Design of a Lightweight Camping Cot Using Carbon Fiber Tent Poles and Ripstop Nylon

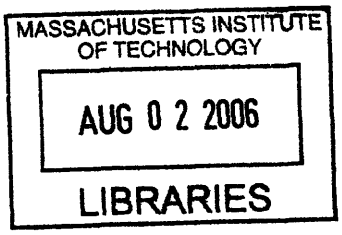
by

Walton Ward

SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2006



Signature of Author:_____
Department of Mechanical Engineering
May 12, 2006

Certified by:_____
David R. Wallace
Associate Professor of Mechanical Engineering
Thesis Supervisor

Accepted by:_____
John H. Lienhard V
Professor of Mechanical Engineering
Chairman, Undergraduate Thesis Committee

ARCHIVES

Design of a Lightweight Camping Cot Using Carbon Fiber Tent Poles and Ripstop Nylon

by

Walton Ward

Submitted to the Department of Mechanical Engineering
on May 12, 2006 in partial fulfillment of the
requirements for the Degree of Bachelor of Science in
Mechanical Engineering

ABSTRACT

A lightweight camping cot is currently unavailable in the backpacking market. Although camping cots do exist, they are not competitive in weight and size with sleeping pads typically used by campers. On average, sleeping pads weigh 2 pounds while the lightest weight camping cot on the market is 5 pounds. In addition, the cot does not collapse to the size of a sleeping pad. These factors prevent cots from being a suitable alternative to sleeping pads.

In order to bridge this discrepancy, a lightweight cot was designed and constructed in order to give campers a viable alternative to sleeping pads. The lightweight cot designed for this thesis weighs approximately 3 pounds and collapses to the size of a sleeping pad. This 1 pound increase in weight from a sleeping pad is made up for by increased comfort while sleeping and safety during lightning storms.

The lightweight cot utilizes carbon fiber poles for its structural support and ripstop nylon for the cot surface. The carbon fiber poles are connected with plastic fittings. Each of the cot's components was selected due to its highly lightweight properties and overall strength.

Thesis Supervisor: David R. Wallace
Title: Associate Professor of Mechanical Engineering

Acknowledgements

The author gratefully acknowledges the invaluable support and guidance of Professor Wallace during the preparation of this thesis and also thanks the MIT Outing Club for their feedback on camping preferences and needs.

Table of Contents

List of Figures

1 Introduction

This thesis covers the design evolution and construction of a lightweight cot for use in tents. The final prototype of the lightweight cot is designed from carbon fiber poles, ripstop nylon, and plastic fittings for joining the carbon fiber poles. Each of the components was chosen due to its compact size, strength, and lightweight properties.

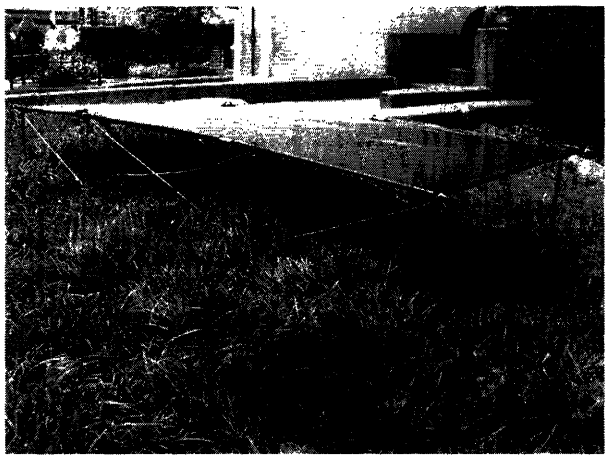


Figure 1: Cot prototype

When surveyed, campers responded that a sleeping pad's weight is the most important quality. Although several varieties of cots are available, they are not competitive in weight and collapsibility when compared to the sleeping pads typically used for hiking and camping.[1,2] The roughly three pound cot created for this thesis is not as lightweight as a typical sleeping pad, which weighs between one and two pounds, but is 40-63% lighter in weight than competing cots.

Of the cots available, the EZ Sales Standard 3 Leg Cot, seen in Figure 2 on the following page, is the closest in weight to the lightweight cot. However, its weight of 5 pounds is 67% heavier than the lightweight cot design.

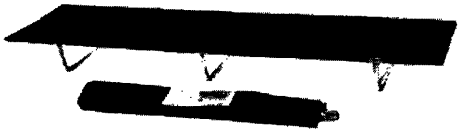


Figure 2: The EZ Sales Standard 3 Leg Cot

The lightweight cot is much lighter than the EZ Sales cot, which is a key concern for campers.

The added benefits of carrying a cot weighing an additional pound are comfort and greater protection from adverse weather. Sleeping pads serve as a buffer between the user and the ground. However, unless the ground is level and free of obstructions, users will still feel bumps and other inconveniences when using a sleeping pad. The lightweight cot solves these problems by separating the user from the ground and ensuring a smooth, level surface to sleep on. Concerning weather, the user is more likely to suffer electrocution from lightning in a sleeping pad than in the lightweight cot. Although both products are non-conducting, it has been shown that cots are more effective at preventing electrocution from lightning.[3]

The aim of this study was to make a lightweight cot. The following sections will detail the original concepts leading to the design of the lightweight cot, the structural design of the cot, the choice of components meeting the design's needs, the cot's overall performance, and further work for improvement.

1.1 Background

As a preliminary to a detailed analysis of the new cot design, it is necessary to explain the approach to the problem of camping in comfort and the decision to design and build a lightweight cot. From the outset, the scope of this thesis was focused on sleeping outdoors, although it began with a very different concept before evolving to the design of a lightweight cot.

The original concept involved integrating an air mattress into a tent. The goal was to foster an environment where a camper would sleep on an air mattress that afforded the same comfort as an at-home spring mattress. After the formulation of the "tent with a built-in mattress" concept, 49 campers were surveyed about their camping habits and needs. Fifty-one percent of the campers surveyed expressed interest in a tent with a built-in mattress. The two most common qualities that the tent would need to feature were:

lighter weight than a typical sleeping pad plus tent, and easy setup/breakdown, seen below in Figure 3. Complete results of the user survey are listed in Appendix B.

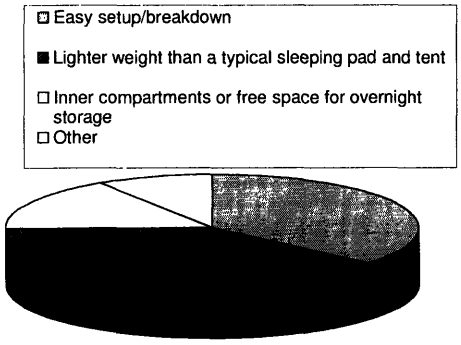


Figure 3: User preferences to tent with built-in mattress features

Although tents with built-in mattresses are currently available, they are far from lightweight and require air pumps to inflate. Additionally, the primary market for these tents is car camping, not backpacking. The goal was to enter a new market by introducing lightweight tents with built-in mattresses to backpackers.

After further analysis, it was decided that a backpacker's tent with a built-in mattress would need to be lightweight, easy to setup/breakdown, durable, easy to fix or replace the mattress, easy to clean, and includes space for overnight storage of equipment inside the tent. Aside from weight and setup/breakdown, durability is a key issue. .Unlike car camping, the tent and mattress will be subject to uneven and abrasive terrain. If the mattress is punctured or damaged in any way, the camper will be left sleeping uncomfortably on the ground. In addition, if the mattress were damaged, the entire product, including the tent, would need to be replaced, or the design must incorporate the option of a replaceable mattress.

Overnight storage of equipment and cleanliness are also key concerns of the campers. Often, campers will bring toiletries, clothing, food, or daypacks into the tent overnight. An issue that arises is the efficient location of storage space and sleeping

space. A tent with a built-in mattress will limit the size and location of storage space allowed to the camper. This equipment, and possibly the camper, will not be clean. After dirt and other debris have accumulated, it will be difficult to clean the mattress quickly given the added obstruction of a built-in mattress.

One final thought about this concept concerns the size of the tent and number of campers. If the tent and built-in mattress are designed for two campers, it would pose a significant weight inconvenience for a camper who has purchased the tent but would also like to use it occasionally without a companion.

A complete examination of the "tent with a built-in mattress" concept led to the conclusion that a built-in mattress did not present a viable option for backpackers. After this conclusion was reached, the problem of sleeping outdoors in comfort was approached in a different manner.

2 Proposed Design

Although it was determined that a tent with a built-in mattress did not provide an optimal solution, the related research led to an alternate solution. The key features of a mattress are support and comfort. By sleeping on an elevated surface that provides continuous support, users can sleep in comfort. By that logic, it should be feasible to create a similar product by elevating the user on a plane that offers both comfort and support. This product is the lightweight camping cot, seen below in Figure 4.

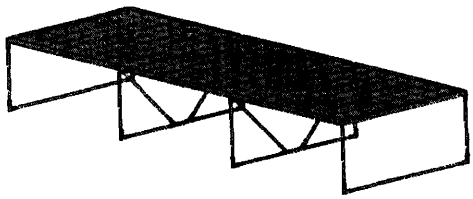


Figure 4: Lightweight cot design

Previous cot design iterations involved a pre-stressed carbon fiber beam support structure, whereby four supporting legs that were 1.5" longer than the width of the cot were bent into arches. In theory, these bent carbon fiber poles would keep the ripstop nylon tight, and they would also elevate the user about 3.5" off the ground. This design was not possible due to the high amounts of stress in specific locations on the nylon. While these areas of stress might have been distributed to prevent stretching or ripping at the joints, a greater cause for concern with the pre-stressed poles was the likelihood of wear-and-tear on the nylon. If the nylon were to lose its strength in any location due to the wear-and-tear of everyday use, the structure would become less rigid, allowing the poles to fully extend and unbend, thus leaving the cot only partially elevated, uneven, and ineffective.

Although a pre-stressed cot design saves 32% on weight, its will not wear well due to the high stress in the fabric caused the pre-stressed members.

The final lightweight cot design utilizes a simple, unstressed support structure, as seen in Figure 5 on the next page.

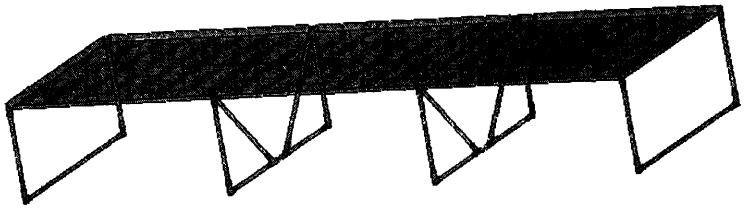


Figure 5: Bottom view of lightweight cot design

The weight distribution of the human body requires more support towards the middle of the cot. Therefore, the middle legs have additional 45 degree carbon fiber poles for added upward support and side-to-side stability, seen below in Figure 6.

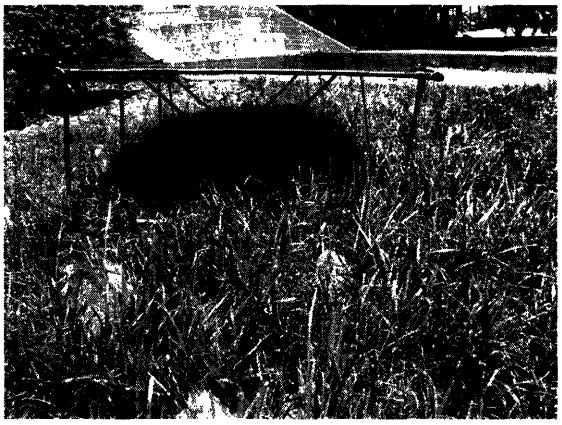


Figure 6: Side view of light cot

Although not pictured in the model in Figure 5, light-weight rope in tension is used to provide diagonal support between the four legs. This rope adds longitudinal stability by preventing the cot from swaying in a head-to-toe direction.

3 Components

In Sections 2.1-2.3, the components of the cot and their specifications are discussed. As previously mentioned, these components were chosen for their compact size, strength, and light weight. In addition to these three qualities, the components were chosen based on their availability and due to their familiarity to campers. Dimensioned drawings of each component can be found in Appendix A.

3.1 Carbon fiber pole

The carbon fiber pole is a commonly used support for tents. The poles are mass produced in several standard diameters and lengths, and, therefore, are easy to obtain

(provide a typical source?). In addition to being readily available, carbon fiber poles are extremely strong and flexible, allowing them to provide a spring-like support similar to that of mattresses.

The carbon fiber pole chosen for the lightweight cot design has a 3/8" diameter. The cot also uses three common lengths of carbon fiber poles, in order to decrease setup time and allow for easy part replacement. A model of one of the carbon fiber poles can be seen in Figure 7.

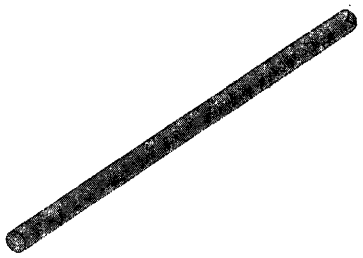


Figure 7: 3/8" diameter carbon fiber pole

The carbon fiber poles weigh 8.015×10^{-2} lb/ft. The total length of the carbon fiber poles is 34.88 ft, giving the poles a combined weight of 2.80 lbs. The carbon fiber poles comprise 84.5% of the cot's weight.

An added convenience of using common-sized poles is adaptability to newer technology. If newer poles are invented that are stronger and/or lighter weight, they would be readily adaptable without further modification in the design of the cot.

3.2 Plastic fittings

The plastic fittings serve as joints that connect the carbon fiber poles. For the prototype, modified Toro 3/8" plastic funny pipe were used as simple substitutes to custom fittings.[4] Models of the custom 3/8" inner diameter plastic fittings can be seen in Figure 8 on the following page.

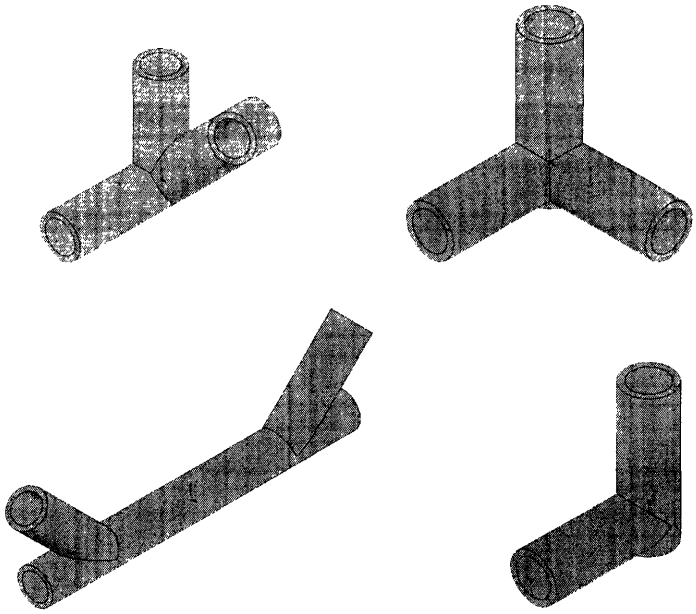


Figure 8: Plastic fittings for carbon fiber poles

The total estimated weight of the custom plastic fittings is 0.359 lbs. This corresponds to 10.9% of the cot's overall weight. The inner diameter of the fittings is 3/8", which conforms to the 3/8" diameter of the carbon fiber poles.

3.3 Ripstop nylon

The original design employed the orange fencing, as seen in Figure 9, which is typically used at construction sites.

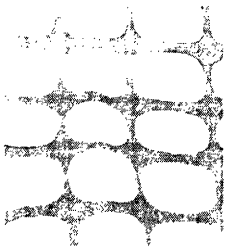


Figure 9: Orange fencing for original cot surface

However, the orange fencing was not a suitable cot surface due to its weight and stretching under relatively low tension. Given these issues, ripstop nylon was employed as a lightweight cot surface. Ripstop nylon is a form of lightweight nylon fabric that has interwoven threads in a crosshatch pattern, making the material highly resistant to ripping and tearing.[5] A model of the ripstop nylon cot surface can be seen in Figure 10.

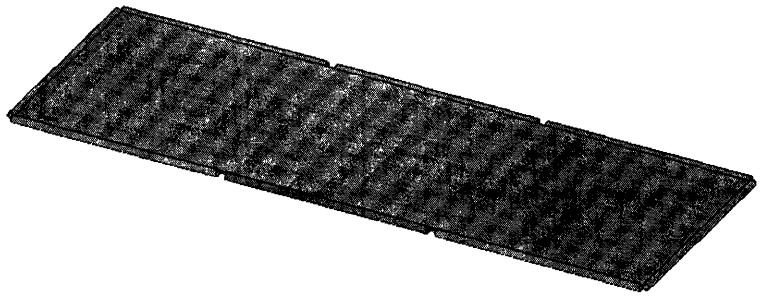


Figure 10: Ripstop nylon cot surface

Sleeves are located around the edges of the ripstop nylon in order to hold the supporting carbon fiber poles. Holes are located along the length of the sleeves to accommodate the plastic fittings that connect the carbon fiber poles.

The ripstop nylon dimensions are 23.75" x 70" and the ripstop nylon weighs 9.19×10^{-5} lb/in^2. This gives the ripstop nylon a weight of 0.152 lbs, constituting 4.6% of the total cot weight.

4 Discussion

The lightweight cot is intended for campers who are looking for a more comfortable alternative to sleeping pads. When assembled, the lightweight cot has a

footprint of 23.75" x 70". A typical two-person tent with a 54" x 84" footprint can easily accommodate two campers, each using their own lightweight cot. The current height of the cot from the ground is 10.57". Based on user preferences, the final height can be decreased to adapt to smaller tents by using shorter carbon fiber poles for the legs. This change in height would also save on overall weight. For example, a cot with a height of 3" will weigh 2.67 lbs, a 19% decrease in weight from the current model, seen below in Figure 11.

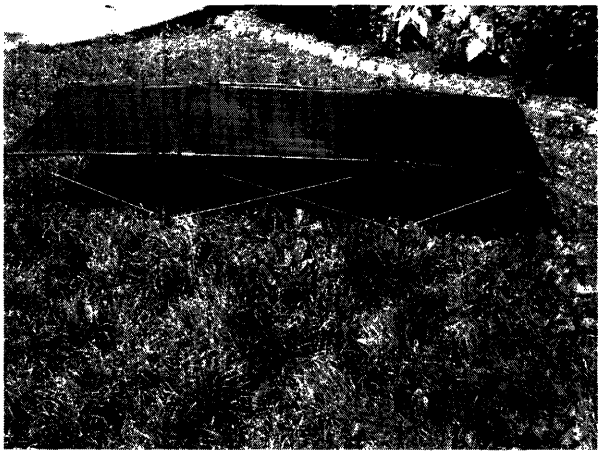


Figure 11: Overhead view of lightweight cot

When collapsed, the carbon fiber poles have an approximate rectangular cross-section of 2.18in^2, seen in Figure 12 on the following page.

Figure 12: Collapsed carbon fiber poles

This cross-section of $2.18in^2$ and total length of 24.14in make the size of the collapsed cot comparable in size to a compacted sleeping pad.

With the current four-leg support structure, there is flex in the carbon fiber poles located in the middle of the cot.

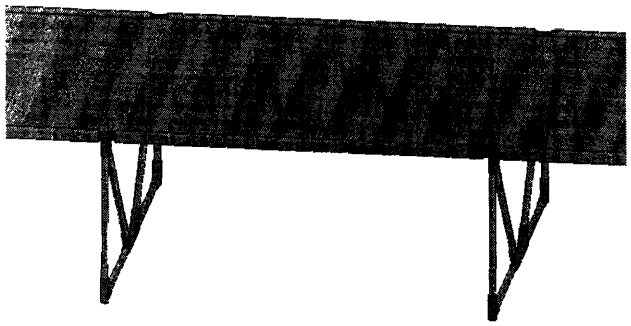


Figure 13: Close-up of the cot's central supports

When the user lies on the cot, the horizontal bar running through the middle sleeve of the cot flexes. Although the user does not experience significant discomfort, this problem can be fixed with a few simple countermeasures.

The first solution to countering the amount of flex in the poles located in the middle of the cot is to use a wider pole or use a different type of material that is not as lightweight and is more rigid. A second, more viable, solution is to add a fifth leg for support. The added leg will help keep the horizontal bars running through the nylon sleeves more rigid, and the added leg will also help distribute the stresses on the nylon.

While the user is getting onto the cot, high stresses can build around the location where the ripstop nylon meets the supporting legs because of uneven loading. By adding another supporting leg, the ripstop nylon will undergo less stress at each joint and will be less prone to ripping. Another solution to decreasing the stress at the joints is to use a bracket or brace that distributes the stress over a larger area on the ripstop nylon.

Any change in weight due to the addition of support can be negated by decreasing the height of the cot to 3". Since the cot would not be changing in weight, its overall collapsed size will not be altered either.

Another addition of support is the use of thin rope that connects the legs. The rope is extremely lightweight and does not add any appreciable weight to the overall cot. The thin rope is in tension and connects the top of one leg to the bottom of another leg, seen in Figure 14.

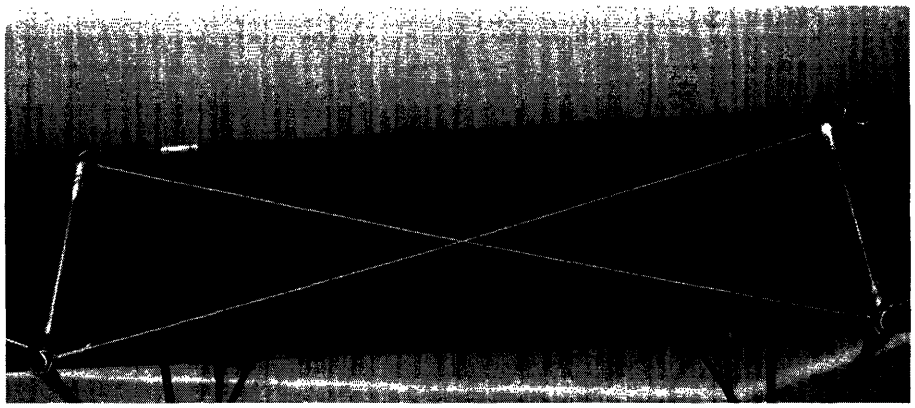


Figure 14: Thin rope connecting legs of cot

The addition of rope between the legs keeps the legs perpendicular to the ground and helps increase the stability of the cot.

5 Conclusion

Several iterations of lightweight cot designs were constructed and tested. The final lightweight cot designed in this thesis provides a lighter product than cots that currently exist in the camping market. Weight is a key issue for backpackers and the lightweight cot is 40-63% lighter than similar cots. Also, the lightweight cot is comparable in size and approximately one pound higher in weight than a sleeping pad. However, this small increase in weight is compensated for by increased comfort and safety from lightning.

The design utilizes carbon fiber poles at pin joints to provide a stable support system for the user. By avoiding pre-stressed designs, the ripstop nylon will not be in danger of compromising the cot's structure if wear-and-tear occurs while camping. Campers looking for a suitable lightweight alternative to sleeping pads will discover that this lightweight cot more than fits their needs.

6 Further Work

The final prototype provides the most appropriate structural design. Although the carbon fiber poles fit tightly into the plastic fittings, they do not snap into place. Incorporating a locking mechanism between the plastic fittings and carbon fiber poles will help with setup and will also maintain the cot's structure if it needs to be moved.

As previously noted, the final product will be stronger and easier to place in a tent if it is lower to the ground and provides an additional leg for support. This can be accomplished easily by decreasing the length of the vertical poles and 45 degree poles that make up the legs.

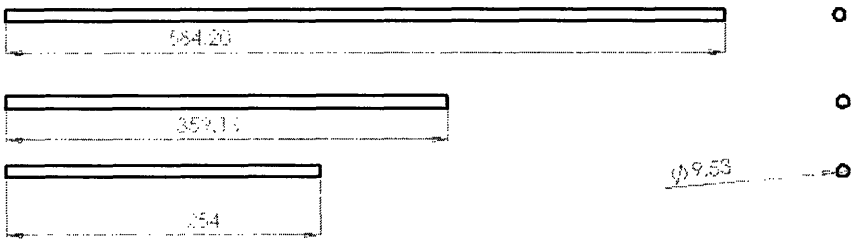
A final area for further improvement concerns the thin rope connecting the legs. Placing hooks on either end of each rope will help connect them to each leg quickly.

7 Appendix A

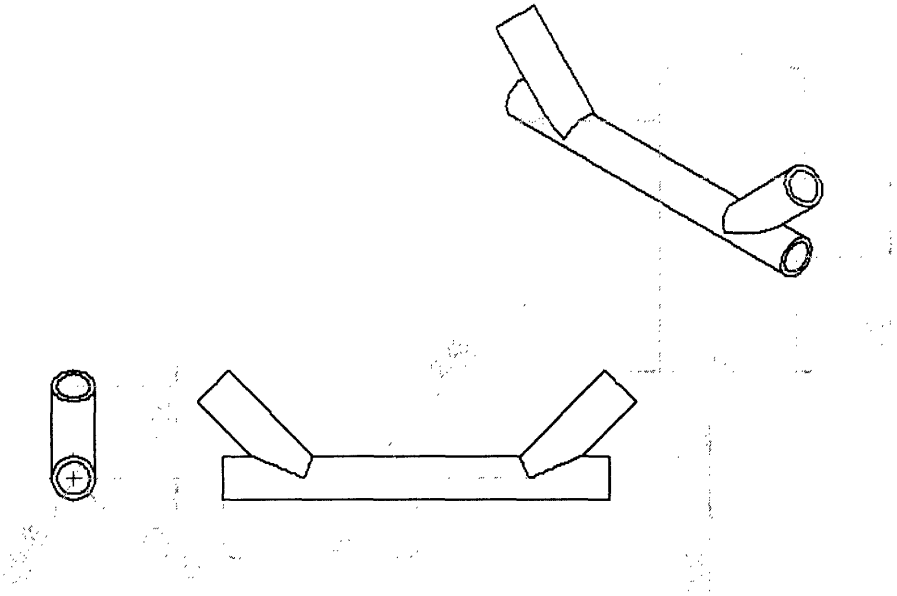
This appendix provides size and weight specifications for the cot. All dimensions are given in inches and all weights are given in pounds.

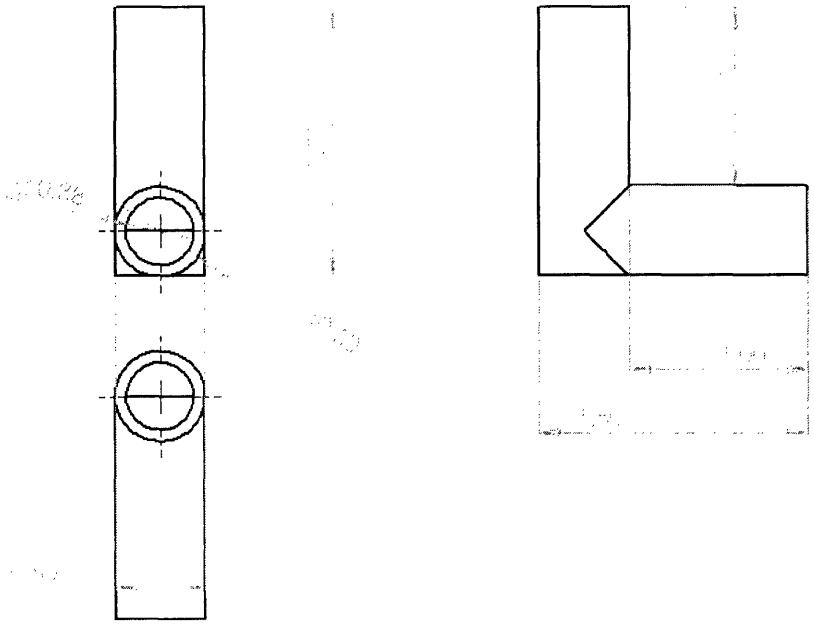
Appendix A1

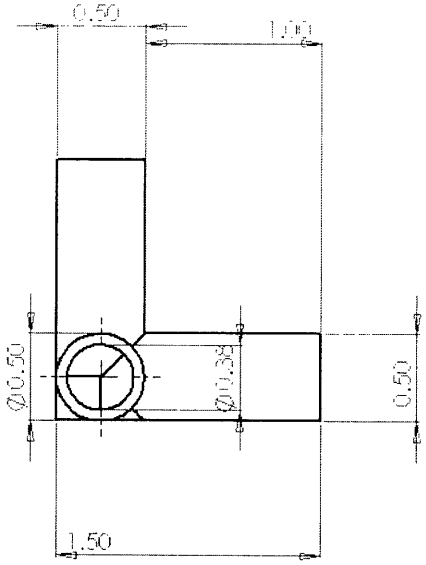
Carbon Fiber Poles

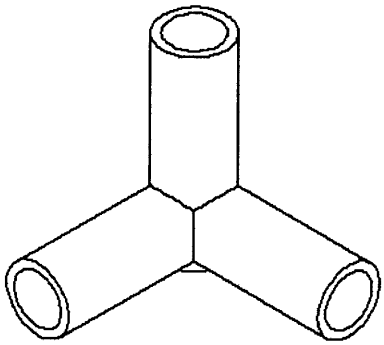


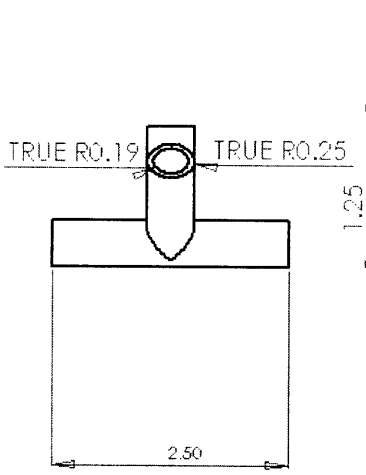
Appendix A2
Plastic Fittings

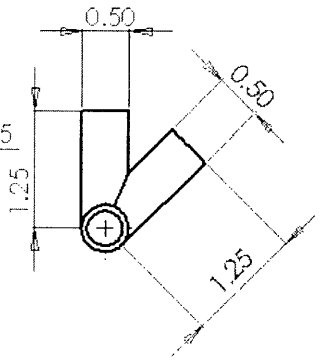


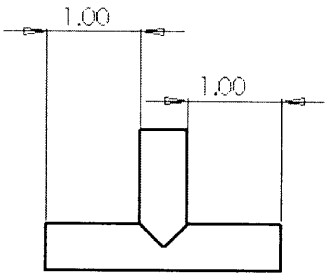


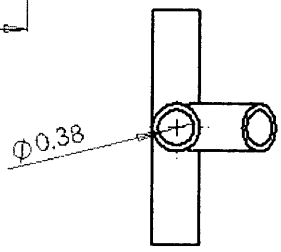

0.50
1.00
Ø0.50
Ø0.38
0.50
1.50



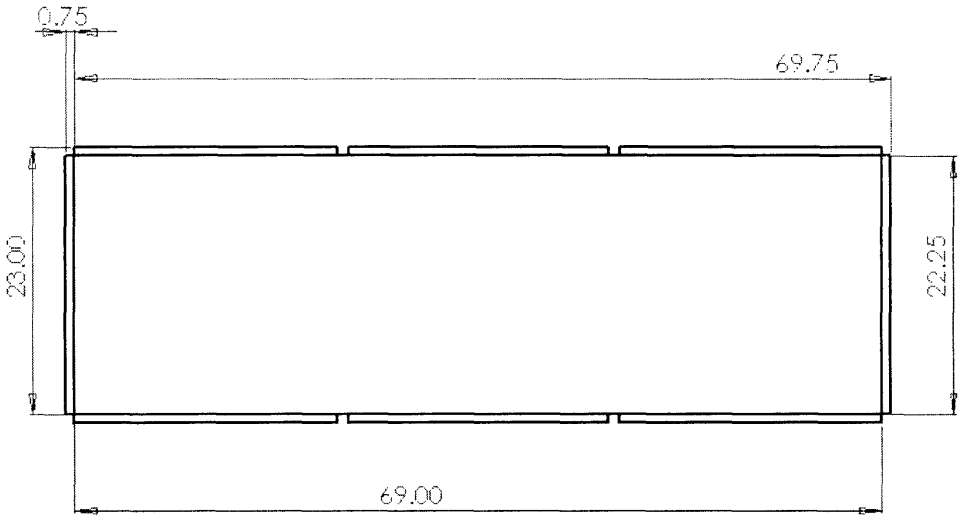

TRUE R0.19
TRUE R0.25
2.50


0.50
0.50
1.25
1.25


1.00
1.00


Ø0.38

Appendix A3
Ripstop nylon



8 Appendix B

Survey Results

1	How often do you camp each year?	Results	
	Never		0%
	1-5 times	28	57%
	6-12 times	7	14%
	12+ times	14	29%
2	How long is your typical camping trip?		
	Never		0%
	1-3 days	42	81%
	4-7 days	6	12%
	7+ days	4	8%
3	When do you go camping? (circle all that apply)		
	Summer	48	33%
	Fall	42	29%
	Winter	22	15%
	Spring	35	24%
4	When camping, where to you usually sleep? (circle all that apply)		
	Inside a car	5	6%
	In a tent on a car	1	1%
	In a tent on the ground	48	62%
	On the ground - no tent	20	26%
	Other	4	5%
5	What type of terrain do you usually sleep on? (circle all that apply)		
	Smooth and flat	32	30%
	Twigs, pebbles, mostly flat	47	44%
	Larger, more abrasive obstructionss or not flat	20	19%
	Extremely rough, abrasive, and/or inclined	7	7%
6	Do you bring anything in the tent with you overnight?		
	Yes	49	100%
	No		0%
	N/A		0%
7	If you answered yes, what do you bring? (circle all that apply)		
	Day pack	22	14%
	Large backpack	23	15%
	Shoes or sandals	32	21%

	Toiletries	36	24%
	Food or drinks	24	16%
	Other	16	10%
8	How many people usually sleep in a tent with you?		
	0	15	23%
	1	42	64%
	2	5	8%
	3	1	2%
	4	2	3%
	5+	1	2%
	N/A		0%
9	Do you sleep on a pad when camping?		
	Yes	46	94%
	No	3	6%
10	If you answered yes, what kind of pad?		
	Thin foam pad	23	40%
	Thin air pad	21	36%
	Thin foam/air pad	12	21%
	Other	2	3%
11	What are the qualities of a sleeping pad that help you determine whether or not to use it? (circle all that apply)		
	Lightweight	41	26%
	Durable	32	20%
	Comfortable	29	18%
	Dampens roughness of underlying terrain	22	14%
	Low maintenance	22	14%
	Other	13	8%
12	Would you be interested in using a thicker mattress that dampens the underlying terrain more than a typical sleeping pad?		
	Yes	26	55%
	No	21	45%
13	If you answered yes, what qualities would it need? (circle all that apply)		
	Lightweight	30	31%
	Durable	20	21%
	Air-filled	1	1%
	Foam	2	2%
	Low maintenance	17	18%
	Soft	3	3%
	More comfortable than other options	15	15%

	Other	9	9%
14	If a tent featured a built-in mattress, what qualities would it need? (circle all that apply)		
	Easy setup/breakdown	36	36%
	Lighter weight than a typical sleeping pad and tent	38	38%
	Inner compartments or free space for overnight storage	16	16%
	Other	9	9%
15	Would you be interested in a tent with a built-in mattress?		
	Yes	25	51%
	No	19	39%
	Maybe	5	10%

9 References

1 OutdoorMind LLC. http://www.byerofmaine.com/ct-trilite.htm. (February, 2006 - May, 2006)

2 Family On Board. http://www.familyonboard.com/CAMPINGFURNITURE.html. (February, 2006 - May, 2006)

3 Jones, Sgt. Robert L. Stormy weather poses hazards. http://www.dix.army.mil/PAO/post03/post060603/StormSeason.htm. (April, 2006 - May, 2006)

4 The Toro Company. http://www.toro.com/sprinklers/pipes/fittings/53390.html. (April, 2006 - May, 2006)

5 Wikipedia. Ripstop nylon. http://en.wikipedia.org/wiki/Ripstop_nylon. (April, 2006 - May, 2006)