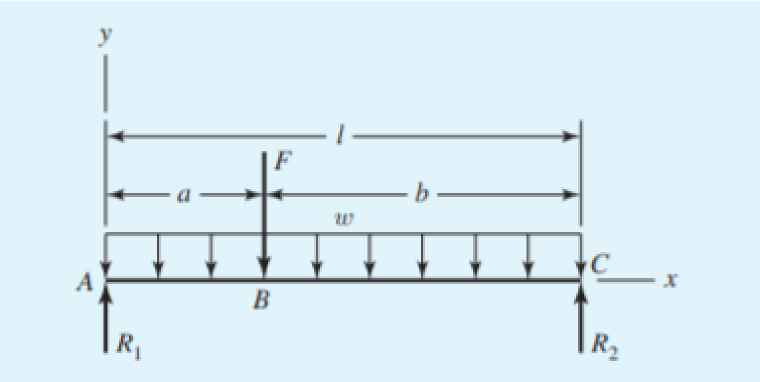


Figure 79: Simply supported beam

The value of fixed supports equals $R_1 = R_2 = \frac{wxl}{2}$

The deformation is calculated in x and y-axis by using the following equation.

$$y = \frac{wx}{24EI}(2Lx^2 - x^3 - l^3) \qquad (27)$$

Where y is deformation, w is load per unit length, L length of the beam, I is moment of inertia, E is modulus of elasticity and x is the location where the deformation is calculated.

Moment of inertia:

$$\mathrm{I} = \frac{\pi}{64}(\mathrm{D_o^4} - \mathrm{D_i^4}) \qquad (28)$$

Where

D_0 *is the outside diameter of the beam and* D_i *is the inside diameter of the beam*

$$\mathrm{I} = \frac{\pi}{64}((42.164\mathrm{x}10^{-3})^4 - (31.877\mathrm{x}10^{-3})^4) = 1.045 \times 10^{-7}\ \mathrm{m}^4$$

Modulus of elasticity of PVC pipe:

$$\mathrm{E} = 55.2\ \mathrm{MPa}$$

Deformation in x-axis.

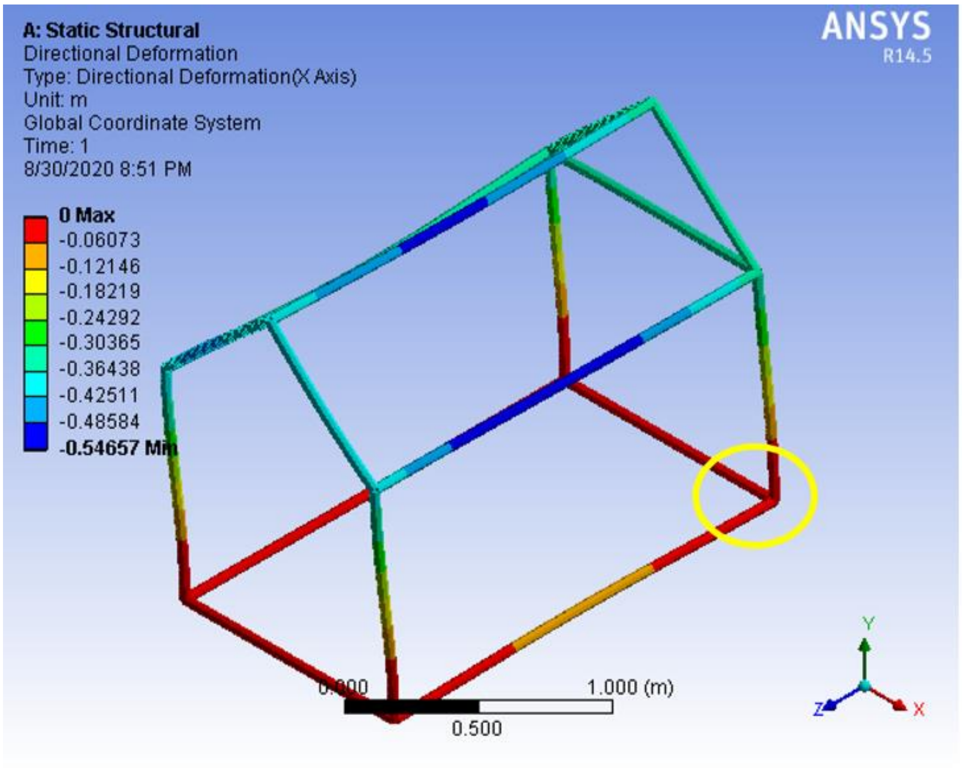


Figure 80: Deformation in x-axis for the frame from ANSYS workbench

The validation will be for the beam at the corner as shown in the previous Figure, where the value of both x and l equals 1.1. The unit of w in the deformation equation is N/m, since the wind load will produce the deformation in x-axis, the wind load equals 109.81 Pa. By multiplying the pressure with the surface area of the beam and divided on the length of the pipe the desired unit of the load will be achieved.

$$P = 109.81\ Pa = \frac{F}{S.A}$$

Where the surface area of the beam equals $\pi D_o l$

$$w = \frac{f}{l} = P\pi D_o = 109.81\ x\ \pi\ x\ 42.164x10^{-3} = 14.55\ N/m$$

Substituting,

$$X = \frac{14.55x1.1}{24x55.2x10^6x1.045x10^{-7}}(2x1.1x1.1^2 - 1.1^3 - 1.1^3)$$

$$X = 0\ m$$

Which is closed to the answer calculated from ANSYS.

Deformation in y-axis.

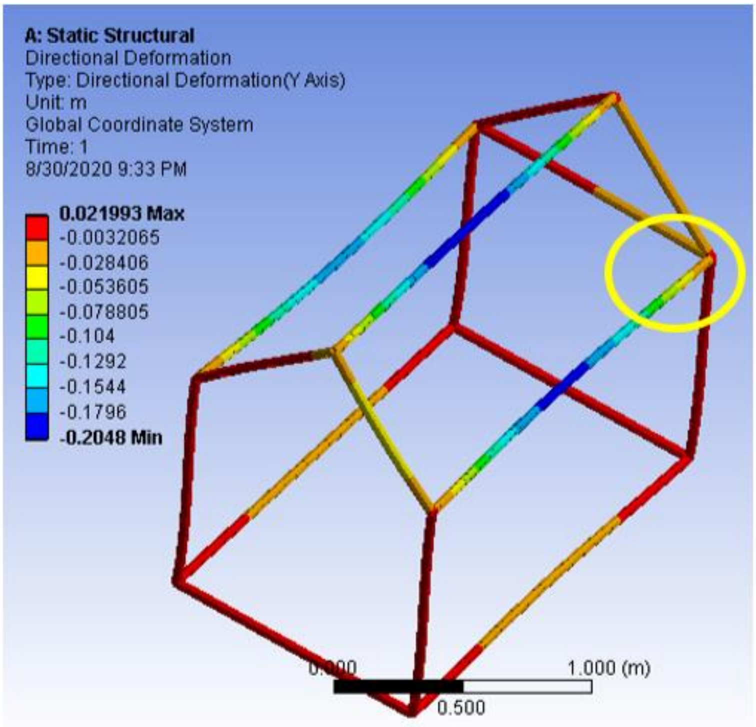


Figure 81: Deformation in y-axis for the frame from ANSYS workbench

The validation will be for the beam at the upper corner as shown in the previous Figure, where the value of both x and l equals 1.1. The unit of w in the deformation equation is N/m, since the snow load will produce the deformation in y-axis, the snow load equals 137.9 Pa. By multiplying the pressure with the surface area of the beam and divided on the length of the pipe the desired unit of the load will be achieved.

$$P = 137.9\ Pa = \frac{F}{S.A}$$

Where the surface area of the beam equals $\pi D_o l$

$$w = \frac{f}{l} = P\pi D_o = 137.9\ x\ \pi\ x\ 42.164x10^{-3} = 18.2665\ N/m$$

Substituting,

$$Y = \frac{18.2665x1.1}{24x55.2x10^6x1.045x10^{-7}}(2x1.1x1.1^2 - 1.1^3 - 1.1^3)$$

$$\mathrm{Y = 0\ m}$$

Which is closed to the answer calculated from ANSYS.

Bending stress

Since t<<r, then the beam considered to be closed thin tube [Prof. Richard G. Budynas and Prof. J. Keith Nisbett. Shigley's Mechanical Engineering Design. Tenth edition. Khon Kaen University.].

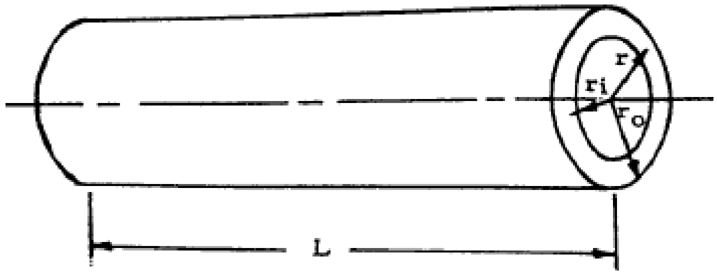


Figure 82: Closed thin tube

Figure 121 shows the loads that will lead to bending stress which are due to snow and wind.

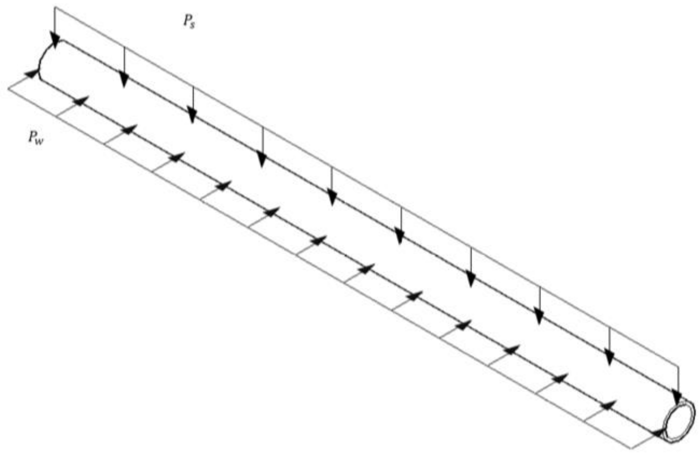


Figure 83: Loads that will lead to bending stress

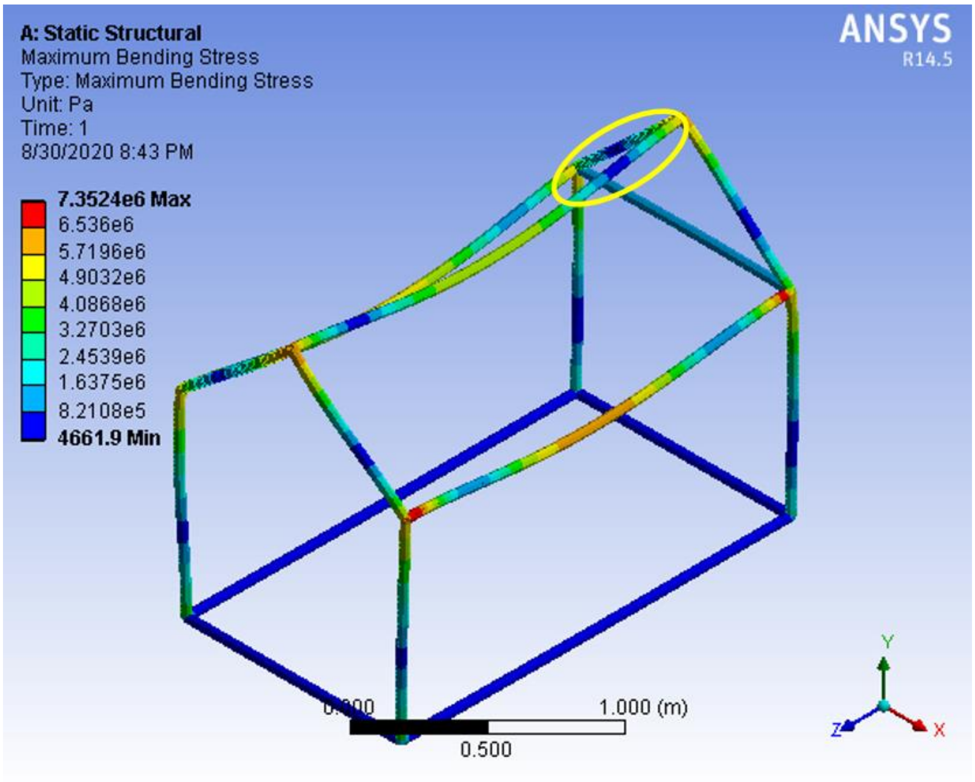


Figure 84: Bending stress due to snow from ANSYS workbench

Since the force is uniformly distributed, the following equation will be used in order to find the bending stress (Uniformly distributer stress)

$$\sigma = \frac{Mr_o}{I} \quad (29)$$

Outer diameter:

$$\mathrm{D_o} = 42.164\ \mathrm{mm} = \mathrm{r_o} = 21.082$$

Tube thickness:

$$\mathrm{t} = 5.144\ \mathrm{mm}$$

Inner diameter:

$$\mathrm{D_i} = 31.877\ \mathrm{mm}$$

Tube length:

$$\mathrm{L} = 2\ \mathrm{m}$$

Moment of inertia:

$$\mathrm{I} = \frac{\pi}{64}((42.164\mathrm{x}10^{-3})^4 - (31.877\mathrm{x}10^{-3})^4) = 1.045 \times 10^{-7}\ \mathrm{m}^4$$

Pressure due to snow:

$$\mathrm{P_s} = 137.9\ \mathrm{Pa}$$

Distributed load due to snow (From deformation part):

$$\mathrm{W_s} = P_s L = 18.2665\ N/m$$

Since the beam is assumed to be simply supported beam the moment due to snow is calculated from the following equation:

$$\mathrm{M_s} = \frac{W(6LX - 6X^2 - L^2)}{12}\ N.m \qquad (30)$$

Substituting,

$$\mathrm{M_s} = \frac{18.2665(6(2)(0.5) - 6(0.5)^2 - (2)^2)}{12} = 0.7611 N.m$$

Bending stress due to snow:

$$\sigma = \frac{0.7611x21.082x10^{\wedge} - 3}{1.045x10^{-7}} = 153.5455x10^3\ Pa$$

Table 44: ANSYS and hand calculations values

	Bending stress [pa]	Deformation in x [m]	Deformation in y [m]
Hand calculation	153.5455x10^3	0	0
ANSYS result	$[8.2108x10^5 - 4661.9]$	0	-0.0032

Appendix J (Weight, cost and lifespan)

Weight of PVC pipes for the fourth alternative solution:

The overall mass of the pipes is calculated from Ansys workbench which equals 15.765 Kg. The following table shows the overall mass of PVC pipes schedule 80 that used to build 4 seasons tent.

Table 45: Calculation of frame mass

Density [kg/m^3]	Length [m]	Cross section area [m^2]	Volume [m^3]	Mass [kg]	Number of pipes	Total mass [kg]
1300	1.00	0.000598206	0.000598	0.778	4	3.11
1300	1.10	0.000598206	0.000658	0.855	3	2.57
1300	2.00	0.000598206	0.001196	1.555	5	7.78

1300	0.74	0.000598206	0.000445	0.578	4	2.31
						15.77

The mass of each pipe is calculated from the following equation:

$$m = \rho \; x \; v$$

Where m is the mass of the beam, ρ is the density of the beam (PVC schedule 80) which equals 1300 kg/m^3, and v is the volume of the beam in m^3.

The volume is calculated as follows:

$$v = Axl$$

Where A is the cross-section area of the beam and l is the length of the beam, and the cross-section area is calculated as follows.

$$A = \frac{\pi}{4}\,(D_{outer}^2 - D_{inner}^2) \qquad (31)$$

Where D_{outer} is the standard outside diameter of the beam which equals 42.164 mm and D_{inner} is the standard inner diameter of the beam which equals 31.877 mm.

Substituting;

$$A = \frac{\pi}{4}\,((42.164x10^{-3})^2 - (31.877\text{x}10^{-3})^2) = 5.9821x10^{-4}\,m^2$$

As an example, the volume and mass for the PVC pipe with length equals 1 m is discussed and the calculation of this pipe as follows.

$$v = 5.9821x10^{-4}x1 = \; 5.9821x10^{-4}\,m^3$$

$$m = 1300 \; x \; 5.9821x10^{-4} = 0.778 \; kg$$

Since the number of pipes used with this length equals 4, the total mass will be $0.778 \; x \; 4 = 3.11 \; kg$ the calculation for the different length is the same and the total weight of the beams equals 15.77 kg which equals the value calculated from ANSYS.

Table 46: Total cost

Component	Weight [kg]
PVC Pipes and Fittings	16
Mylar	0.0003
Polyester Wool	7
PU Coating	0.35
Stabilizing Bag	0.5
Duratop	0.00015
	0.0003

Water-resistant Fiber Reinforced Mylar	
Packaging	0.5
Total Weight	24.35

Table 47:Life span

components	Life Span (years)
PVC Pipes and Fittings	100
Mylar	4
PU Coating	25
Polyester Wool	50
Velcro	4
4 Seasons Tent	**4**

Table 48:Cost

Component	Quantity	Price [KD]	Total Price [KD]	Market
Duratop (Windows)	1 roll	1	1	Amazon
Water-resistant Fiber Reinforced Mylar (Floor)	1 roll	3	3	Amazon
Mylar	1 roll	3	3	Amazon
Polyester Wool	8 rolls	6	48	Ali Express
PU Coating	5 rolls	6.7	33.5	Ali Express
Stablizing Bag	4	0.5	2	Ali Express
PVC Pipe (2 meters)	8	1.75	14	Aladsani
PVC Pipe (0.8 meters)	4	0.9	3.6	Aladsani
PVC Pipe (1.4 meter)	4	1.3	5.2	Aladsani
45 deg. Elbow	4	0.36	1.44	Aladsani
4 Tee Elbow	2	0.43	0.86	Aladsani
Tee Elbow	2	0.3	0.6	Aladsani
3 Way Elbow	4	0.52	2.08	Aladsani
Sleeping Bag	2	2.11	4.22	Albasman
Polyester Velcro	10 meters	3.25	3.25	Alblockat
Packaging	1	7.5	7.5	Albasman
Sewing Process		18	18	Albasman
Fire-resistant Coating Process		6.4	6.4	Shuwiekh
Shipping		7	7	-
Total Cost			164.65	

Appendix I (Sample calculations)

Assumptions: 1) Floor assumed to be adiabatic.

2) Human body assumed to be a cylinder with a diameter equals 0.3 m and height equals 0.9 m.

3) Density of the air inside the tent assumed to be 1.2342 Kg/m3.

4) Specific heat of air inside the tent assumed to be 1000 J/Kg

The assumptions are taken in summer and winter.

The Following analysis will be taken in winter at sun set (5:50 PM)

In order to find the value of film coefficient at 5:50 Pm the outside surface temperature is assumed to be 6.5 ° C.

$$Tf = \left(\frac{6.5 + 7}{2}\right) + 273 = 279.75\ k$$

$$B = \frac{1}{Tf} = 0.00357\ K^{-1}$$

Kinematic viscosity v @ Tf = 13.86 x10^-6 m^2/s

For the vertical plate:

$$Gr_l = \frac{9.81 * 0.00357 * (6.5 - 7)0.8^3}{(13.86x10^\wedge - 6)^2} = 4.67x10^7$$

Ra = 4.67x10^7 x 0.72 = 33.624x10^6

Therefore, the flow type is laminar. By using equation 12.

$$\overline{Nu_l} = 0.68 + \frac{0.670 * (33.624x10^6)^\wedge 1/4}{\left[1 + \left(\frac{0.492}{0.2}\right)^{\frac{9}{16}}\right]^{4/9}} = 39.9$$

Value of thermal conductivity @ Tf = 24.63 [w/mk] x10^-3

$$h = \frac{Nu * k}{l} = \frac{39.9 * 24.63 * 10^{-3}}{0.8} = 1.23 \text{ w/m^2.k}$$

For the inclined plate:

$$Gr_l = \frac{9.81 * \cos(45) * 0.00357 * (-6.5 + 7)0.8^3}{(13.86x10^\wedge - 6)^2} = 33.04x10^6$$

Ra = 33.04 x10^6 x 0.72 = 23.79 x10^6

By using equation 13:

$$\overline{Nu_l} = 0.825 + \left(\frac{0.387 * \frac{(23.79x10^6)^1}{6}}{\left[1 + \left(\frac{0.492}{0.72}\right)^{\frac{9}{16}}\right]^{\frac{8}{27}}} \right)^2 = 31.15$$

$$h = \frac{Nu*k}{l} = \frac{31.15*24.63*10^{-3}}{0.8} = 1 \text{ w/m^2.k}$$

For the following calculation the average value of convection coefficient during the day is used which equals 1.23 w/m^2.k

The volume of the air inside the tent is calculated as follows:

Where, V_{air} = The volume of the air inside the tent

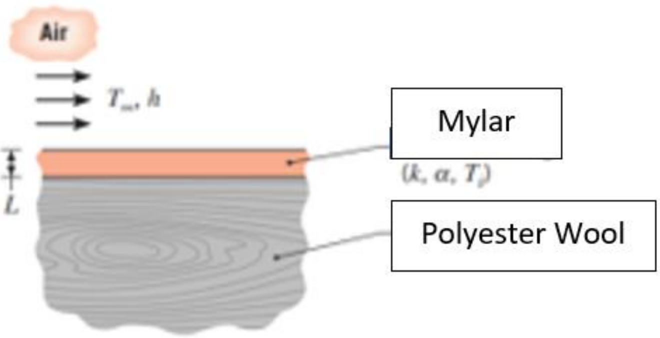
= (0.8*2*2) + ($\frac{1}{2}$ * 2 *1*2) = 5.3 m^3.

A = Area of the outside surface of the tent = 14.0568 m^2

h= outside convection coefficient 1.23 w/m^2 k

$E_{generation} = 106\ w$

In winter, the Mylar is applied to the insulation, and the heat loss from the insulation may be neglected and the interface of the insulation is assumed to be adiabatic.



$$Bi = \frac{hL}{k} = \frac{1.213 * 15 * 10^{-6}}{0.154} = 0.00012 < 0.1$$

The analysis is started from sunset at 5:10 PM, where the outside temperature equals 8 ° C and the inside temperature at that time is assumed to be 18˚C. The change of this temperature after 10 min is studied as follows.

$$T_\infty = 8\,^\circ C$$

$$T_{in} = 18\,^\circ C$$

$$a = 2.657x10^{-3}, b = 0.0165$$

$$t = 600\ s$$

Substituting in equation 23:

$$\frac{T-8}{18-8} = \exp(-2.657x10^{-3}x600) + \frac{0.0165/_{2.657x10^{-3}}}{18-8}[1-\exp(-2.657x10^{-3}x600)]$$

$$T = 14.98\,°\,C$$

The value of the previous temperature is taken as an initial temperature at 5:50 PM, where the outside temperature equals 7˚C and the change of this temperature after 30 min is studied as follows.

$$\frac{T-7}{14.98-7} = \exp(-2.657x10^{-3}x1800) + \frac{0.0165/_{2.657x10^{-3}}}{14.98-7}[1-\exp(-2.657x10^{-3}x1800)]$$

$$T = 13.23\,°\,C$$

Similar calculations and analysis are taken in order to find the value of the inside temperature during the day and night. The results are shown appendix K.

In winter and at time 5:50 PM, the heat flow is

$$q = UA(T_{in} - T_\infty) = (0.32)(14)(13.2-7) = 27\text{ W}$$

$$q = hA(T_s - T_\infty) = (1.213)(14)(T_s - 7) = 27\,W$$

$$T_s = 8\text{ ℃}$$

Compare this value with the assumed one of the inner surface temperatures.

For summer:

The calculation in summer is taken at sunrise @ 6:50 A.m.

In order to find the value of film coefficient at 6:50 A.m. the outside surface temperature is assumed to be 22.5 ° C, where the outside temperature at that time equals 23.

$$Tf = \left(\frac{22.5+23}{2}\right) + 273 = 295.75\,k$$

$$B = \frac{1}{Tf} = 0.00338\,K^{-1}$$

Kinematic viscosity ν @ Tf = 15.3 x10^-6 m^2/s

For the vertical plate:

$$Gr_l = \frac{9.81 * 0.00338 * (23-22.5)0.8^3}{(15.3x10\text{^}-6)^2} = 36.26x10^6$$

Ra = 36.26x10^6 x 0.72 = 26.11x10^6

Therefore, the flow type is laminar. By using equation 12.

$$\overline{Nu_l} = 0.68 + \frac{0.670 * (26.11x10^6)^\wedge 1/4}{\left[1 + \left(\frac{0.492}{0.2}\right)^{\frac{9}{16}}\right]^{4/9}} = 37.5$$

Value of thermal conductivity @ Tf = 26.07 [w/mk] x10^-3

$$h = \frac{Nu*k}{l} = \frac{37.5*26.07*10^{-3}}{0.8} = 1.23 \text{ w/m^2.k}$$

For the inclined plate:

$$Gr_l = \frac{9.81 * \cos(45) * 0.00338 * (23 - 22.5)0.8^3}{(15.3x10^\wedge - 6)^2} = 19.1x10^6$$

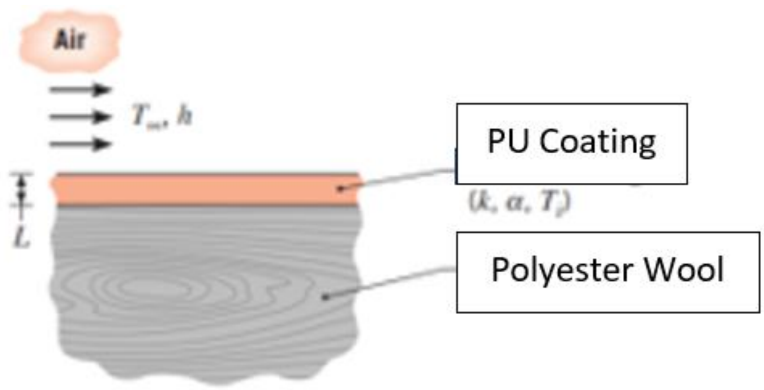
Ra = 19.1 x10^6 x 0.72 = 13.752 x10^6

By using equation 13:

$$\overline{Nu_l} = 0.825 + \left(\frac{0.387 * \frac{(13.752x10^6)^{1/6}}{1}}{\left[1 + \left(\frac{0.492}{0.72}\right)^{\frac{9}{16}}\right]^{\frac{8}{27}}} \right)^2 = 26.1$$

$$h = \frac{Nu*k}{l} = \frac{26.1*26.07*10^{-3}}{\sqrt{2}} = 0.48 \text{ w/m^2.k}$$

In summer, the PU coating is applied to the insulation, and the heat gain from the insulation may be neglected and the interface of the insulation is assumed to be adiabatic.



$$Bi = \frac{hL}{k} = \frac{1.213 * 0.5 * 10^{-3}}{0.14} = 0.004 < 0.1$$

lamped capacitance method can be used.

Energy Balance and General Lumped Capacitance Analysis in summer:

The analysis is started from at 6:50 AM, where the outside temperature equals $23\,°\,C$ and the inside temperature at that time is assumed to be 19 ˚C.

$$T_\infty = 23\,˚C$$

$$T_{in} = 19\,˚C$$

$$a = 2.657x10^{-3}, b = 0.0165$$

$$t = 1800\ s$$

Substituting in equation 3:

$$\frac{23 - T}{23 - 19} = \exp(-2.657x10^{-3}x1800) + \frac{0.0165 / 2.657x10^{-3}}{23 - 19}[1 - \exp(-2.657x10^{-3}x1800)]$$

$$T = 19.8\,°\,C$$

The value of the previous temperature is taken as an initial temperature for time 7:20 AM, where the outside temperature equals 26 ˚C and the change of this temperature after 30 min is studied as follows.

$$\frac{26 - T}{26 - 19.8} = \exp(-2.657x10^{-3}x1800) + \frac{0.0165 / 2.657x10^{-3}}{26 - 19.8}[1 - \exp(-2.657x10^{-3}x1800)]$$

$$T = 21.8\,°\,C$$

Similar calculations and analysis are taken in order to find the value of the inside temperature during the day and night. The results are shown appendix J.

In summer and at time 6:50 A.M, the heat flow is

$$q = UA(T_{in} - T_\infty) = (0.32)(14)(23 - 19) = 17.92\text{ W}$$

$$q = hA(T_s - T_\infty) = (1.213)(14)(23 - T_s) = 27\ W$$

$$T_s = 21.5\,℃$$

Compare this value with the assumed one of the outer surface temperatures, they are closed to each other.

The types of ventilation in this tent are due to natural sources, which are temperature difference and wind. The cross-section ventilation is achieved due to wind and stack effect is achieved due to temperature difference.

Cross Section Ventilation

For cross ventilation, two windows at the center in right left and sides of the tent, with geometries $^1/_8 \times ^1/_8$ and $^1/_{16} \times ^1/_{16}$, respectively.

Opening area

$$A_1 = 0.0156\, m^2 \text{(Inlet area from right)}$$

$$A_2 = 0.0.004\, m^2 \text{(Outlet area from left)}$$

Ventilation due to wind for cross ventilation according to Ainsley method

$$Q = \sqrt{\frac{C_{p1} - C_{p2}}{\frac{1}{A_1^2\, C_{d1}^2} + \frac{1}{A_2^2\, C_{d2}^2}}}V$$

Assume that the upstream opening is the window in the left side and the downstream opening is the window located in the right side, so the high pressure will occur in the left side.

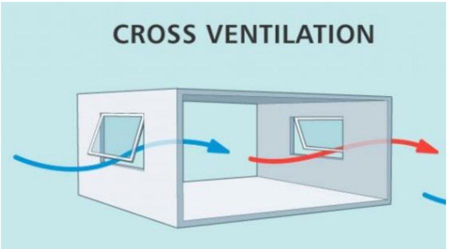


Figure 85: Cross ventilation direction

Summer conditions

$$average\ v\ for\ inlet = 4\, m/s$$

$$average\ v\ for\ outlet = 3\, m/s$$

$$\dot{m} = \rho V A = 1.225\ \times 4 \times\ 0.0156 = 0.0764\, kg/s$$

C_{d1} *and* C_{d2} Are assumed to be 0.65 (for unobstructed opening according to ASHRAE).

The tent is not built yet, therefore, it is difficult to measure the static pressure at certain height, then the pressure coefficients are assumed to be $C_{p1} = 0.8$ and $C_{p2} = 0.7$.

$$Q = \sqrt{\frac{0.8 - 0.7}{\frac{1}{(0.0156)^2(0.65)^2} + \frac{1}{(0.004)^2(0.65)^2}}}(4) = 0.00319\frac{m^3}{s} = 6.761\, cfm.$$

This value is accepted, where the value of recommended ventilation for low residential in ventilation requirements for occupants in ASHRAE standard is between 7-10 cfm.

Appendix j (Result of summer)

Table 49:Properties of the outside air in summer

Time	T_Outside	Weather	Wind	T_S1	T_f	β	Kinematic viscosity ν
	[C̊]		Km/h		[K]	[K^-1]	[m^2/s] x10^-6
0:20	24	Clear.	9	23.5	296.75	0.00337	15.39
0:50	27	Clear.	11	26.5	299.75	0.003336	15.67
1:20	25	Passing clouds.	11	24.5	297.75	0.003359	15.48
1:50	24	Clear.	13	23.5	296.75	0.00337	15.39
2:20	24	Clear.	11	23.5	296.75	0.00337	15.39
2:50	24	Clear.	15	23.5	296.75	0.00337	15.39
3:20	25	Clear.	15	24.5	297.75	0.003359	15.48
3:50	23	Passing clouds.	15	22.5	295.75	0.003381	15.3
4:20	23	Clear.	No wind	22.5	295.75	0.003381	15.3
4:50	21	Clear.	4	20.5	293.75	0.003404	15.12
5:20	19	Clear.	2	18.5	291.75	0.003428	14.94
5:50	19	Clear.	9	18.5	291.75	0.003428	14.94
6:20	20	Sunny.	7	19.5	292.75	0.003416	15.03
6:50	23	Sunny.	7	22.5	295.75	0.003381	15.3
7:20	26	Sunny.	6	25.5	298.75	0.003347	15.58
7:50	28	Sunny.	7	27.5	300.75	0.003325	15.76
8:20	30	Passing clouds.	4	29.5	302.75	0.003303	15.95
8:50	31	Sunny.	7	30.5	303.75	0.003292	16.04
9:20	32	Passing clouds.	7	31.5	304.75	0.003281	16.13
9:50	33	Passing clouds.	6	32.5	305.75	0.003271	16.23
10:20	33	Sunny.	9	32.5	305.75	0.003271	16.23
10:50	34	Passing clouds.	9	33.5	306.75	0.00326	16.32
11:20	35	Passing clouds.	7	34.5	307.75	0.003249	16.41
11:50	35	Passing clouds.	7	34.5	307.75	0.003249	16.41
12:20	36	Passing clouds.	6	35.5	308.75	0.003239	16.51
12:50	36	Sunny.	11	35.5	308.75	0.003239	16.51
13:20	37	Passing clouds.	11	36.5	309.75	0.003228	16.6
13:50	38	Sunny.	15	37.5	310.75	0.003218	16.7
14:20	38	Passing clouds.	11	37.5	310.75	0.003218	16.7
14:50	38	Passing clouds.	13	37.5	310.75	0.003218	16.7
15:20	38	Passing clouds.	11	37.5	310.75	0.003218	16.7

15:50	39	Passing clouds.	9	38.5	311.75	0.003208	16.79
16:20	39	Passing clouds.	11	38.5	311.75	0.003208	16.79
16:50	40	Passing clouds.	19	39.5	312.75	0.003197	16.89
17:20	39	Passing clouds.	26	38.5	311.75	0.003208	16.79
17:50	38	Sunny.	26	37.5	310.75	0.003218	16.7
18:20	37	Sunny.	26	36.5	309.75	0.003228	16.6
18:50	36	Sunny.	22	35.5	308.75	0.003239	16.51
19:20	35	Sunny.	19	34.5	307.75	0.003249	16.41
19:50	32	Sunny.	15	31.5	304.75	0.003281	16.13
20:20	32	Clear.	19	31.5	304.75	0.003281	16.13
20:50	32	Clear.	19	31.5	304.75	0.003281	16.13
21:20	32	Clear.	20	31.5	304.75	0.003281	16.13
21:50	31	Clear.	20	30.5	303.75	0.003292	16.04
22:20	30	Clear.	15	29.5	302.75	0.003303	15.95
22:50	29	Clear.	17	28.5	301.75	0.003314	15.85
23:20	28	Clear.	13	27.5	300.75	0.003325	15.76
23:50	29	Clear.	13	28.5	301.75	0.003314	15.85

Table 50: Properties of the vertical plates in summer

Time	Grl	Ra	Types of flow	$\overline{Nul}$	Thermal conductivity [w/mk] x10^-3	outside h w/m^2.k
0:20	3.57E+07	2.57E+07	Laminar	37.361	26.14	1.221
0:50	3.41E+07	2.46E+07	Laminar	36.941	26.36	1.217
1:20	3.52E+07	2.53E+07	Laminar	37.224	26.21	1.220
1:50	3.57E+07	2.57E+07	Laminar	37.361	26.14	1.221
2:20	3.57E+07	2.57E+07	Laminar	37.361	26.14	1.221
2:50	3.57E+07	2.57E+07	Laminar	37.361	26.14	1.221
3:20	3.52E+07	2.53E+07	Laminar	37.224	26.21	1.220
3:50	3.63E+07	2.61E+07	Laminar	37.500	26.07	1.222
4:20	3.63E+07	2.61E+07	Laminar	37.500	26.07	1.222
4:50	3.74E+07	2.69E+07	Laminar	37.781	25.92	1.224
5:20	3.86E+07	2.78E+07	Laminar	38.068	25.77	1.226
5:50	3.86E+07	2.78E+07	Laminar	38.068	25.77	1.226
6:20	3.80E+07	2.73E+07	Laminar	37.924	25.84	1.225
6:50	3.63E+07	2.61E+07	Laminar	37.500	26.07	1.222
7:20	3.46E+07	2.49E+07	Laminar	37.076	26.29	1.218
7:50	3.36E+07	2.42E+07	Laminar	36.807	26.44	1.216
8:20	3.26E+07	2.35E+07	Laminar	36.532	26.59	1.214
8:50	3.21E+07	2.31E+07	Laminar	36.401	26.66	1.213
9:20	3.17E+07	2.28E+07	Laminar	36.272	26.73	1.212
9:50	3.12E+07	2.25E+07	Laminar	36.134	26.81	1.211
10:20	3.12E+07	2.25E+07	Laminar	36.134	26.81	1.211
10:50	3.07E+07	2.21E+07	Laminar	36.007	26.88	1.210
11:20	3.03E+07	2.18E+07	Laminar	35.881	26.96	1.209

11:50	3.03E+07	2.18E+07	Laminar	35.881	26.96	1.209
12:20	2.98E+07	2.15E+07	Laminar	35.746	26.96	1.205
12:50	2.98E+07	2.15E+07	Laminar	35.746	26.96	1.205
13:20	2.94E+07	2.12E+07	Laminar	35.622	27.1	1.207
13:50	2.90E+07	2.09E+07	Laminar	35.490	27.18	1.206
14:20	2.90E+07	2.09E+07	Laminar	35.490	27.18	1.206
14:50	2.90E+07	2.09E+07	Laminar	35.490	27.18	1.206
15:20	2.90E+07	2.09E+07	Laminar	35.490	27.18	1.206
15:50	2.86E+07	2.06E+07	Laminar	35.368	27.25	1.205
16:20	2.86E+07	2.06E+07	Laminar	35.368	27.25	1.205
16:50	2.81E+07	2.03E+07	Laminar	35.238	27.32	1.203
17:20	2.86E+07	2.06E+07	Laminar	35.368	27.25	1.205
17:50	2.90E+07	2.09E+07	Laminar	35.490	27.18	1.206
18:20	2.94E+07	2.12E+07	Laminar	35.622	27.1	1.207
18:50	2.98E+07	2.15E+07	Laminar	35.746	26.96	1.205
19:20	3.03E+07	2.18E+07	Laminar	35.881	26.96	1.209
19:50	3.17E+07	2.28E+07	Laminar	36.272	26.73	1.212
20:20	3.17E+07	2.28E+07	Laminar	36.272	26.73	1.212
20:50	3.17E+07	2.28E+07	Laminar	36.272	26.73	1.212
21:20	3.17E+07	2.28E+07	Laminar	36.272	26.73	1.212
21:50	3.21E+07	2.31E+07	Laminar	36.401	26.66	1.213
22:20	3.26E+07	2.35E+07	Laminar	36.532	26.59	1.214
22:50	3.31E+07	2.39E+07	Laminar	36.674	26.51	1.215
23:20	3.36E+07	2.42E+07	Laminar	36.807	26.44	1.216
23:50	3.31E+07	2.39E+07	Laminar	36.674	26.51	1.215

Table 51: Properties of the inclined plate in summer

GrL	Ra	$\overline{Nul}$	outside h
1.79E+07	1.29E+07	2.56E+01	4.81E-01
1.85E+07	1.33E+07	2.58E+01	4.81E-01
1.88E+07	1.35E+07	2.59E+01	4.80E-01
1.88E+07	1.35E+07	2.59E+01	4.80E-01
1.88E+07	1.35E+07	2.59E+01	4.77E-01
1.85E+07	1.33E+07	2.58E+01	4.83E-01
1.91E+07	1.37E+07	2.61E+01	4.81E-01
1.91E+07	1.37E+07	2.61E+01	4.85E-01
1.96E+07	1.41E+07	2.63E+01	4.87E-01
2.03E+07	1.46E+07	2.66E+01	4.85E-01
2.03E+07	1.46E+07	2.66E+01	4.82E-01
1.99E+07	1.44E+07	2.65E+01	4.76E-01
1.91E+07	1.37E+07	2.61E+01	4.74E-01
1.82E+07	1.31E+07	2.57E+01	4.73E-01
1.77E+07	1.27E+07	2.54E+01	4.71E-01
1.71E+07	1.23E+07	2.52E+01	4.71E-01
1.69E+07	1.22E+07	2.51E+01	4.70E-01
1.66E+07	1.20E+07	2.50E+01	4.69E-01
1.64E+07	1.18E+07	2.48E+01	4.71E-01
1.64E+07	1.18E+07	2.48E+01	4.69E-01

1.61E+07	1.16E+07	2.47E+01	4.68E-01
1.59E+07	1.15E+07	2.46E+01	4.69E-01
1.59E+07	1.15E+07	2.46E+01	4.67E-01
1.57E+07	1.13E+07	2.45E+01	4.67E-01
1.57E+07	1.13E+07	2.45E+01	4.65E-01
1.55E+07	1.11E+07	2.44E+01	4.65E-01
1.52E+07	1.10E+07	2.43E+01	4.66E-01
1.52E+07	1.10E+07	2.43E+01	4.66E-01
1.52E+07	1.10E+07	2.43E+01	4.66E-01
1.52E+07	1.10E+07	2.43E+01	4.64E-01
1.50E+07	1.08E+07	2.41E+01	4.65E-01
1.50E+07	1.08E+07	2.41E+01	4.63E-01
1.48E+07	1.06E+07	2.40E+01	4.66E-01
1.50E+07	1.08E+07	2.41E+01	4.67E-01
1.52E+07	1.10E+07	2.43E+01	4.68E-01
1.55E+07	1.11E+07	2.44E+01	4.69E-01
1.57E+07	1.13E+07	2.45E+01	4.69E-01
1.59E+07	1.15E+07	2.46E+01	4.76E-01
1.66E+07	1.20E+07	2.50E+01	4.72E-01
1.66E+07	1.20E+07	2.50E+01	4.72E-01
1.66E+07	1.20E+07	2.50E+01	4.72E-01
1.66E+07	1.20E+07	2.50E+01	4.74E-01
1.69E+07	1.22E+07	2.51E+01	4.75E-01
1.71E+07	1.23E+07	2.52E+01	4.76E-01
1.74E+07	1.25E+07	2.53E+01	4.77E-01
1.77E+07	1.27E+07	2.54E+01	4.73E-01
1.74E+07	1.25E+07	2.53E+01	4.75E-01
1.74E+07	1.25E+07	2.53E+01	4.73E-01

Table 52: calculation of internal temperature in summer

Time	Outside Temperature ℃	Inside Temperature ℃	ΔT ℃	Heat Flow (without insulation) [W]	Heat Flow (with insulation) [W]
6:50 AM	23	19.0			
7:20 AM	26	19.8	6.2	28.1	47.4
7:50 AM	28	21.8	6.2	28.1	47.4
8:20 AM	30	23.8	6.2	28.1	47.4
8:50 AM	31	24.8	6.2	28.1	47.4
9:20 AM	32	25.8	6.2	28.1	47.4
9:50 AM	33	26.8	6.2	28.1	47.4
10:20 AM	33	26.8	6.2	28.0	47.3
10:50 AM	34	27.8	6.2	28.1	47.4
11:20 AM	35	28.8	6.2	28.1	47.4
11:50 AM	35	28.8	6.2	28.0	47.3
12:20 PM	36	29.8	6.2	28.1	47.4
12:50 PM	36	29.8	6.2	28.0	47.3
1:20 PM	37	30.8	6.2	28.1	47.4

1:50 PM	38	31.8	6.2	28.1	47.4
2:20 PM	38	31.8	6.2	28.0	47.3
2:50 PM	38	31.8	6.2	28.0	47.3
3:20 PM	38	31.8	6.2	28.0	47.3
3:50 PM	39	32.8	6.2	28.1	47.4
4:20 PM	39	32.8	6.2	28.0	47.3
4:50 PM	40	33.8	6.2	28.1	47.4
5:20 PM	39	32.8	6.2	28.0	47.2
5:50 PM	38	31.8	6.2	28.0	47.2
6:20 PM	37	30.8	6.2	28.0	47.2
6:50 PM	36	29.8	6.2	28.0	47.2
7:20 PM	35	28.8	6.2	28.0	47.2
7:50 PM	32	25.8	6.2	27.9	47.1
8:20 PM	32	25.8	6.2	28.0	47.3
8:50 PM	32	25.8	6.2	28.0	47.3
9:20 PM	32	25.8	6.2	28.0	47.3
9:50 PM	31	24.8	6.2	28.0	47.2
10:20 PM	30	23.8	6.2	28.0	47.2
10:50 PM	29	22.8	6.2	28.0	47.2
11:20 PM	28	21.8	6.2	28.0	47.2
11:50 PM	29	22.8	6.2	28.1	47.4
12:20 AM	24	17.8	6.2	27.8	47.0
12:50 AM	27	20.8	6.2	28.1	47.5
1:20 AM	25	18.8	6.2	28.0	47.2
1:50 AM	24	17.8	6.2	28.0	47.2
2:20 AM	24	17.8	6.2	28.0	47.3
2:50 AM	24	17.8	6.2	28.0	47.3
3:20 AM	25	18.8	6.2	28.1	47.4
3:50 AM	23	16.8	6.2	28.0	47.2
4:20 AM	23	16.8	6.2	28.0	47.3
4:50 AM	21	14.8	6.2	28.0	47.2
5:20 AM	19	12.8	6.2	28.0	47.2
5:50 AM	19	12.8	6.2	28.0	47.3
6:20 AM	20	13.8	6.2	28.1	47.4

Table 53:Dew point temperature in summer

time	inside T	Humidity	Dew point
6:50	19.0	45%	6.8
7:20	19.8	37%	4
7:50	21.8	33%	4.8
8:20	23.8	27%	3.7
8:50	24.8	24%	2.8
9:20	25.8	24%	3.7
9:50	26.8	26%	5.7

10:20	26.8	24%	4.5
10:50	27.8	23%	4.8
11:20	28.8	20%	3.6
11:50	28.8	18%	2.1
12:20	29.8	18%	2.9
12:50	29.8	17%	2.1
13:20	30.8	17%	2.9
13:50	31.8	15%	2
14:20	31.8	16%	2.9
14:50	31.8	16%	2.9
15:20	31.8	13%	0
15:50	32.8	13%	0.7
16:20	32.8	11%	-1.5
16:50	33.8	11%	-0.8
17:20	32.8	13%	0.7
17:50	31.8	15%	2
18:20	30.8	18%	3.7
18:50	29.8	19%	3.7
19:20	28.8	22%	4.9
19:50	25.8	22%	2.5
20:20	25.8	22%	2.5
20:50	25.8	21%	1.8
21:20	25.8	24%	3.7
21:50	24.8	25%	3.4
22:20	23.8	27%	3.7
22:50	22.8	26%	2.3
23:20	21.8	47%	10
23:50	22.8		10
0:20	17.8	37%	2.9
0:50	20.8	42%	7.4
1:20	18.8	44%	6.3
1:50	17.8	44%	5.4
2:20	17.8	44%	5.4
2:50	17.8	42%	4.7
3:20	18.8	47%	7.2
3:50	16.8	47%	5.4
4:20	16.8	53%	7.2
4:50	14.8	60%	7.1
5:20	12.8	64%	6.2
5:50	12.8	60%	5.2
6:20	13.8	50%	3.6

Appendix j (Result of winter)

Table 54: Properties of the outside air in winter

Time	T_Outside	Weather	Wind	T_S1	T_f	β	Kinematic viscosity ν
0:20	[C˚]		Km/h		[K]	[K^-1]	[m^2/s] x10^-6
Wed, 1 Jan	5	Passing clouds.	4	4.5	277.75	0.0036	13.69
0:50	4	Passing clouds.	6	3.5	276.75	0.003613	13.6
1:20	5	Partly cloudy.	4	4.5	277.75	0.0036	13.69
1:50	4	Partly cloudy.	4	3.5	276.75	0.003613	13.6
2:20	4	Partly cloudy.	6	3.5	276.75	0.003613	13.6
2:50	3	Partly cloudy.	4	2.5	275.75	0.003626	13.6
3:20	3	Partly cloudy.	6	2.5	275.75	0.003626	13.6
3:50	3	Partly cloudy.	4	2.5	275.75	0.003626	13.6
4:20	2	Partly cloudy.	No wind	1.5	274.75	0.00364	13.42
4:50	2	Partly cloudy.	No wind	1.5	274.75	0.00364	13.42
5:20	2	Partly cloudy.	No wind	1.5	274.75	0.00364	13.42
5:50	2	Partly cloudy.	6	1.5	274.75	0.00364	13.42
6:20	2	Partly cloudy.	7	1.5	274.75	0.00364	13.42
6:50	2	Partly cloudy.	6	1.5	274.75	0.00364	13.42
7:20	2	Partly cloudy.	7	1.5	274.75	0.00364	13.42
7:50	2	Broken clouds.	9	1.5	274.75	0.00364	13.42
8:20	2	Broken clouds.	6	1.5	274.75	0.00364	13.42
8:50	4	Broken clouds.	6	3.5	276.75	0.003613	13.6
9:20	5	Broken clouds.	6	4.5	277.75	0.0036	13.69
9:50	4	Broken clouds.	7	3.5	276.75	0.003613	13.6
10:20	4	Broken clouds.	7	3.5	276.75	0.003613	13.6
10:50	7	Broken clouds.	6	6.5	279.75	0.003575	13.86
11:20	7	Broken clouds.	7	6.5	279.75	0.003575	13.86
11:50	8	Broken clouds.	6	7.5	280.75	0.003562	13.95
12:20	8	Broken clouds.	7	7.5	280.75	0.003562	13.95
12:50	8	Broken clouds.	4	7.5	280.75	0.003562	13.95
13:20	10	Broken clouds.	15	9.5	282.75	0.003537	14.13
13:50	10	Broken clouds.	11	9.5	282.75	0.003537	14.13
14:20	9	Broken clouds.	17	8.5	281.75	0.003549	14.04

14:50	9	Broken clouds.	15	8.5	281.75	0.003549	14.04
15:20	9	Broken clouds.	13	8.5	281.75	0.003549	14.04
15:50	9	Broken clouds.	7	8.5	281.75	0.003549	14.04
16:20	9	Broken clouds.	13	8.5	281.75	0.003549	14.04
16:50	8	Broken clouds.	9	7.5	280.75	0.003562	13.95
17:20	8	Partly cloudy.	9	7.5	280.75	0.003562	13.95
17:50	7	Partly cloudy.	11	6.5	279.75	0.003575	13.86
18:20	6	Partly cloudy.	7	5.5	278.75	0.003587	13.77
18:50	6	Partly cloudy.	2	5.5	278.75	0.003587	13.77
19:20	4	Partly cloudy.	9	3.5	276.75	0.003613	13.6
19:50	3	Partly cloudy.	11	2.5	275.75	0.003626	13.6
20:20	5	Partly cloudy.	9	4.5	277.75	0.0036	13.69
20:50	2	Partly cloudy.	6	1.5	274.75	0.00364	13.42
21:50	2	Partly cloudy.	4	1.5	274.75	0.00364	13.42
22:20	1	Partly cloudy.	4	0.5	273.75	0.003653	13.34
22:50	1	Partly cloudy.	7	0.5	273.75	0.003653	13.34
23:20	1	Passing clouds.	6	0.5	273.75	0.003653	13.34
23:50	0	Passing clouds.	6	-0.5	272.75	0.003666	13.25

Table 55: Calculation of vertical plate in winter

Vertical plate.					
Grl	Ra	Types of flow	$\overline{Nul}$	Thermal conductivity [w/mk] x10^-3	outside h w/m^2.k
4.82E+07	3.47E+07	Laminar	40.221	24.71	1.242
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.82E+07	3.47E+07	Laminar	40.221	24.71	1.242
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.92E+07	3.55E+07	Laminar	40.423	24.55	1.240
4.92E+07	3.55E+07	Laminar	40.423	24.55	1.240
4.92E+07	3.55E+07	Laminar	40.423	24.55	1.240
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246

5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.82E+07	3.47E+07	Laminar	40.221	24.71	1.242
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.67E+07	3.36E+07	Laminar	39.907	24.63	1.229
4.67E+07	3.36E+07	Laminar	39.907	24.63	1.229
4.60E+07	3.31E+07	Laminar	39.745	24.94	1.239
4.60E+07	3.31E+07	Laminar	39.745	24.94	1.239
4.60E+07	3.31E+07	Laminar	39.745	24.94	1.239
4.45E+07	3.20E+07	Laminar	39.427	25.09	1.237
4.45E+07	3.20E+07	Laminar	39.427	25.09	1.237
4.52E+07	3.26E+07	Laminar	39.585	25.01	1.238
4.52E+07	3.26E+07	Laminar	39.585	25.01	1.238
4.52E+07	3.26E+07	Laminar	39.585	25.01	1.238
4.52E+07	3.26E+07	Laminar	39.585	25.01	1.238
4.52E+07	3.26E+07	Laminar	39.585	25.01	1.238
4.60E+07	3.31E+07	Laminar	39.745	24.94	1.239
4.60E+07	3.31E+07	Laminar	39.745	24.94	1.239
4.67E+07	3.36E+07	Laminar	39.907	24.63	1.229
4.75E+07	3.42E+07	Laminar	40.070	24.78	1.241
4.75E+07	3.42E+07	Laminar	40.070	24.78	1.241
4.91E+07	3.53E+07	Laminar	40.387	24.63	1.243
4.92E+07	3.55E+07	Laminar	40.423	24.55	1.240
4.82E+07	3.47E+07	Laminar	40.221	24.71	1.242
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.08E+07	3.65E+07	Laminar	40.725	24.48	1.246
5.16E+07	3.71E+07	Laminar	40.882	24.4	1.247

5.16E+07	3.71E+07	Laminar	40.882	24.4	1.247
5.16E+07	3.71E+07	Laminar	40.882	24.4	1.247
5.24E+07	3.78E+07	Laminar	41.055	24.33	1.249

Table 56: Properties of the inclined plate in winter

inclined plate			
GrL	Ra	$\overline{Nul}$	outside h w/m^2.k
2.58E+07	1.86E+07	2.87E+01	5.02E-01
2.53E+07	1.82E+07	2.86E+01	4.98E-01
2.58E+07	1.86E+07	2.87E+01	5.02E-01
2.58E+07	1.86E+07	2.87E+01	5.01E-01
2.59E+07	1.86E+07	2.88E+01	5.01E-01
2.59E+07	1.86E+07	2.88E+01	5.00E-01
2.59E+07	1.86E+07	2.88E+01	5.00E-01
2.67E+07	1.92E+07	2.91E+01	5.05E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.58E+07	1.86E+07	2.87E+01	4.98E-01
2.53E+07	1.82E+07	2.86E+01	4.98E-01
2.58E+07	1.86E+07	2.87E+01	5.02E-01
2.58E+07	1.86E+07	2.87E+01	5.01E-01
2.45E+07	1.77E+07	2.83E+01	4.93E-01
2.45E+07	1.77E+07	2.83E+01	4.93E-01
2.41E+07	1.74E+07	2.81E+01	4.90E-01
2.41E+07	1.74E+07	2.81E+01	4.96E-01
2.41E+07	1.74E+07	2.81E+01	4.96E-01
2.34E+07	1.68E+07	2.79E+01	4.91E-01

2.34E+07	1.68E+07	2.79E+01	4.94E-01
2.38E+07	1.71E+07	2.80E+01	4.97E-01
2.38E+07	1.71E+07	2.80E+01	4.95E-01
2.38E+07	1.71E+07	2.80E+01	4.95E-01
2.38E+07	1.71E+07	2.80E+01	4.95E-01
2.38E+07	1.71E+07	2.80E+01	4.95E-01
2.41E+07	1.74E+07	2.81E+01	4.98E-01
2.41E+07	1.74E+07	2.81E+01	4.96E-01
2.45E+07	1.77E+07	2.83E+01	4.99E-01
2.50E+07	1.80E+07	2.85E+01	4.96E-01
2.50E+07	1.80E+07	2.85E+01	4.99E-01
2.58E+07	1.86E+07	2.87E+01	5.04E-01
2.59E+07	1.86E+07	2.88E+01	5.01E-01
2.53E+07	1.82E+07	2.86E+01	4.96E-01
2.67E+07	1.92E+07	2.91E+01	5.08E-01
2.67E+07	1.92E+07	2.91E+01	5.03E-01
2.71E+07	1.95E+07	2.92E+01	5.06E-01
2.71E+07	1.95E+07	2.92E+01	5.04E-01
2.71E+07	1.95E+07	2.92E+01	5.04E-01
2.76E+07	1.98E+07	2.94E+01	5.07E-01
2.76E+07	1.98E+07	2.94E+01	5.05E-01

Table 57: Inside temperature in winter

Time	Outside Temperature ℃	Inside Temperature ℃	ΔT ℃	Heat Flow (without insulation) [W]	Heat Flow (with insulation) [W]
5:10 PM	8	18.0			
5:20 PM	8	15.0	7.0	30.5	53.2
5:50 PM	7	13.2	6.2	27.2	47.4
6:20 PM	6	12.2	6.2	27.2	47.4
6:50 PM	6	12.2	6.2	27.2	47.3
7:20 PM	4	10.2	6.2	27.2	47.4
7:50 PM	3	9.2	6.2	27.2	47.4
8:20 PM	5	11.2	6.2	27.1	47.2
8:50 PM	2	8.2	6.2	27.3	47.5
9:50 PM	2	8.2	6.2	27.2	47.3
10:20 PM	1	7.2	6.2	27.2	47.4
10:50 PM	1	7.2	6.2	27.2	47.3

11:20 PM	1	7.2	6.2	27.2	47.3
11:50 PM	0	6.2	6.2	27.2	47.4
12:00 PM	0	6.2	6.2	27.2	47.3
12:20 AM	5	11.2	6.2	27.0	47.0
12:50 AM	4	10.2	6.2	27.2	47.4
1:20 AM	5	11.2	6.2	27.1	47.2
1:50 AM	4	10.2	6.2	27.2	47.4
2:20 AM	4	10.2	6.2	27.2	47.3
2:50 AM	3	9.2	6.2	27.2	47.4
3:20 AM	3	9.2	6.2	27.2	47.3
3:50 AM	3	9.2	6.2	27.2	47.3
4:20 AM	2	8.2	6.2	27.2	47.4
4:50 AM	2	8.2	6.2	27.2	47.3
5:20 AM	2	8.2	6.2	27.2	47.3
5:50 AM	2	8.2	6.2	27.2	47.3
6:20 AM	2	8.2	6.2	27.2	47.3
6:50 AM	2	8.2	6.2	27.2	47.3
7:20 AM	2	8.2	6.2	27.2	47.3
7:50 AM	2	8.2	6.2	27.2	47.3
8:20 AM	2	8.2	6.2	27.2	47.3
8:50 AM	4	10.2	6.2	27.1	47.2
9:20 AM	5	11.2	6.2	27.1	47.2
9:50 AM	4	10.2	6.2	27.2	47.4
10:20 AM	4	10.2	6.2	27.2	47.3
10:50 AM	7	13.2	6.2	27.0	47.1
11:20 AM	7	13.2	6.2	27.2	47.3
11:50 AM	8	14.2	6.2	27.1	47.2
12:20 PM	8	14.2	6.2	27.2	47.3
12:50 PM	8	14.2	6.2	27.2	47.3
1:20 PM	10	16.2	6.2	27.1	47.2
1:50 PM	10	16.2	6.2	27.2	47.3
2:20 PM	9	15.2	6.2	27.2	47.4
2:50 PM	9	15.2	6.2	27.2	47.3
3:20 PM	9	15.2	6.2	27.2	47.3
3:50 PM	9	15.2	6.2	27.2	47.3
4:20 PM	9	15.2	6.2	27.2	47.3

Table 58: Dew point temperature in winter

Time	Inside tempreture [C]	Humidity	Dew point
17:10	18.00	87%	15.8
17:20	14.98		12.9
17:50	13.23	90%	11.6
18:20	12.22	93%	11.1
18:50	12.21	93%	11.1

19:20	10.23	93%	9.1
19:50	9.22	93%	8.51
20:20	11.20	93%	10.1
20:50	8.24	93%	7.2
21:50	8.21	93%	7.2
22:20	7.22	93%	6.1
22:50	7.21	93%	6.1
23:20	7.21	93%	6.1
23:50	6.22	100%	6.2
12:00:00 PM	6.21	100%	6.2
0:20	11.17	100%	11.1
0:50	10.22	93%	9.1
1:20	11.20	100%	11.2
1:50	10.22	93%	9.1
2:20	10.21	87%	9.1
2:50	9.22	93%	8.1
3:20	9.21	93%	8.1
3:50	9.21	81%	6.1
4:20	8.22	81%	5.1
4:50	8.21	71%	3.3
5:20	8.21	71%	3.3
5:50	8.21	66%	2.2
6:20	8.21	54%	-0.6
6:50	8.21	50%	-1.6
7:20	8.21	50%	-1.6
7:50	8.21	54%	-0.6
8:20	8.21	50%	-1.6
8:50	10.20	50%	0.2
9:20	11.20	50%	1.2
9:50	10.22	53%	1
10:20	10.21	53%	1
10:50	13.19	57%	4.9
11:20	13.21	61%	5.8
11:50	14.20	61%	6.8
12:20	14.21	70%	8.8
12:50	14.21	81%	11
13:20	16.20	66%	9.8
13:50	16.21	81%	12.9
14:20	15.22	81%	12
14:50	15.21	81%	12
15:20	15.21	87%	13
15:50	15.21	87%	13
16:20	15.21	93%	14.1