TensiNews

Newsletter Nr. 30
April 2016
published twice a year
price €15 (post incl)
www.tensinet.com

Newsletter of the European based Network for the Design and Realisation of Tensile Structures

RESEARCH

PROJECT SPEEDKITS FIELD TEST

MULTITEXCO SMART MULTIFUNCTIONAL TECHNICAL TEXTILES

REPORT

STRUCTURAL MEMBRANES 2015

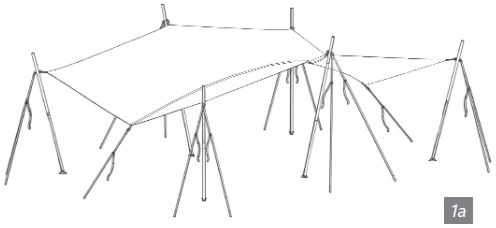
PROJECTS

TRAFFIC HUB IN CALIFORNIA

BUILDING SHELL MADE OF ETFE CUSHIONS

SPEEDKITS: Clever Roof set-up in Senegal © Vincent Virgo / Guy Buyle ▲
The exterior shell of the three-storey ARTIC building © John Linden ►

PROJECT SPEEDKITS!


1a

Context

Humanitarian organizations use a large variety of emergency kits to support an affected population after a disaster. These kits should be able to be deployed immediately after a disaster has stricken and provide all basic needs such as medical care, clean and sufficient drinking water, proper sanitation, energy supply, shelters, etc. The European project S(P)EEDKITS, which started in 2012, developed several emergency kits which emphasises the SPEED of the kit solutions and the possibility to act as a SEED to rebuild the affected environment, to allow fast and early reconstruction and to reduce as much as possible the temporary or transitional phase. The project started by investigating the Red Cross's Emergency Items Catalogue and obtaining the feedback from field experts from different humanitarian organizations. This will highlighted the strength and shortcomings of currently used solutions and allowed to define the field of possible research. Secondly, complementary features and new concepts were developed to drastically reduce the volume and weight for transportation, and to improve their performance. All European partners (Italy, Belgium, Netherlands, Luxembourg, Norway and Germany) worked on the following topics:

- Improving the supply chain in terms of logistic - and transport parameters and dedicating sufficient research on standardized packaging systems with 3 harmonized scales (bag-europallet-20ft container)
- The development of 4 adequate shelter types which can cover the 4 elementary needs based on family and community requirements
- The cleaning and purification of water which provides sustainable access to safe drinking water and basic sanitation
- Developing new infrastructure systems which includes medical, energy and re-building solutions
- Improving supporting tools which are able to assess, monitor and evaluate future deployments

The S(P)EEDKITS designs are to be deployed in an affected city, a spontaneous or planned camp or a scattered rural region, in order to support the transformation of the 'temporary' post-disaster situation towards the rebuilding of economic and social life.

The Clever roof + Cocoon

This article will solely focus on one novel shelter solution developed in the framework of the S(P)EEDKITS project: the Clever roof + Cocoon. The Architectural Engineering Department of the Vrije Universiteit Brussel (VUB), the Architecture - Built environment and Construction Engineering Department of the Politecnico di Milano (POLIMI), the Belgian Textile Research Centre Centexbel, the membrane manufacturer Sioen Industries and the International Federation of Red Cross and Red Crescent Societies (Shelter Research Unit) worked together to develop this innovative shelter solution. The kit composes of a 'Clever Roof' which is a mechanically stressed membrane and a 'Cocoon' which is a perfectly waterproof, insulated chamber.

The Clever roof shelter kit provides a shelter solution which consists of a PVC coated polyester fabric, structural elements, connectors, pegs, belts, a hammer and a clear manual. The basic function of this Clever Roof kit is to provide cover (24m²) against heat and rain. It is not only a fast solution able to meet the basic needs during an emergency phase but also a cover having a longer lifetime than the existing products to ensure a long use or even better be part of a reconstruction process as a first element. This ensuring that reconstruction phase after disaster begins at day 0 just after distribution. Because of its straightforward design, the shelter can be deployed by the affected population themselves. The total package of the Clever roof only weights 30kg and is provided in an easy to carry bag to facilitate the transportation on site (Fig. 1). The total volume and weight of the package is minimized to reduce the cost needed for transportation. The shelter itself can be erected by two persons in a time span of 15min. The


1b


1c

Figure 1. a: Slightly double curved 'Clever Roof' b and c: Different configurations

clear manual ensures that non-experts are able to correctly set-up the shelter solution. The main research question for these shelter solutions was to properly tension a flat piece of membrane. The classic use of cutting patterns for tensioned textile surfaces has been neglected for this particular case to reduce the fabrication cost of the product. The membrane is manually tensioned between a set of high and low boundary points in order to create a cover with a slight double curvature and a basic pretension (Fig. 1a).

Most currently used shelter solutions lack versatility in shape (tent solutions) or do not provide sufficient materials or knowledge on site to built a safe shelter. The Clever roof shelter kit is a new shelter solution not existing on the current humanitarian market, which provides a versatile product that can be used for several functions. Different shapes are

2a


2b

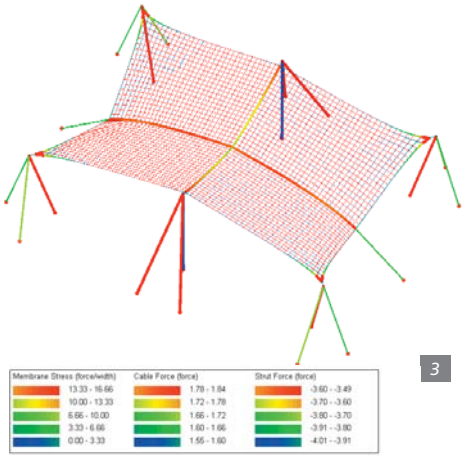
Figure 2: Insulated Cocoon

obtainable with the same set of components to provide an adequate solution for different cultural needs and to guarantee a good rain/sun protection (Fig. 1b and 1c).
In a first stage, the 'Clever Roof' has no walls and solely provides protection against heat and rain. In a second stage, walls can be added to make a closed family shelter. These walls can be made by connecting standard tarps to the structural Clever Roof or by using an insulated Cocoon (Fig. 2).

The cocoon is an insulated room which can be hung underneath the Clever roof using the same structure. All walls, roof and floor of the cocoon are fabricated from a nonwoven material which insulates the closed box. The walls and roof of the cocoon consists of the now woven material with a layer of PVC coated polyester at one side to assure decent water tightness. The ground sheet of the cocoon consists of a non woven material which has a layer of PVC coated polyester at both sides. Two windows guarantee a decent cross-ventilation of the inner volume. The cocoon can also be used separately without the Clever roof as partitioning element in a temporary settlement inside large public buildings. The total weight of the cocoon is also 30kg which facilitates the transportation on site. The placement of the Cocoon underneath the Clever roof still provides a covered outside area which can be used for cooking and daily social activities.

Clever roof analysis

The researchers at the Architectural Engineering Department of the Vrije Universiteit Brussel (VUB) investigated experimentally and numerically the structural behaviour of the Clever Roof (Fig. 3). The analysis had to verify that tensioning a flat piece of membrane provides enough curvature and tension to create a structurally safe cover. In a first step the material properties of membrane, struts and belts were defined.



3

The next step was the form finding of the Clever Roof. This means that a flat tarp of 4m by 6m was tensioned in a slightly anticlastic configuration by elevating the corner points and pre-tensioning the tie-down cables. Further improvement of the numerical model was needed as the stress concentrations at the membrane connections were very high and did not represent the real situation. In reality, the connection is a belt loop stitched onto the membrane, transmitting the force more smoothly into the membrane. Therefore, the numerical model is adapted by adding 2 links at the connections which represents these belt loops (Fig. 4).

Step 3 defines the load cases and the load combinations: self-weight and wind load (longitudinal direction versus transversal, uplift versus pressure, symmetrical versus asymmetrical). The analysis has shown that the two symmetric load cases, with wind in the longitudinal direction, are most critical for this form-active membrane shelter. Therefore, these two load cases were considered in the Limit State Designs (SLS and ULS). The last step demonstrates the Service Limit State and Ultimate Limit State (Longitudinal wind down and wind up, symmetric loading). The real dynamic behaviour of the membrane structure will not be as dramatic as shown by this static calculation (Fig. 5). However, as a result of the limited pre-tension in the membrane, the structure will deform significantly under the dynamic wind actions. For these highly flexible membrane structures the deformations under extensive wind load calculations (with a detailed distribution pattern of wind loads) are about 30% larger compared to the simplified uniform wind load distribution.

The Clever Roof is adequately dimensioned to withstand the Ultimate Limit State design:

- Membrane: taking into account the simplifications in the design model (approximation by a cable net) lower values and a better distribution of the stresses at the connections are expected. To provide resistance to the stress concentrations, it is proposed to apply multiple layers of membrane at the connection zones, or to implement a high strength membrane locally.
- Struts: the buckling resistance is never reached.
- Tie-down belts: the tensile strength of the belts is almost twice the maximum occurring force.

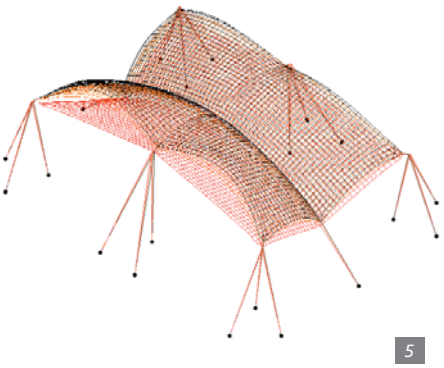

5

Figure 3. Isometry of the basis configuration of the Clever Roof
Figure 5. Deflection under longitudinal upward wind loading

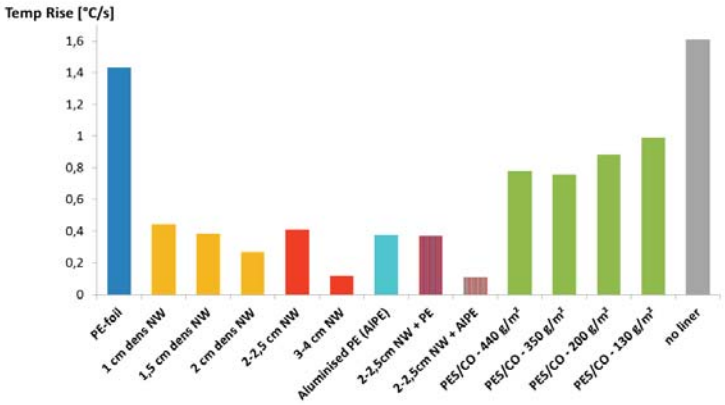

4a


4b

Figure 4: Connection in the test set-up

Membrane material development

To optimise comfort and life span, the materials of the innovative shelter were very precisely chosen and developed. The Clever Roof is made of a coated textile which is 100% waterproof. Ordinary tarps lose their water repellent quality due to UV deterioration. The selected advanced materials are already used for technical applications but were until now never used for emergency housing. Compared with the ordinary tarps (which have a lifespan of about 1 year) these coated fabrics have a life span which is more than 10 times higher. The Cocoon is made of a special developed layered fabric combining coated textiles and a nonwoven layer. The nonwoven material is already used as thermal insulation in the traditional housing industry.
At Centexbel several types of nonwovens (different thicknesses and densities) were evaluated for their thermal behaviour, and



Graph 1. Evaluation of the insulating performance of the cladding materials (radiant panel test)

compared with the currently used polyester/cotton tent fabrics. This laminate really outperforms the currently used cladding materials as can be seen in graph 1.

Prototypes

Several prototypes were manufactured, tested, evaluated and further optimised. All membrane materials were produced and developed by SIOEN Industries in collaboration with the Belgian Textile Research Centre CENTEXBEL. The Architectural Engineering Department of the Vrije Universiteit Brussel together with the Architecture, Built environment and Construction Engineering Department of the Politecnico di Milano performed the design and the structural calculation for both 'Clever roof' and 'Cocoon'. The field experience of the Shelter Research Unit was crucial in the whole process to assure the practical relevance of the designed shelters. The latest prototype of the innovative shelter (Fig. 6) was demonstrated at the Médecins Sans Frontières site in Belgium during the AidEx fair (November 2015) and is tested on site in Senegal since December 2015. The first results after 2 months are extremely good and the beneficiary feedbacks are really promising.

Senegal field test

To demonstrate the relevance and the efficiency of the designed product, there has been decided in close collaboration with Luxemburgish Red Cross, to ship mockups to a small fisherman's village near the Mauritanian border in Senegal (Fig. 7). The beneficiaries (20 families) evaluated and tested the sent products on their usability, set-up time and effectiveness. In total 20 'Clever roofs' and 10 'Cocoons' have been sent to the site. The beneficiaries are frequently affected by floods where they lose their homes (due to erosion of the walls). This background provides the ideal circumstances to test our newly developed product. Packaging, ease of transport, assembling time and satisfaction level have been measured through means of questionnaires. In parallel the internal climate of the shelter solutions have been measured with temperature/humidity loggers. The first feedbacks are excessively positive and the Red Cross delegates are really glad to daily observe the efficiency of the intervention.

Acknowledgement

S(P)EEDKITS received funding from the European Commission's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 284931.
Read more about the project at
http://www.speedkits.eu/.

Guy Buyle (guy.buyle@centexbel.be)
Ine De Vilder (Ine.DeVilder@centexbel.be)
Pieter Heyse (Pieter.Heyse@centexbel.be)
www.centexbel.be

Marijke Mollaert (Marijke.Mollaert@vub.ac.be)
Jan Roekens (jroekens@vub.ac.be)
Jimmy Colliers (jimmy.colliers@vub.ac.be)
Lars De Laet (lars.de.laet@vub.ac.be)
Evi Corne (Evi.Corne@vub.ac.be)
www.vub.ac.be/ARCH/ae-lab/lightweight

Alessandra Zanelli (alessandra.zanelli@polimi.it)
Salvatore Viscuso (salvatore.viscuso@polimi.it)
Marta Barozzi (marta.barozzi@mail.polimi.it)
www.polimi.it

Vincent Virgo (Vincent.Virgo@croix-rouge.lu)
www.croix-rouge.lu/presentation-du-sru/

Bert Groenendaal (Bert.Groenendaal@sioen.be)
www.sioen.com/technical-textiles/eu-calls

REFERENCE

[1] http://procurement.ifrc.org/catalogue/detail.aspx?volume=1&groupcode=111&familycode=111001&categorycode=SHEK&productcode=KRELSHEK02

Figure 6. Prototype of the Clever roof installed during the AidEx fair
Figure 7. The Clever Roof set-up in Senegal (© Vincent Virgo / Guy Buyle)