SPEEDKITS

DISASTER SHELTER 'CLEVER ROOF'

More and more disasters, either natural or man-made, occur worldwide. As a result, countless people are rendered homeless without any medical care, sufficient and clean water, decent sanitation or energy supply. In case of such an emergency, humanitarian organizations (like the Red Cross, Red Crescent Movement and Médecins Sans Frontières) send disaster relief items and skilled people to assist in rebuilding the affected sites. Such relief items usually consist of: water and sanitation requirements, nutrition, food, medical care and shelters. The focus of this paper will be on this last topic: sheltering.

Context

When looked to the emergency phase of a recovery intervention, the most used product by the humanitarian organizations are the tarpaulins (polyethylene sheeting of 4X6m). The versatility and low cost makes this product the default choice for many organizations. In the case of sheltering, this product is mostly distributed in addition with a shelter kit. Such a kit usually consists of some rope, a handsaw, nails, a shovel, a hoe, a machete, shears and a claw hammer. We can clearly see that structural components, to make a frame for the shelter, aren't included in the standard shelter package and need to be sent separately to the affected site. The set-up of a shelter is also done by the affected population itself and not by trained humanitarian officials. This makes that the know-how isn't on site, which can be detrimental for both the stability and the safety of the shelter (Fig. 1).

To clearly respond to an affected population it is better to have one shelter kit solution, with every component to erect the shelter in one package accompanied by a clear manual. To provide a better solution than currently existing shelter solutions, a new concept has been designed: the clever roof. The main function of this clever roof is to provide cover against heat and rain, so no necessity for walls. It will be the first shelter product arriving on site. Later this roof will be upgraded to a family shelter by adding walls and increasing the internal comfort of the shelter. To greatly reduce the fabrication cost of the clever roof, there has been decided to start with a flat piece of membrane which we give some pretension and small curvatures.

Figure 1. Shelters made of tarpaulins and 'collected' structural elements.

First prototype

The first prototype forms a simple saddle shape with two high and two low points (Fig. 2). The high points are supported by columns of 2,1m and the low with columns of 1,8m. The difference in length is only 30cm, which can only produce a slight double curvature. The structural part of the fabric is 4x4m. The type of membrane used is a PVC coated polyester fabric (260 g/m²) produced by Sioen. The orientation of the fabric is in such a way that the fiber directions are parallel to the sides of the fabric (from high to low point and from low to high point). The membrane is tensioned between 4 poles and 8 tie down ropes (Fig. 3 to 4). In this set-up the membrane acts in a peculiar way. The sides of the fabric are visually well tensioned while the middle of the fabric sacks under its self weight. The lines connecting the middle of opposite edges are not tensioned (no increase in length), while the sloped edges are stressed according to a non-negligible increase in length. A numerical calculation has been made to verify this experimental outcome. The numerical simulation has been made in the software EASY in the following way:

- The membrane is modeled as a cable net where each cable segment represents a strip out of the membrane parallel to the fiber directions
- To approximate the reality, no boundary cables are inserted
- In a first iteration a flat piece of membrane is modeled (Fig. 5)
- In the second iteration two opposite corner points are pulled upward and the other two corner points downward. Also a small component in the xy-plane is added to spread the membrane outwards (which also corresponds to the reality)
- The equilibrium shape is calculated by taking the following material properties into account: shear stiffness (10kN/m), crimp stiffness (70kN/m), Young modulus in both directions (210kN/m)

The material parameters don't correspond with the material properties of the actual model, but these numerical tests are simply to get a global view on the stress distribution in the membrane and visualize the stresses.

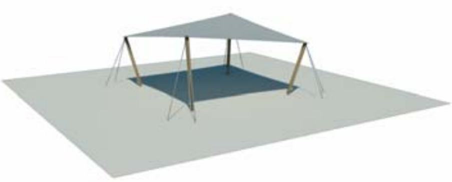
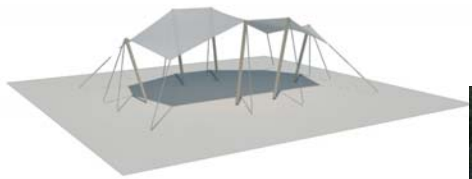


Figure 2. Prototype 1 forms a saddle shape with two high and two low points

Figure 3 to 4. Connection details

Figure 5. numerical model - software EASY



In terms of stress distribution in the numerical model, the same conclusion can be made as in the experimental model. The four sides are tensioned while the middle of the membrane isn't (Fig. 6).

Second prototype

In the second prototype the positions of high and low points have been changed. The main idea is to use the membrane more optimal in terms of fiber orientation. The best way is to align the fiber direction with the direction of main curvatures. This principle has been tried out in the following model (Fig. 7).
The set-up of this experimental model is the same as before. The difference is in the size of the cover and the position of high and low points. The membrane has a span of 4x6m (instead of the 4x4m) and is also made of PVC-coated polyester fabric (260g/m²). Two high points with a height of 2m are positioned in the middle of both 6m sides. The four corners and the middle of the 4m sides are the low points with a height of 1.6m. The main principle curvatures are now in the direction of the fibers (from high to high point and from low to low point). Visually a more uniform tension in the membrane can be attained. However, further numerical investigation should quantify this increase in tension. The numerical model of the second prototype is constructed in the same manner as before. Because of the new boundary conditions posed on the membrane we can clearly distinguish a more optimized stress distribution in the fabric. In comparison with previous prototype this model has the possibility to be tensioned more uniformly. However, there is still a large stress difference between the middle fabric and the corners (Fig. 8). This last prototype has been tested in Sag-nioniogo camp in Burkina Faso close by

Figure 7. Prototype 2 - in search to optimise tensioning

Ouagadou- gou (Mali refugees). The field test was made possible by the Luxembourg Red Cross. The following pictures show the different steps for set-up. The first is a simple clever roof. The second and third are a family shelter where the latter is more optimized in terms of internal climate, for example by adding a shade net (Fig. 9). Future research should further investigate the feasibility of the clever roof. One of the first steps will be to test this prototype under loading and look for appropriate and easy solutions to reinforce the structure.
However, the initial concept of the shelter should always be kept in mind. In the end, we want to realize a shelter solution which is structurally withstanding but is cheap and minimal at the same time, is a lightweight solution but is also stable and stiff, with a simple and straightforward in set-up using a minimum of different elements in one shelter package, … Eventually, it is a very complex matter where several contra dictionary parameters play an important role in the design process of a - at first hand - simple shelter.
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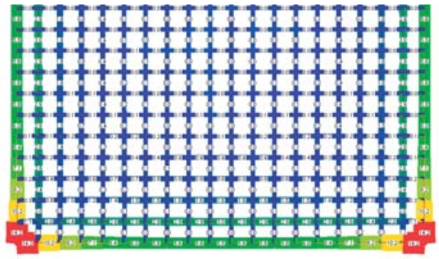

Figure 6: dz=+20/-20cm;dxdy=0cm

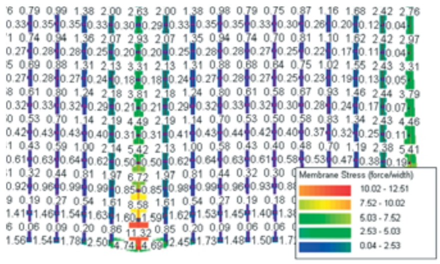

Figure 8. >
2 points long sides dx,dy,dz 2cm, 1cm, +15cm, midpoints short sides dy,dz 5cm, -20cm, corners dx,dy,dz 2cm, 5cm, -15cm

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Figure 9. Testing of prototype 2 on location, refugee camp Burkina Faso