Accordion tent for refugee camps

Final report

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Accordion emergency tent

Introduction

When a disaster happens, thousands of people lose their house. It often takes years for them to rebuild their homes. For the mean time, emergency tents are used to give everybody at least some shelter. This is a mass product that has to be put up as quick as possible in very large numbers. The Red Cross and other aid agencies provide these tents and stocks with ten thousands of them.

In the western world, many tons of old clothes are collected each year. About half of these, can still be worn. They are sold in many different places, from vintage shops in Amsterdam to markets in Africa. The other half can not be worn anymore. Reuse is the only option. Research about this, has recently led to a sorting machine, so the cotton, polyester, wool and other fibres can be seperated. New research should provide applications for this raw fibres.

This rapport is connecting two very different issues: providing tents for emergency situations and finding new uses for reused textile fibres. The goal of the assignment is to make a tent completely out of reused textile.

First, the requirements will be examined. A tent is not a normal building, so what specifications apply to it? What characteristics does the textile based material need to have to be used in tents? After this, the basic shape of the tent is determined, leading to a conceptual design. A model is made to illustrate the design. The elaboration consists of several topics, like structural design, material, indoor climate and estimation of the price.

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1. Program of requirements

1.1 Requirements

The requirements that apply to emergency shelter solutions can be divided in four different categories;

- General requirements
- Logistic requirements
- Technical requirements
- Social requirements

1.1.1 General requirements.

The design concerns a rapid deployable emergency shelter. The design should be manufactured entirely from recycled textiles, including the frame. When textile solutions for certain elements turn out to be unfeasible, the use of composites with textile is allowed, or a description of the specific characteristics of the required material should be given.

1.1.2 Logistical requirements

Packaging and transport

Due to transportation costs, which are approximately one third of the total costs, the volume of the packed tents needs to be as small as possible. After production, the tents will be transported with containers to their destination. For the design to be financially feasible, there should be as many tents as possible in one container.

Weight

To further cut down transportation costs, and therefore the price per unit, the weight of the packed tents should be as low as possible. Research into existing shelter solutions showed that weights of modern tents usually range from 30 to 60 kilograms. The older canvas shelters weights between 80 and 100 kilograms. For this design, the weight should be no more than the existing canvas solutions. Further engineering and optimization of the design can than cut down the weight.

Price

The final product can only be competitive with existing products if the price is competitive. The previous requirements helps to keep the price per unit down. In addition, the choice and quantity of the materials is important. The price of an emergency shelter consists mainly of three parts, which have an equal share;

- Material costs
- Transportation costs
- Production costs

Existing solutions, such as the UNHCR LWET and all weather tent, cost approximately 210 Euros. For this design, the goal is to approach this price as closely as possible.

Mounting

In an emergency situation, help should arrive as fast as possible. Therefore, rapid deployability of emergency shelters is very important. With a few instructions, locals have to be able to mount the proposed solution. Because rapid deployability is so important in emergency relief, the design has to be able to be mounted in a matter of hours. Aspects such as weight and price can always be optimized in a later stage of the engineering process. Rapid deployability however, should be integrated in the design process from the very beginning.

1.1.3 Technical requirements

Form:

Surface and volume

The minimal surface required per person depends on the local climate type. The following guide lines apply[1];

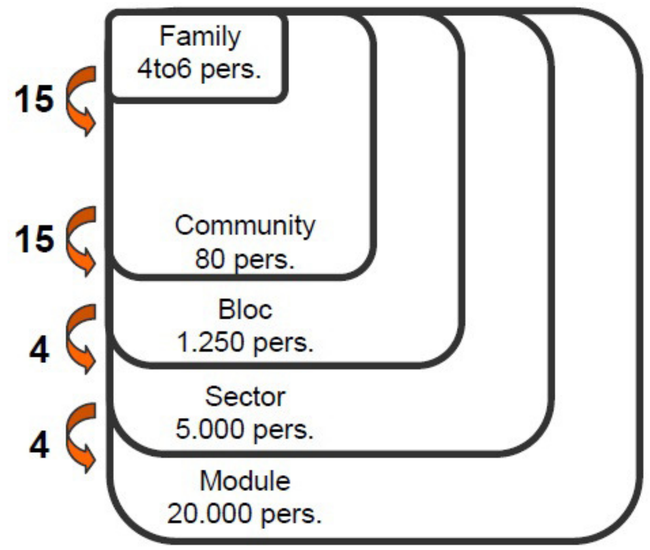
- Warm climate: 3.5 m^2/pp
- Moderate climate: 3.5 m^2/pp
- Cold climate: 4.5 m^2/pp

Based on a capacity of five persons, the usable surface of the tent should be between 17.5 - 22 square meters, depending on the local climate.

For a sustainable use of the tent, it's necessary to use the floor surface as efficiently as possible. This means that the surface that has a free height of 1.8 meters should be as large as possible.

Construction

As stated in the general requirements, the construction of the tent, including the frame, needs to be constructed of recycled textiles or textile composites. The tent will be engineered to cope with a Bwh climate, explained in chapter 1.2. In the climate type for which the tent is designed, wind is normative. and there is little or no snow Therefore, snow calculations are not relevant.



Picture 1: Scales in refugee camp[1]

Durability

Research has shown that refugees sometimes will use their emergency shelter up to 3 years[2]. Therefore, shelter solutions must have a large enough durability to last this period.

Indoor environment:

Ventilation

The required air change rate of an emergency shelter depends on the local atmosphere[1]. If the tent is situated in an non polluted atmosphere, the requested fresh air is 12 liter per person per second. When it is situated in a polluted environment it's 18 liter per person per second. This design is based on the first type, which brings the total requested fresh air rate per tent on 60 liter per second. The ventilation rate should therefore be between 5.4 and 6.8, depending on the footprint of the shelter.

Indoor temperature

In the Bwh climate type, outdoor temperatures can range from zero till 40 degrees Celsius. Since no additional cooling can be installed in the tents, indoor temperature must be regulated by ventilation and shading, and by some form of insulation. Keeping the indoor temperature as low as possible during the day is more important, since the design doesn't concern a winterized tent. The goal is to keep the indoor temperature during the day under the outside temperature.

Insulation

In this design no additional insulation, such as the insulation made from recycled textiles, is included. Heat loss during the night should be minimized by modular design, proper detailing, and the combination of an inner and outer canvas. Extra attention should be given to detailing the seams of the tent, since that is where heat losses are generally the largest.

Impermeability

Due to health issues, it is important that the tent is impermeable for pests and vermin. Extra attention in detailing should be paid to the edges on the bottom and on the openings of the tent. An upright edge at the bottom of an opening is recommended.

Reflectivity

The outer canvas of the tents should have good reflective properties to reduce overheating of the tents. The climate type for which the tents are designed has temperatures up to 40 degrees Celsius. To reduce the required ventilation capacity, the canvas should reflect solar radiation as much as possible. Research will point out which material is best suited.

Other:

Orientation

Local NGO employees should access the local conditions to determine the optimal orientation of the tents. Proper orientation significantly decreases wind loadings and can increase ventilation.

Situation and soil quality

A flat surface is required for the mounting of the tents. The design is aimed at areas with no sudden height variations.

1.1.4 Social demands.

Adaptability

The design concerns an emergency shelter and not a transitional shelter. Therefore, adaptability during the user phase is not important, because of the impermanent nature of the solution. Adaptability during the design phase is more important. Hereby, the design can be easily adapted to suit for example colder climates.

Flexibility

The design should be flexible in a way that it can accommodate families of different shapes and sizes. A modular design approach is therefore recommended.

Privacy and safety

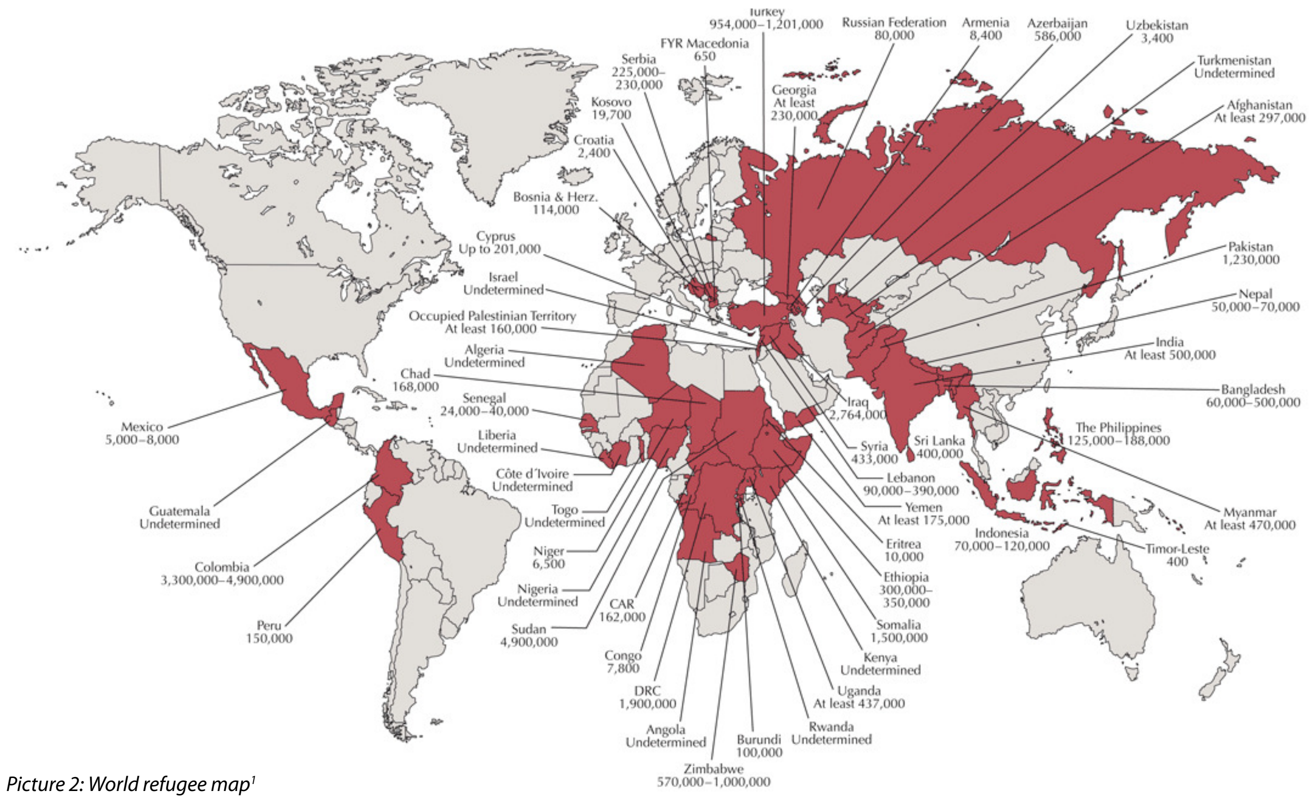
Privacy and safety is often a problem in refugee camps, mainly for women. Therefore, people have to be able to completely shut their tent. Also, a front portal before entering the main tent is included.

Ethical and cultural

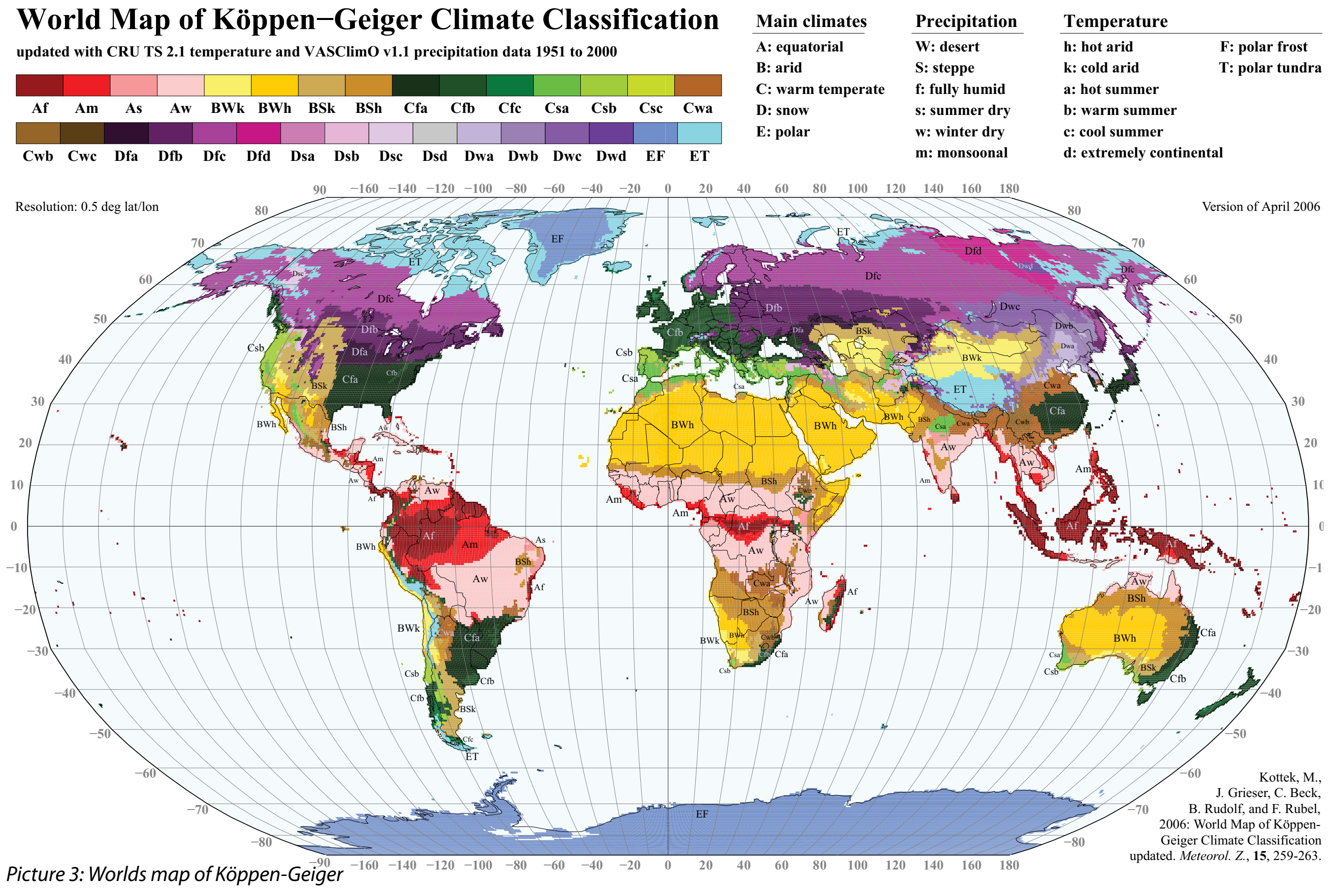
The area for which this design is aimed knows many different countries and cultures. Therefore, it is not possible to create one solution which suits with the vernacular architecture. In addition, the nature of an emergency shelter is to provide a shelter for those in need, which is more important than fitting in the local culture.

1.2 Climate analysis

For the emergency relief tents there is a large demand for rapid-deployable tents. To develop an emergency relief tent, it is important to perform research into the needs of refugees in the different climate types for emergency relief tents. To give a clear overview of which climate types with associated weather conditions have the largest amounts of



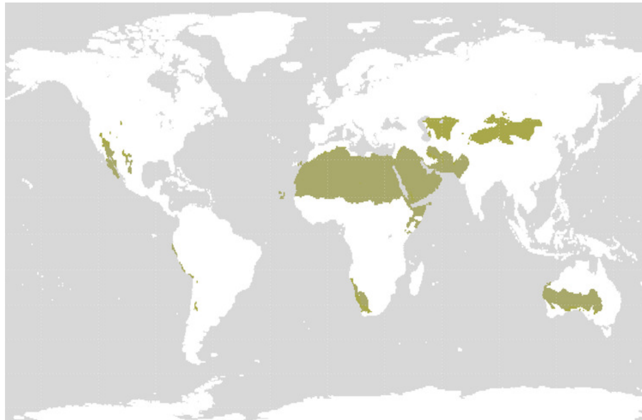
Picture 2: World refugee map[1]



Picture 3: Worlds map of Köppen-Geiger

refugees two maps are used, the World Refugee Map and the World Map of Köppen-Geiger Climate Classifications (Picture 2 and 3). These maps provide an overview of the demands of emergency relief tens in the different kind of climate types.
The refugees all over the world are indicated in the image on the upper left, the World Refugee Map. The climates are indicated in the World Map of Köppen-Geiger, on the bottom left.
By comparing both maps, the number of refugees can be determined per climate type. The main climate are types C, D and E and have cold winters. The climatetype E has no refugees and will therefore not be in the overview. The goal is to design a rapid-deployable tent, with a solution for the largest number of refugees living in one or more climate type.

This overview concludes that the largest number of refugees (13037900) is located in climate-type B. And in particular in the climate type Bwh (11050500), the dry dessert climate. The dessert climate covers 12% of the earth's surface. There is little vegetation, mainly strong plants that can last long without water, such as cactus and other succulents. There is almost no rainfall (less than 200mm per year), but when it rains (once every few years) it comes with large quantities simultaneously from the sky. The soil in this climate-type is dry, infertile and usually consist of sand and rocks.
The dessert climate has a large temperature difference between day and night. During the day the temperatures are between 25 ºC and 45 ºC and at night, temperatures in some areas drop below 0 ºC.
As the tables show, climate-type A also contains many refugees (9365200), divided in climate-type Af, Tropical Rainforest (5758000) and the climate-type Aw, Tropical Savanna (3607200).
This analysis shows that when the tent is designed for the Bwh climate, it will reach most refugees.


Picture 5 Climatetype Bwh

Filipijnen	188000	**Af**-Am		
Indonesie	120000	**Af**		
Sri Lanka	400000	Aw-**Af**		
Peru	150000	**Af**-Am-Bwh-Et		
Colombia	4900000	**Af**-Am	Af	5758000
Liberië	n.b.	**Am**		
Guatemala	n.b.	**Am**-Aw	Am	0
India	500000	**Aw**-BSh-Csa-Cwa		
Bangladesh	500000	**Aw**		
Timor Leste	400	**Aw**		
Kenia	n.b.	**Aw**-Cfa		
Oeganda	437000	Am-Af-**Aw**		
Rwanda	n.b.	**Aw**		
Burundi	100000	**Aw**		
DR Congo	1900000	Af-Am-**Aw**		
Congo	7800	Af-Am-**Aw**		
Centraal Afrika Rep.	162000	**Aw**		
Nigeria	n.b.	Am-**Aw**-Bsh		
Togo	n.b.	**Aw**		
Ivoorkust	n.b.	**Aw**	Aw	3607200
			A	**9365200**

Oezbekistan	3400	**BWk**		
Turkmenistan	n.b.	**BWk**	Bwk	3400
Afghanistan	297000	**Bwh**-Bsk-Dsb		
Pakistan	1230000	**Bwh**		
Irak	2764000	**Bwh**-Bsh		
Jemen	175000	**Bwh**		
Eritrea	10000	**Bwh**-BSh		
Somalië	1500000	**Bsh**-**Bwh**		
Soedan	4900000	Aw-Bsh-**Bwh**		
Tsjaad	168000	Aw-**Bwh**-Bsh		
Niger	6500	Bsh-**Bwh**		
Algerije	n.b.	**Bwh**-Csa	Bwh	11050500
			Bw	**11053900**

Picture 4: Number of refugees per climate type

Azerbeidzjan	586000	**BSk**		
Ethiopie	350000	Cwb-**BSh**-Aw		
Zimbabwe	1000000	**Bsh**-Cwa		
Angola	n.b.	**Bsh**-Cwa-Aw		
Senegal	40000	Aw-Bwh-**Bsh**		
Mexico	8000	**Bsh**-Bwh-Aw	Bsh	1984000
			Bs	**1984000**

Armenia	8400	**Cfa**	Cfa	8400
Bosnië & Herzegovina	114000	**Cfb**		
Kroatië	2400	**Cfb**		
Kosovo	19700	**Cfb**		
Servië	230000	**Cfb**		
Macedonië	650	**Cfb**	Cfb	366750
			Cf	**375150**

Syrië	433000	Bwh-Bsh-**Csa**		
Libanon	390000	**Csa**		
Palestina	160000	**Csa**		
Israël	n.b.	**Csa**		
Cyprus	201000	**Csa**		
Turkije	1201000	**Csa**-**Csb**-Aw	Csa	2385000
			Cs	**2385000**

Nepal	70000	**Cwa**-Cwb		
Myanmar	470000	**Cwa**-Aw-Am	Cwa	540000
			Cw	**540000**

Georgië	230000	**Dfb**-Cfb	Dfb	230000
Rusland	80000	Dfb-**Dfc**-Dfd-Dwc	Dfc	80000
			Df	**310000**

2. Shapes

Before choosing which shape is perfect for this tent, an overview of all possible tent shapes was produced. The inspiration comes from existing tents and other temporary structures. This collage shows different tent shapes.
The first shape is the inflateble tent. Strictly speaking, this isn't a shape but rather a structure type. The use of inflatable tents would make it possible to make a tent completely out of textiles, because no frame is needed. However, this requires high-tech solutions and the availability of an energy source. The shape is therefore unadequate for use in emergency situation.

Low-tech solutions have the advantage that they are in general cheap and easy to deploy. They are also durable and do not brake down very easy. If they do, they can be fixed with simple means. The most lowtech solution is to put a canvas over a pole. The tent is fixed by means of tent pins. To get a better ratio between tent surface and surface that is high enough to stand, additional poles can be added. Two easy solutions are the frame with two vertical poles, connected by one horizontal pole and the tent with one pole in the middle and a shorter pole in each corner. (see pictures 6, the white tent). All these tents are affordable, easy to deploy and durable. However, it does take several people to deploy them, because the poles have to be held in place until the tent pins are in place. On top of that, the need for tent pins can be a disadvantage in rocky areas. Another problem is the fact that the frame does not take full advantage of the characteristics of textile-based materials. These materials are flexible and have a high tensile strenght, whereas the poles of these tents are mainly pressed.

The type of tent that is most used nowadays, is the dome tent. Because the frame is built up from flexible arches, it is much lighter than the traditional tent. Also, the tent has some inherent stability which makes it easier to deploy. It is a low tech solution, which makes it cheap and easy to use. A problem can be repairing the tent. The poles are more fragile than poles of traditional tents. This tent is not rapidly deployable. The poles need to be attached to the canvas, which requires time and some experience.

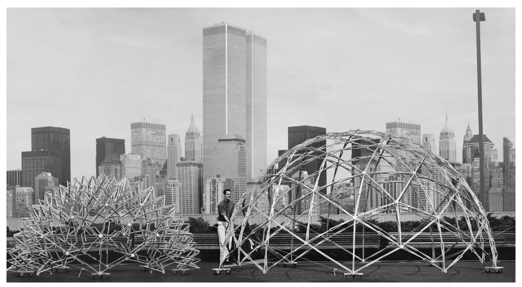
A tent that resembles the dome tent a lot, is the quecha foldable tent. This tent has a frame and the canvas integrated, which solves the problem of deploying it. As soon as the joints are released, the tent pops in shape automatically. This makes it one of the fastest possible solutions. However, the company that makes these tents, doesn't have any of these bigger than about 3x3 metres. They do have bigger tents, but they work like regular dome tents. We assume that this means it is not possible to make this structure strong enough for a big tent.

Hanging a tent on a tree branche would lead to a tent with only tensile forces in it. Two examples are shown. The first one is a triangle hanging from a branch and secured with tent pins. The second shape is a design by Dre Wapenaar. "The form for these tents naturally developed itself, when I hung a circular platform with a rope on the side of a tree. My inspiration for the shape was not the dewdrop. Form followed function." To make a tent with textiles only, this solution would be one of the most realistic, because no real frame is needed. However, in the case of an emergency











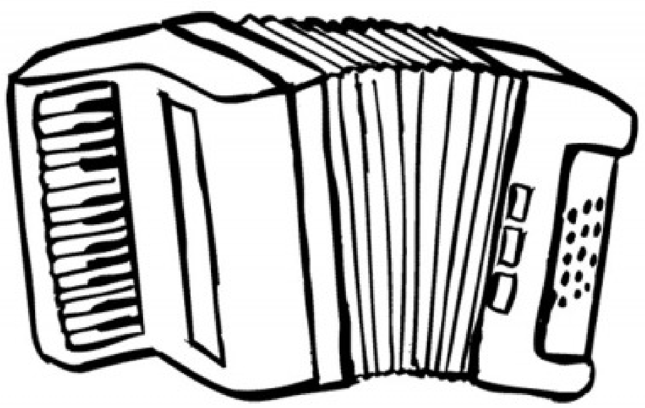
Picture 6: Different shapes

solution, there would never be enough trees to house all the homeless people, so it would not really work. Still, an interesting idea for other circumstances.
The Hobermansphere is a nice toy. The sphere can be pulled out and pressed back because of a special construction with many hinges. There are also bigger hoberman spheres that can be used as a dome. We are not the first ones that tought of making a tent with this principle. The inventor of the sphere has developed a tent with it. This tent is used for military purposes right now. Because of the relatively complex structure and the use of many hinges, it is not really suitable for an emergency situation.
The ‘harmonica’ is a bit like the dome tents, but with perpendicular poles, instead of crossing poles. This tent is very simple, thus affordable and durable and can be deployed very fast if the poles and the canvas are integrated. The shape also has a good ratio between floor space and space where it is possible to stand up straight. The picture shows a special example, with the poles not exactly vertical, but leaning over to form triangles. This makes the shape very stable.

In the table (Figure 7) the pros and cons of all possible shapes are mentioned. The dome and the harmonica are the best solutions. They are easy, their frames are based on tensile strenght, they can be deployed easily and it is also a strong and durable shape.

	Inflatable	Poles	foldable tent	dome tent	hanging on tree	water drop	hoberman	accordeon
low-tech	1	5	3	3	4	2	2	3
No resources available	1	5	5	5	3	3	5	5
Efficient shape	5	3	3	4	2	1	4	5
Small packaging	4	4	3	5	2	3	1	3
low weight	5	3	4	4	3	4	4	4
low cost	2	5	3	3	4	2	2	3
'foolproof'	3	5	5	4	2	3	5	5
fast deployable	5	2	5	3	3	3	4	4
size 17-22 m2	5	5	1	5	1	1	5	5
wind resistance	5	4	5	5	1	1	5	4
textile frame	5	1	5	5	5	5	2	5
strong	2	3	5	5	4	2	3	3
durable	1	4	3	3	4	3	3	3
possible without pegs	5	1	3	5	1	5	5	3
total	49	50	53	59	39	38	50	55

Picture 7: comparison between different shapes

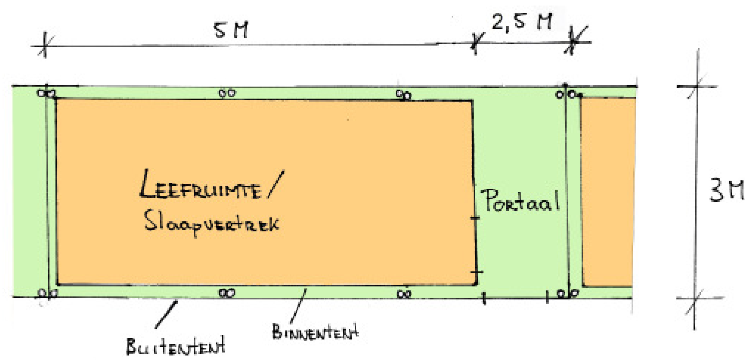


Picture 8

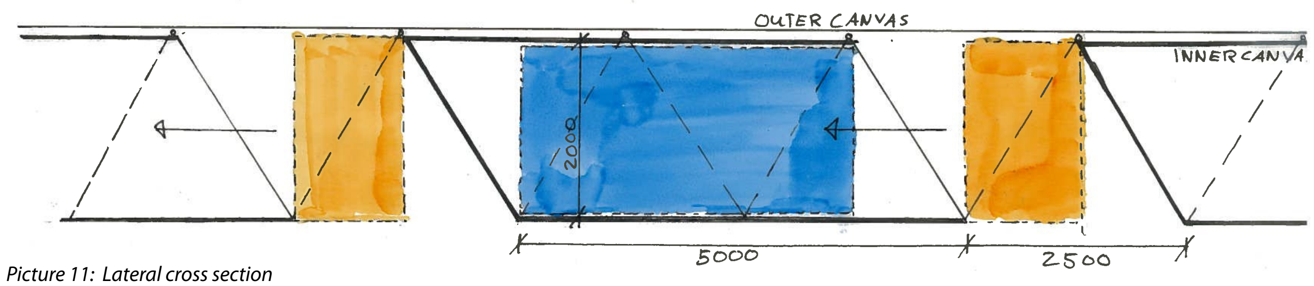
Picture 9: The design of an emergency tent by Dre Wapenaar

3. Concept

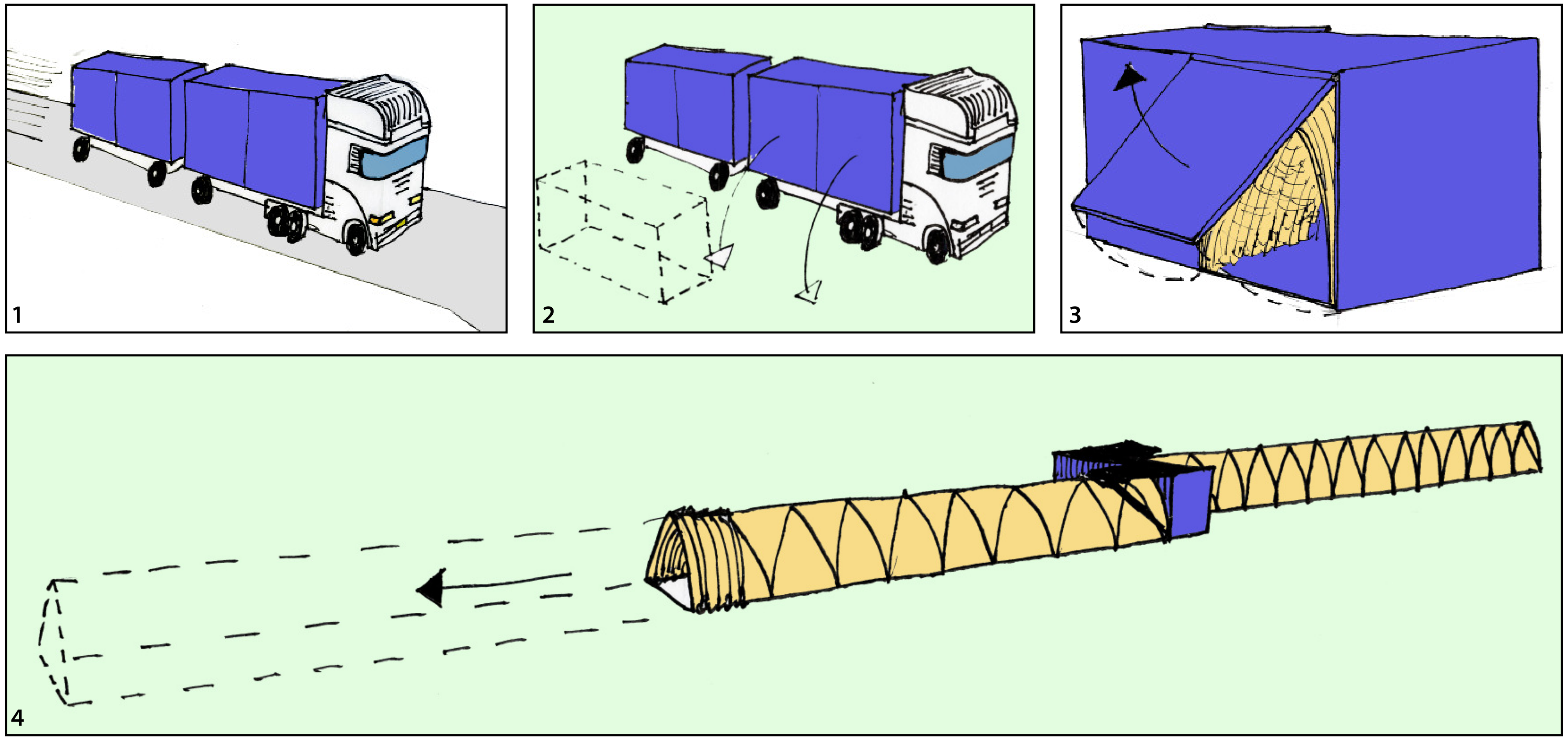
There is not really a limit to the maximum lenght of an accordion tent. It can be as long as you want. So why not making one very large tent for several families? The design does not focus on the level of one family, but on the scale of an 80 person community. One container provides them with everything they need, from tents to sanitation and food. This creates a small community within the larger refugee camp, providing people with a sense of safety and comfort. The long tent can be set up very quick and will be in the right shape immidiately. Only four tent pins are really needed to keep the tent in shape, the rest is for safety only. Every family gets about 18 m2, that is seperated from their neighboors by a textile partition. To prevent sound hindrance, an entrance area works as a buffer between the living areas. An inner tent hangs in the outer tent. There are twelve tents in each container, housing about 80 people.
When a disaster happens, containers are brought to the place by truck or by boat. They are deployed on site. The container is placed in the right spot. After that, the tent is pulled out and secured with tent pins and guy ropes. And that's it. People can now sleep in a dry and safe shelter.



Picture 10: Plan



Picture 11: Lateral cross section

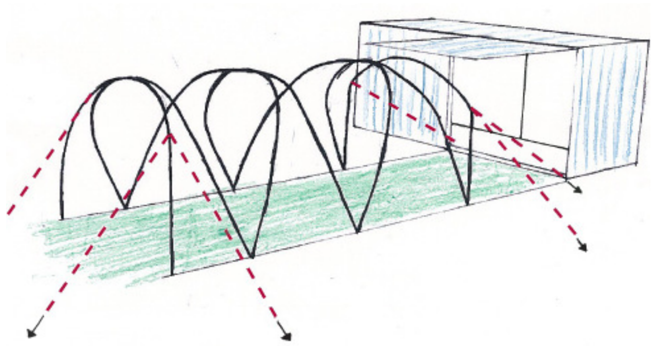


Picture 12: Transportation sequence; 1. The container is brought to the emergency area; 2. Unloading of the container; 3. The container is opens; 4. Tents are pulled out and immediately have the right shape.

4. Structural enginering

4.1 Frame structure

The framework of the tent is built up from prestressed arches, which are connected at the top and bottom. When they are built out of their container, the framework folds out like an accordion (picture 12). By making the framework arched, the frame can be prestressed, which makes it stiffer. A higher stiffness of the frame means it can resist higher wind loads. The climate type for which the tent is designed, isn't subjected to much rain or snowfall. Therefore, wind loadings are normative for determining the strength, stiffness and stability of the tent.

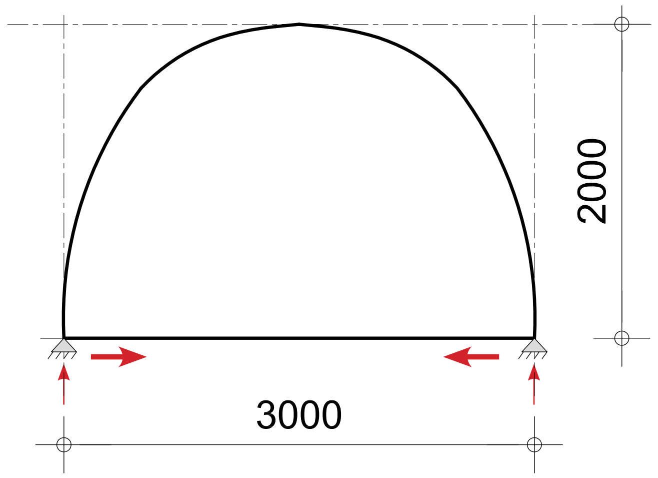


Picture 13 Structural principle

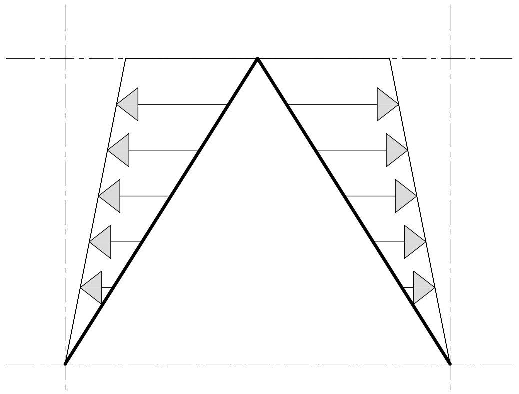
These three factors which determine whether the frame is structurally sound, are very dependent on the material which is used. This however, is an unknown factor in this phase of the design. Little is known about the structural behaviour of textile elements, or textile composites. Therefore, we will analyse and estimate the stability of the framework and where the largest forces will occur.

As explained before, the frame is build up from prestressed arches (Picture 13). The bottom of the arches are connected with each other by a textile strip. This causes the entire structure to be subjected to only tensile forces, and no pressure forces. This is beneficial for textile structures, since it strength is to absorb tensile forces and not pressure forces (Picture 14). In picture 14 a cross section of the frame is given with the red arrows as reaction forces. Obviously, the largest forces will occur at the bottom of the arch, where it's clamped. The strip which connects the outer ends of an arch has to be strong enough to resist these forces. Extra attention in detailing of the clamping at the bottom is necessary.

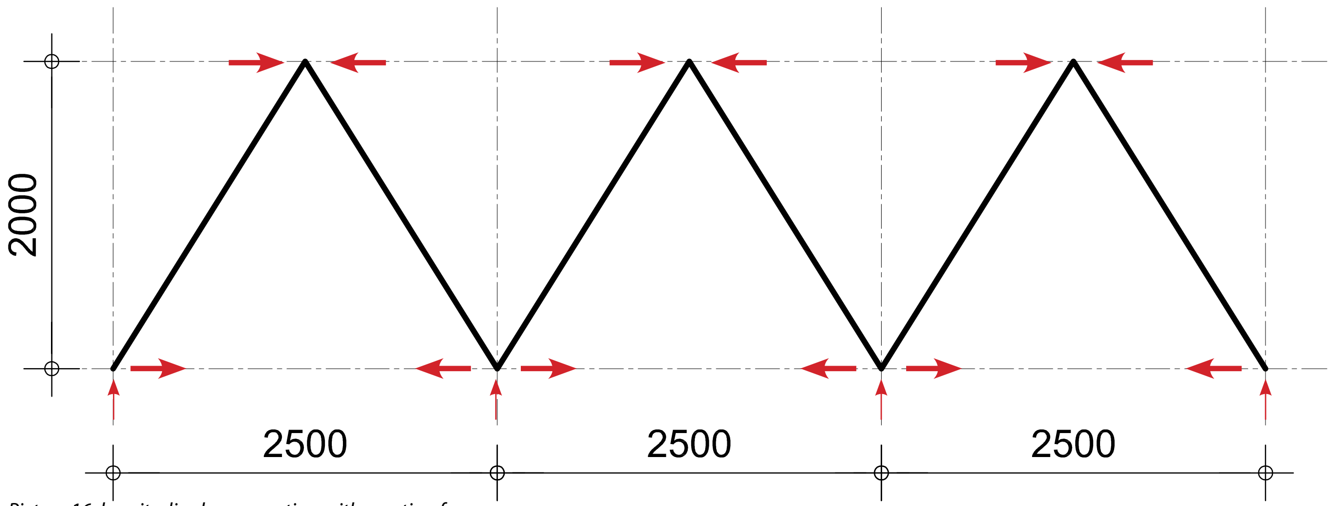
The outer canvas of the tent also has a structural purpose. Because the tents are fixed at the ends with guy ropes, the tension in the canvas keeps the frame at a fixed interval (2.5 meters). Therefore, the tensile strength of the canvas used should be strong enough to resist these forces. Also, large openings in the tent are purposely put in the triangles with their base at the bottom. Here, it's reason to expect that tensile forces in the canvas are significantly lower than in the top triangles. In fact, tensile forces in the canvas will



Picture 14: Cross section with reaction forces



Picture 15: Loading scheme



Picture 16: longitudinal cross-section with reaction forces

gradually increase form the bottom to the top of the tent. Therefore, openings in the tent are never in the top.

4.2 Stability

By folding the frame out like an accordion, the arches form triangles in the lateral direction of the tent (picture 16). There is already a stable form, if they were manufactured of a stiff material. However, the plane between the frames is made from a poly cotton fabric, which has virtually no stiffness. Additional bracing and guy ropes are therefore needed, to ensure the stability of the tents. In the lateral direction, one guy rope on each corner is sufficient to make the tents stable. This means only four ropes in total. In the transverse direction one guy rope at each corner of a tent should ensure stability.

To minimize wind loadings, the tents should be placed with the lateral direction facing the prevailing wind direction. This will significantly decrease wind loadings on the surface of the tents. However, it will also decrease the possible ventilation capacity. Further research should determine which option has the most benefits.

5. Material

Regular tent materials contain textiles. To decide which materials to use, first a normal tent is regarded. Than the material for the frame, the fabric and the connections are chosen.

5.1 Standard situation

Tents normally consist of a frame, an inner tent and an outer tent. The fabric can be made from different materials. Most used are cotton, polyester, nylon and polycotton. Cotton is the oldest material. It has been used for tents for decades and is still popular because cotton tents are cool in summer and the material 'breathes', so no condense problems occur. Also, cotton is a very durable material. On the other hand, it is a lot heavier than other fabrics. Polyester and nylon are both synthetic materials. They are very light, but cannot let vapor out, so the tent can become moist. Nylon stretches a lot, so a tent made from nylon will have to be stretched again after a shower. Polyester is a durable material, it can resist rotting best. However, cotton is better resistant to UV light and tearing. Polycotton combines the advantages of polyester with cotton. The material gives an adequate inner climate, without being too heavy.
The poles are usually made of glass fiber, carbon fiber or aluminium if the poles are bended and steel or aluminium if the poles are straight. Carbon fibres are expensive, and are not used that much. Aluminium is the strongest material, so the poles can be small with the same strenght as glass fibre poles that are twice as big. None of these materials can be made of textiles. However, we see right now that tents are either made from metal or from composites that are reinforces with some sort of fibre. Textile poles will probably be based on the second type.

5.2 Material choices

5.2.1 Textile based frame

To make a frame out of textile, it needs to be made stiff. This can be done in different ways. The French company Metisse collects old clothes and sorts them. The next step is to remove buttons and zippers and take the materials apart, so that fibres are left. This is the raw material. The fibres are then mixed with thermosetting plastics and heated and/or pressed. The temperature and the pressure make the difference between a blanket that is used for insulating and a stiff plate.

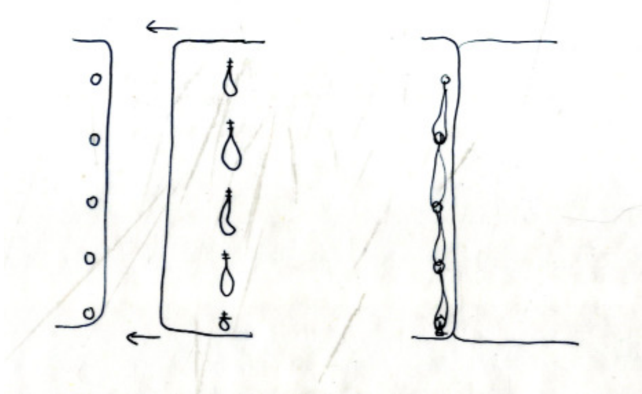
Another possibility is needle punching. Needlepunched nonwovens are created by mechanically orienting and interlocking the fibers of a spunbonded or carded web. This mechanical interlocking is achieved with thousands of barbed felting needles repeatedly passing into and out of the web. The resulting material is a kins of felt, that has many applications like tennis court surfaces, automotive carpeting and synthetic leather. Altough the material gets a lot more inflexible, it is not really stiff.
Both these processes result in panels. In theory however, every shape is possible. The least strong frame material, fiber glass, has a strenght of maximum 60 N/mm2. This is a low quality material. Because this design is big and has to resist storms, 60 N/mm2 probably isn't enough. Aluminium tents are much stronger. The aluminium used in tent frame has strenghts that are about ten times higher: over 600 N/mm2. Also the price is important. Glass fibres are the most cheap frame material, 5 euro per meter in camping shops for a pole with a thickness of 9,5 mm. Aluminium costs 10 euros per meter, if it has the same thickenss, but can be much slimmer. The price of the textile fibre has to be lower than the aluminium price, so maximum 10 euros per meter.

5.2.2 Tent fabric

For the fabric of the tents, polycotton is chosen. Table 18 shows why this material is preferred. Two types are used: a heavy fabric for the outer tent and a lighter and cheaper fabric for the inner tent. This material will have to be made from recycled fibres.

5.2.3 Connections

To close the doors, a simple, yet very durable connection is needed. Zippers are very vulnerable, and if they break down, it is not easy to repair them. Therefore, another connection method is chosen, using nooses of rope linking in each other. It costs a bit more time to close the tent, but it is almost impossible to break. Picture 17 illustrates the principle.



Picture 17: The doors close with this system

Material - Sheet :	Coton	Polycoton	Nylon	Polyester
Reliability	XXX	XXXX	XXX	XXX
UV resistance	XXX	XXX	XX	XX
Inside climate	XXXXX	XXXX	XX	XX
Water resistance	XXX	XXXX	XXX	XXXX
Rot resistance	XXX	XXXX	XXXX	XXXXX
Life span	XXX	XXXX	XXX	XXX
Cost	middle	middle	high	low
Σ	✗	✓	✗	✗

Picture 18: Table showing the characteristics of different fabrics

6. Indoor Climate

The Bwh climate is very hot, but it can be cold at night. First the cooling principles and ventilation measures are explained. Secondly, the heating principles will be explained.

6.1 Cooling

To protect the refugees against the heat, the most important contribution comes from ventilation. The ventilation is regulated by means of openings in the outer tent and a wire mesh in the inner tent. A small mesh size prevents bugs and mosquitoes from getting in the tent. Four small triangles in the top of the tent provide a minimal ventilation rate at all times. When more ventilation is wanted, two doors facing each other will be opened. Also, the lower part can be opened almost completely in the outer tent as well as the inner tent, so fresh air can enter from below. Together with the triangles, that are in the top, this will lead to a lot more ventilation. Picture 20 shows the situation with all openings open, so there is maximum ventilation.

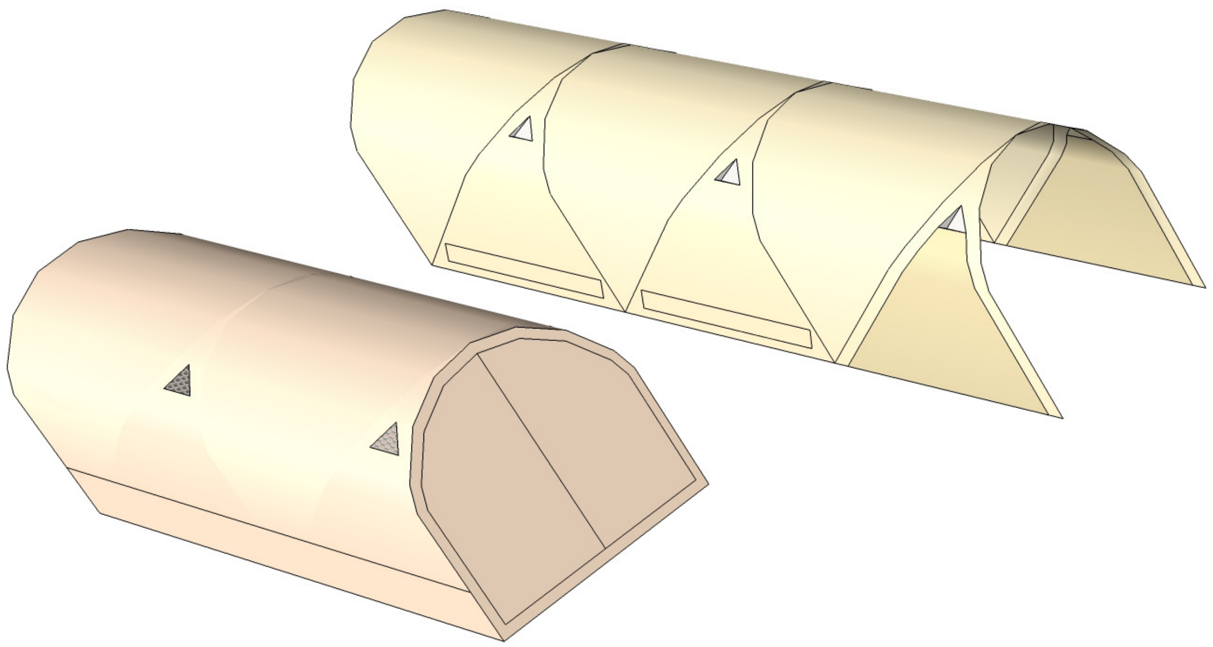
To increase the effect of this cross ventilation, the inner tent can also be removed completely, altough the protection against bugs and other animals would then be gone. It is also helpful to erect the tent in the right (wind) direction to catch as much wind as possible. The material of the fabric, polycotton, has good heat qualitities compared to sythetic fabrics: less condensation of air occurs and the indoor atmosphere is less muggy. Also the white fabric reflects a lot of sunlight.

6.2 Heating

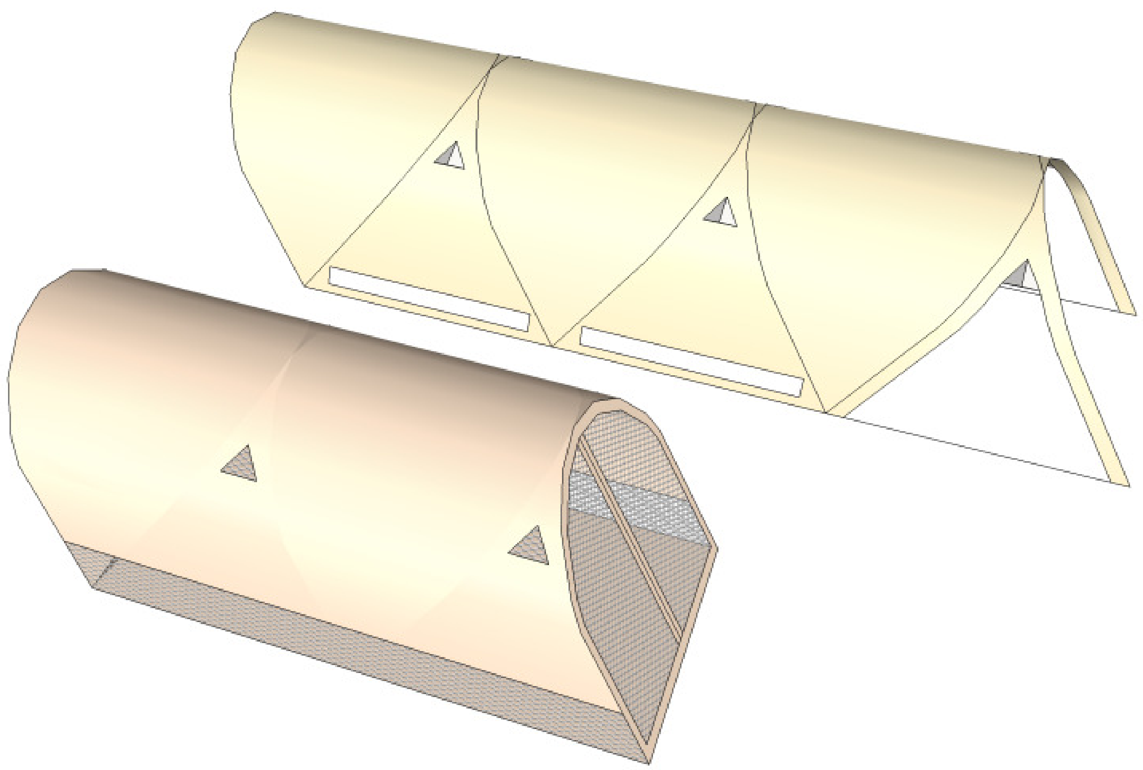
Altough it is not a very cold climate, on some clear nights a little bit of frost can occur. To protect the tent from this, the inner and outer tent form an insulation layer of air in between them. The metabolic rate of the refugees can also keep the tent warm during cold nights. Most ventilation openings can be closed to keep as much heat as possible inside. Picture 19 shows the closed situation, with only the minimal amount of ventilation. Still, infiltration in a tent can be quite large. The fabric can breathe, which means that some air can pass, though no wind gust can pass the material. The largest amount of infiltration is trough seams and openings. Good double seams and an air lock created by the inner tent and outer tent prevent this infiltration.

6.3 Ventilation requirements

According to the document 'Shelter in different climates', the ventilation rate should be 5.5 h^{-1}. This means that 12 liter per person per second is needed. It wasn't possible to really calculate if this requirement is met in the design. However, this design principles give an impression of how they will be met.



Picture 19: Winter situation



Picture 20: Summer situation

7. Price

The costs of an emergency relief tent are provided in the table on the right. At first, the cost of the materials for a single tent are determined. The costs of materials for one single emergency relief tent are **€ 362,25.**

After that the costs of a container with twelve tents as in the concept, is determined. Included are costs of production of the entire container with the twelve tents, such as for cutting and sewing, the material and the container itself. The cost of the overall container with tents is **€ 7271,80.**

The outcome of the costs divided by twelve will give the costs that one single tent including production cost. The price of one single emergency relief tent including material is **€ 605,98.**
As stated in the program of requirements, the UNHCR LWET emergency shelter costs approximately 210 euros. Per tent the difference is significant. However, our solution does not only provide a tent, it's a complete solution for an entire community. Besides the tents themselves, the container has room to store additional emergency supplies. In addition, the container can be used for several purposes during the user phase. These factors aren't included in the calculation shown on the right. Also, optimization and further research can bring down the cost price of this solution. These costs are estimated on basis of the production of the first tent. The costs will be lower if this emergency relief tent is taken into mass production.

The costs of transport from the Netherlands to an emergency location are **€ 1500,-** , of course depending on the exact location.

Costs per single tent

Description	Price (euro) per unit	number	total
Tent pole	€ 8,00 /m	34 m	€ 272,00
Polycotton outer tent	€ 6,25 /m2	42 m2	€ 262,50
Polycotton inner tent	€ 3,50 /m2	45 m2	€ 157,50
Muskito net	€ 4,50 /m2	1 m2	€ 4,50
PVC ground canvas	€ 1,00 /m2	18 m2	€ 18,00
Threat	€ 4,00 /km	0,5 km	€ 2,00
Guy ropes	€ 0,50 /m	12 m	€ 6,00
Accesoires guy rope	€ 0,30 /each rope	4 pcs	€ 1,20
Tent pins	€ 0,20 /each	8 pcs	€ 1,60
Total			€ 725,30
Cost price material (assumption: that is 50%)			**€ 362,65**

Costs per 12 tents

Description	Price (euro) per unit	number	total
Material 12 tents	€ 362,65 /pcs	12 pcs	€ 4.351,80
Container (second hand)	€ 1.000,00 /pcs	1 pcs	€ 1.000,00
Cutting and sewing	€ 160,00 /pcs	12 pcs	€ 1.920,00
Total production of 12 tents			**€ 7.271,80**
Cost price per single tent (incl. container & cutting and sewing)			**€ 605,98**

Transport costs

Description	Price (euro) per unit	number	total
transport Netherlands to Somalia	€ 1.500,00 /pcs	1 pcs	**€ 1.500,00**

Picture 21: Table of the calculation of the price

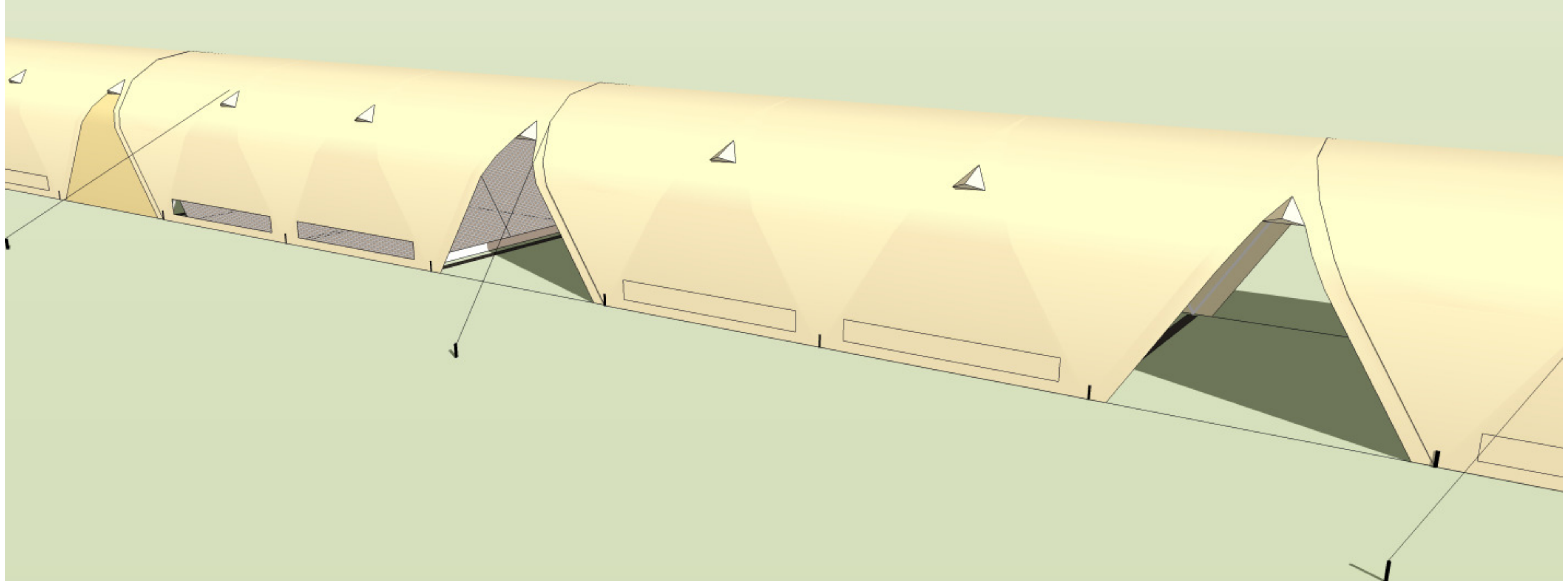
Conclusion

This design for an emergency shelter is made of recycled textiles. Instead of single tents, a whole row of tents is deployed at once, housing about 60 people. The same principle as an accordion is used. These tents meet the need for a destination for recycled textiles as well as the need for an emergency relief tent that is affordable, durable and rapid deployable.

The pictures on this page show the end result. The tent frame consists of the poles and the tensioning cables on the floor. The outer tent is attached to this frame directly and the inner tent via hooks and lines. In this way the two fabrics do not touch, so the tent remains water resistant. The guy ropes and tent pins are attached to make the tent better resistent to wind. In the inner tent are several wire meshes for ventilation and in the outer tent are opening for this purpose.

One disadvantage of this solution is that not so many tents fit in one container. The assumption is twelve tents. This might be fourteen of even sixteen, but it is not much anyway. On the other hand, in the container, not just the tents, but all emergency support for a group of people is provided. The medicines, food and sanitation materials can be stored in the leftover space of this round shape.

All in all, we think that this tent meets the criteria that were set in the program of requirements and that it is a truly new solution.



Literature

1. Sinclair, C; Stohr, K. 2006, *Design like you give a damn*, Thames & Hudson
2. Virgo, V. 2011, *Shelters in different climates*, MAS ASD
3. http://www.kampeerinfo.nl/informatie/0-0-26/tentmaterialen.html
4. http://www.kieskeurig.nl/tent/informatie
5. http://www.abc-van-hiking.nl/wandel-uitrusting/tent-materialen.asp
6. http://www.isolatiemetisse.nl/index.php/oorsprong-en-concept-alias
7. http://web.utk.edu/~mse/Textiles/Needle%20Punched%20Nonwovens.htm
8. http://www.trailspace.com/forums/gear-selection/topics/71754.html
9. http://www.diytrade.com/china/4/products/8219991/aluminium_tent_poles.html
10. http://www.kampeergoed.nl/boogstok-aluminium-pc-8848.html?cPath=71_295_331_2677
11. http://www.esvocampingshop.com/nl/tentdoek.html
12. http://www.balktrade.com/aanbiedingen/
13. http://www.higherlevel.nl/forum/index.php?board=44;action=display;threadid=12079