MEMBRANES FOR SHELTERS

a comparative study to assist humanitarian workers in selecting suitable textile materials
This manual is part of a series of practical guidelines composed by the S(P)EEDKITS partners and based on test results from laboratory and field assessments.

The S(P)EEDKITS manuals:

1. Materials for Shade Nets
2. Fixings used for Shelters made from Flexible Fabrics and Rope Tensioners
3. Membranes for Shelters

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Tents are used in a wide variety of situations. Next to the tent structures commonly deployed by NGO’s, tents are popular shelter solutions at many different outdoor events. They are often used as temporary housing or for recreational or military purposes, as storage facilities, etc. This large range of applications results in all kinds of tent sizes and shapes and in a series of different membrane materials. Also in the humanitarian sector, different tent sizes are applied according to the sphere standards, including sizes of 17.5m² (family tent), 17.5m² - 50 m² (multipurpose tent) and > 50m² (warehouse tent). Each type has its own material specifications.

Based on the state-of-the-art of all sorts of tents used in different kinds of applications, the following subdivision can be made:

- < 6 m² tents are typically made from ultra-light weight membrane materials such as coated nylon and mostly used in the camping sector
- 6 - 50 m² tents are typically made from polycotton-based membrane materials
- > 50 m² tents, such as event tents, warehouse and military tents are mostly made from PVC coated polyester material (PVC/PES)

Because of the large variety of materials, people who are less familiar with textile materials may have problems to see the wood for the trees. As a consequence, less appropriate materials may be selected and used in the field. Sometimes tent fabrics and tarpaulins may encounter problems because the materials are not well adapted to the circumstances they are used in. It is for example not uncommon that a tarpaulin that is designed to last two years, has already lost its strength after only 3 months of use in a sunny climate. It happens that polycotton tents are stored in a moist and hot environment and are already degraded due to fungi growth before they are actually used.

The aim of this study is to compare the currently used tent materials in emergency situations with commonly used tent materials in other application fields.

Depending on the envisioned life span, climatic conditions and use different materials can be an option. This study is a guidance for the selection of the proper shelter material.
TEXTILE TERMINOLOGY

WARP AND WEFT
In weaving, weft (1) is the thread or yarn which is drawn through the warp (2) yarns to create a fabric. Warp is the lengthwise or longitudinal thread in a roll, while weft is the transverse thread.

TEXTILE COATING is the process of depositing one or more layers on top of a textile fabric. The layers are applied as pastes and then dried. E.g. PVC coated Polyester is made by this technique. Another coating technique is applying and spreading a molten polymer (e.g. PE) over the fabric that is then cooled down. PE sheets are produced by the latter technique.
By mixing chemicals into the paste, the desired properties (flame retardancy, antimicrobial...) are added to the fabric. A coating layer is also used to make a fabric waterproof.

A LAMINATED TEXTILE is a fabric which comprises two or more substrates glued together. Many waterproof breathable fabrics are made by laminating a textile to a film or a membrane.
This technique differs from coating in this way that it departs from two (or more) prefabricated substrates, being fabrics, foils, membranes... whereas a coating is realised by spreading a viscous material over a single fabric surface.

TEXTILE FINISHING aka IMPREGNATION or PADDING
The fabric is submerged in a liquid/dispersion containing the chemicals that will confer the desired properties (such as flame retardancy, antimicrobial...). After squeezing, the fabric is dried. The chemicals are on the individual yarns. Contrary to coating or laminating, no full layer covers the fabric, so the breathability is preserved. In most cases, the finishing is not or hardly visible.
BACKGROUND ON TESTING

The specific textile properties of different fabrics are tested in the laboratory. This allows to make a ranking of each characteristic depending on their performances. It will also indicate which materials meet a specific requirement. In general, most humanitarian organisations specify their own requirements (limit values) for each property. For practical reasons, the limit values are not included in this booklet, for they may differ according to the type of tent and intended use of the material (inner or outer tent, tent roof, wall, floor).

The lab testing is related to specific fabric properties. It does not provide any conclusive information on how they are to be used in a complete tent setting. Therefore, an outdoor testing was performed to evaluate the influence of the cladding material on the internal climate in a whole tent.

TESTED MATERIALS

Different tent fabrics were evaluated and compared in respect of a number of properties.

Polycotton tents

The so-called “polycotton” tent fabrics (a 50-50 blend of polyester (PES) and cotton (CO)) are commonly used in emergency situations:

- **Polycotton 200**: PES/CO of 200 g/m² - white - wall of the family tent
- **Polycotton 350**: PES/CO of 350 g/m² - white - roof of the family tent and wall of the multi-purpose tent
- **Polycotton 440**: PES/CO of 440 g/m² - white - roof of the multi-purpose tent and dispensary tent

Tarpaulin

- **PE-sheet 165**: PE (polyethylene) sheet of 165 g/m² - light grey

PVC coated polyester (PVC/PES) tents

- **PVC/PES 240**: PVC/PES of 240 g/m² - light grey
- **PVC/PES 340**: PVC/PES of 340 g/m² - white
- **PVC/PES 450**: PVC/PES of 450 g/m² - light grey

The selected weights correspond with the polycotton qualities.

A higher quality flame retardant PVC/PES

- **PVC/PES 650**: PVC/PES of 650 g/m² - white - comparable with the qualities used in storage tents, e.g. Rubb or O.B. Wiik halls

Two standard commercially available camping tent materials

- **Sil/PA 53**: A siliconised polyamide (Sil/PA) of 53 g/m² - dark green
  [product reference: Vaude Hogan Ultralight Argon 1-2p]
- **PU/PES 55**: A polyester, coated with polyurethane (PU/PES) of 55 g/m² - black
  [product reference: Easy Camp Tipi]
LAB TESTING

Tent materials used by humanitarian organisations need to comply with the requirements defined by the NGO’s. The fabric properties that have been evaluated in this study include tensile and tear strength, water vapour permeability, waterproofness and resistance to UV-light and micro-organisms (soil burial).

Some additional properties such as air permeability, heat and light opacity have also been evaluated for they may have an impact on the indoor comfort. Because fire safety is crucial in a camp setting, the burning behaviour of the fabrics has also been assessed.

OUTDOOR TESTING

In the Netherlands, three multipurpose tents were set up with the same structure but with different cladding materials:

1. original polycotton (PES/CO) cover (440 g/m²)
2. PE cover assembled from commonly used tarpaulins or PE sheeting (180 g/m²)
3. PVC/PES cover, with ‘drop stop’ coating (440 g/m²)

The setup is a simulation of a hospital ward (6 m by 7.5 m) accommodating 15 people. The presence of 15 persons was mimicked by a heating device and humidifiers.

The thermal performance, day light intensity and ventilation rate were monitored over a 2 months’ period during summer and autumn with a very large variations in climatological conditions (excessive rain, heavy winds, big differences in temperature...).

Afterwards, the tents have been mounted in Luxembourg to monitor the long-term performances. The results are represented on page 23 of this booklet.
TENT MATERIAL CHARACTERISATION

1 - Tear strength

The tear strength is determined according to ISO 9073-4 (Textiles - Test methods for nonwovens - Part 4: Determination of tear resistance), both in machine (warp) and cross (weft) direction.

MAIN FINDINGS

• Camping tents have a low tear strength.
• The currently used polycottons show big differences in tear strength depending on the direction of pulling. PVC coated polyester has a similar tear strength in both directions.
• The higher weight PVC coated PES is the strongest quality and its tear strength is uniform in warp and weft.

A striking difference in tear strength was observed between the warp and weft direction of the higher weight polycottons. In both cases the warp direction is remarkably stronger.

PVC coated PES with the same weight as the polycottons has a somewhat lower tear strength, but is uniform in both directions, the latter being an important property for practical use (wind load, snow load, etc.).

When a material is used with a different warp and weft strength, one should pay attention that the fabric is tensioned along the strongest direction to avoid that the cladding is torn.
2 - Tensile strength and elongation

The tensile strength and elongation are determined according to ISO 13934-1 (Textiles - Tensile properties of fabrics - Part 2: Determination of maximum force using the grab method).

Within a same fabric type, the heavier qualities are usually stronger than the lower weight ones. The standard light weight camping materials lack the necessary strength to be used for large tent constructions.

Although elongation is not a requirement according to the 'emergency items catalogue' used by humanitarian agencies, it is an interesting parameter to understand the behaviour of a tent fabric.

The elongation of the polycotton tents in warp direction is twice as big as in the weft direction.

The siliconised PA tent has the largest elongation properties. Nevertheless, none of the tested tent fabrics are very stretchable.

When the fabric is tensioned along the direction with the highest elongation, the cladding of the structure will be subject to deformation.

**MAINT FINDINGS**

- Camping tents have a low tensile strength.
- The currently used polycotton show big differences in tensile strength depending on the pulling direction; also the elongation differs from one direction to the other.
- Higher weight PVC coated PES are the strongest and the tensile strength is uniform in both directions.
3 - Air permeability

In order to create a comfortable climate inside the tent in hot climates or in summertimes, it is important that the air penetrates through the fabric or that ventilation options are integrated in the tent design. Moreover, air permeability/ventilation prevents accumulation of CO and CO$_2$ in the inner tent during cold periods, although excessive heat loss has to be avoided.

The air permeability of the fabrics is evaluated according to ISO 9237 (Textiles - Determination of the permeability of fabrics to air).

Only the polycottons are permeable to air (see table below). The thickness of the fabric also plays an important role: the permeability of the thicker fabrics drops significantly.

No requirements are set for this property. However it is recommended to have a minimum ventilation rate of 2.5 l/s per person inside a family tent and of about 5 l/s per person in a classroom tent$^1$.

1 ANSI/ASHRAE standards 62.1 - 2007 - Ventilation for acceptable indoor air quality

Air permeability tent fabrics – expressed in l/(m$^2$.s)

In general, one may state that coatings have a negative influence on the air permeability of the fabric, in as far as the coated fabrics are no longer breathable. When using coated materials, the tent structure must be ventilated to create a ‘breathable’ atmosphere.

**MAIN FINDINGS**

- Polycotton is the only fabric that is permeable to air.
- The heavier polycottons are significantly less permeable to air.
- The coated materials included in the test are not permeable to air; ventilation of the shelter is therefore recommended.
- Outdoor testing has shown that the breathability of the polycottons lowers the CO$_2$ levels inside. Well-positioned small ventilation openings in PVC/PES and PE cladded tents will lead to similar results.
4 - Water vapour permeability

A person at rest produces approximately 50 g/h of water vapour through respiration and transpiration, resulting in the accumulation of a lot of moisture inside a shelter. Water dripping from the inner tent roof as a result of water vapour condensation is highly undesired, as is the water penetration from outside to the inside of the tent. The ideal material solution is a waterproof and at the same time water vapour permeable textile. Unfortunately, these textiles are expensive.

The water vapour permeability is determined according to ASTM E96 (Standard Test Methods for Water Vapour Transmission of Materials). The polycotton tents are the most permeable; the PVC and PE coated fabrics are almost not permeable. This can be solved by incorporating appropriate ventilation in the tent structure.

According to the “emergency items catalogues”, the fabrics used in the family, dispensary and multipurpose tents should comply with a water vapour permeability of at least 2000 g/(24h.m²).

However, not even the tested materials that are used by the humanitarian organisations today, comply with these specifications. Therefore, the tents must be submitted to a more severe assessment at the moment they are purchased and/or the specifications are too severe and should be lowered.

**MAIN FINDINGS**

- Polycotton is the only material which shows significant water vapour permeability.
- None of the tested polycotton fabrics met the requirement of 2000 g/m²/24h. A thorough check of the supplied quality is advised.
- Outdoor testing in the Netherlands showed less condensation in the polycotton tent compared to the PE and PVC/PES tents.
5 - Waterproofness

The waterproofness is evaluated according to EN 20811 (Textile fabrics - Determination of resistance to water penetration - Hydrostatic pressure test).

All PVC coated PES fabrics are completely waterproof.
The polycotton tents on the other hand are not waterproof.
The PU/PES and Sil/PA tent have intermediate values; this means that after a lot of rainfall the tent will become wet on the inside.

In general, a fabric with a very good waterproofness will not be breathable. Yet, not all materials with a limited waterproofness will be breathable. Of course some materials combine a good waterproofness with breathability. Unfortunately, these materials are too expensive to be used in the humanitarian field.

**MAIN FINDINGS**

- The PVC coated PES are perfectly waterproof.
- The PE-sheet and the siliconised polyamide are also watertight, but after severe and long-lasting rain the water will slowly penetrate the fabric.
6 - Heat opacity

The heat opacity is determined according to EN 410 (Glass in building - Determination of luminous and solar characteristics of glazing). The evaluated spectrum goes from 380 nm to 2500 nm; this comprises the visual light and a large part of the infrared sun light, responsible for the heating of objects.

Part of the heat that is not transmitted or reflected is absorbed by the fabric. This heat absorption results in the warm touch of the fabric.

The large difference in heat reflection between the white PVC/PES of 340 g/m² and the light grey PVC/PES varieties is caused by the colour.

The transmission of the heat should be as low as possible. In general, for the same type and colour of fabric, the heavier the fabric is, the smaller its transmission. For the same weight, grey PVC coated PES performs better than white polycotton. The black PU/PES and dark green SiI/PA fabrics perform the worst (they also have the lowest weight and darkest colours).

MAIN FINDINGS

- The use of heavy PVC coated PES of 900 g/m² results in higher internal temperatures.
- A light coloured tent material is to be preferred in warm climates to control the inner temperature as much as possible. Since the tested white fabric is also slightly transparent, the obtained internal temperature is higher than when the light-grey standard tarpaulin is used.
- In winter times, a darker colour is to be preferred to absorb the heat of the sun.

The influence of the colour and material on the thermal comfort was tested in the field by cladding cubes and measuring the inner temperature over a 10 days period. Outside temperatures at noon reached up to 45°C.
7 - Light opacity - translucency

Privacy is an important issue in refugee camps. Therefore it is essential that the tent fabric is rather opaque. However it is also necessary that, during daytime, the light shines through the fabric to enable the people inside the tent to see.

Inside a tent, a minimum lighting of 200-400 lux is preferred.

Field tests have shown that the light intensity in the translucent polycotton and in PVC tent is very high. During daytime, a sufficient amount of diffuse light enters the tent to ensure visual comfort. Artificial lighting is not needed, not even under a cloudy autumn sky in the Netherlands.

In contrast, the light intensity of the nearly opaque PE tent is below standards.

In general, a darker colour generates less reflection of visible light, and in most cases, less transmission of light, but the actual outcome largely depends on the material characteristics, such as thickness.

MAIN FINDINGS
- When a shelter is made from PE, the lightning inside is not sufficient. This should be taken into account at the tent design stage: windows should be integrated. Airtight windows should be confectioned to avoid heat loss during winter time.
8 - Burning behaviour

Recently, the burning behaviour is of growing importance in the humanitarian sector. More and more agencies have already incorporated, or will soon, incorporate fire requirements in their specifications. Therefore, the burning behaviour of the tent fabrics was evaluated according to ISO 15025 (Protective clothing - Protection against heat and flame – Method of test for limited flame spread) to compare the different aspects of the burning behaviour, including ignition time, flame spread, smouldering, debris, etc.

The currently used polycotton fabric is easily ignited and once it catches fire, the whole tent will burn down in less than 18 seconds. People asleep have almost no chance of escape. The polycotton is also the only material with an afterglow/smouldering effect, due to the nature of cotton.

The PE-sheet and the lightweight materials used for camping tents (PU/PES and Sil/PA) have a bad burning behaviour. They are at least as flammable as the polycotton tents that are used today; the fabric is completely burned down in a short time. The presence of molten and flaming debris enhances the risk of spreading the fire.

PVC coated PES without flame retardant additives is not favourable either. These materials also burn. However, there are flame retardant qualities on the market that do not ignite. When the material comes into contact with a flame, a hole is formed but only locally and the rest of the fabric does not catch fire. The formation of holes in the tent fabric need not be interpreted as negative for it has the advantage that fumes can escape (less risk of suffocation).

<table>
<thead>
<tr>
<th>Material</th>
<th>Polycottens</th>
<th>PE-sheet</th>
<th>PVC coated PES standard</th>
<th>PVC coated PES Flame retardant</th>
<th>PU/PES Sil/PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molten debris</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Flaming debris</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Flame on edge</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Hole formation</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hole formation on edge</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**MAIN FINDINGS**

- The polycottens, PE sheet and the camping materials (siliconised polyamide, polyurethane coated polyester) burn intensively. Even the PVC coated PES shows flame spread.
- Flame retardant qualities of the PVC coated PES are available; in this case the flame spread is suppressed.
- Cladding materials can be treated with a flame retardant to increase the safety of the users.
  - FR finishes add 10 to 20 % to the weight of a tent fabric.
  - FR treatments augment the cost price (e.g for PVC + 15%).
9 - Ageing

Sunlight, and more in particular, the UV-light within the spectrum, can have a negative effect on the properties of materials in the long run. This effect is called material ageing. In synthetic materials, ageing is caused by the formation of radicals that break down the polymer (photo-chemical oxidation). In many cases, materials contain stabilizers to neutralize the activity of the formed radicals so they no longer damage the material. Whether these stabilizers are added (and the used amount) cannot be seen by the naked eye.

The effect of a prolonged exposure to sunlight is simulated by tests accelerating the outdoor weathering effect.

The tent materials were irradiated for 1500 hours with QUV light, which is more aggressive than the actual sunlight. This correlates more or less to a six months use in the field in very sunny conditions. The aim is to compare the resistance to weathering of the different tent materials.

The weathering test was performed according to ASTM G53/94 after which the tensile strength was tested according to ISO 13934-1.

The central part shows the fabric after 1500 hours of UV irradiation. For the commercial camping tent materials this resulted either in a complete discoloration (left - PU/PES fabric) or even in the complete deterioration of the fabric (right - Sil/PA fabric).
The camping tents (PU/PES and Sil/PA) lost all their strength after the exposure to sunlight. The Sil/PA camping tent was totally destroyed and the PU/PES could be torn into pieces without applying any force.

The polycottons lost most of their strength due to the exposure to sunlight. This effect was most visible in the warp direction of the material. This can be explained by the fact that different yarn qualities are used in the warp and weft directions.

The high-end PVC coated PES only showed a slight loss of tensile strength, whereas the lower quality PVC/PES were affected to a larger extent by their exposure to sunlight. More in particular, the tensile strength in the weft direction was largely lost.

On the other hand, the PE-sheet remained completely intact, no loss in strength was observed. The tested PE-sheet has a very good UV-stability. However, the UV-stability tends to show enormous variations in real life conditions. These differences are caused by the different amounts of UV-stabilizers that have been added to the coating. The presence of UV-stabilizers cannot be seen by the naked eye but is reflected in a higher cost price of the material (the price can be multiplied by five).

According to the current ‘emergency items catalogues’ the fabrics of family, dispensary and multipurpose tents have to comply with the following specifications regarding the tensile strength: 30% maximum strength-loss on the minimum required value and 50% maximum loss on the original value of the same product after UV-exposure. The tested camping materials, polycotton and lower quality PVC coated PES did not comply.

Ageing has a similar effect on the elongation of the fabrics. After having been exposed to UV-light, it was no longer possible to elongate the PU/PES and Sil/PA tent fabrics. The polycottons show a significant decrease in elongation strength, except for the weft direction of the polycotton 200 g/m². In this case a slight increase is observed.

The elongation of the PE-sheet and high-end PVC coated PES remained unchanged. On the other hand, the elongation of the lower quality PVC coated PES decreased by which they break down more easily.

**MAIN FINDINGS**

- Polycottons are affected by UV-light; after a prolonged exposure to sunlight they loose their strength.
- Camping materials are not made to be used in sunny conditions over longer periods of time; they degrade completely.
- PE-sheets (tarpaulins) can withstand a prolonged exposure to sunlight if they are well stabilized against UV-light. Adding stabilizers to the coating augments the price. Cheaper qualities will probably not last long.
10 - Soil burial

In the field, a lot of the materials are affected by micro-organisms, such as fungi. This is mostly the case in hot and humid areas. Even during transport and storage, the tent can be affected when they come into contact with moisture.

The picture on the right shows a tent, mounted in Burkina Faso, that came directly from storage. The tent was already completely covered by fungi. Distributing moulded tents is not beneficiary for the users’ health.

In the lab, the tent fabrics were buried for 56 days under controlled conditions (BS 6085-2) to assess of the resistance of materials in contact with soil. This gives an idea of the damage caused by micro-organisms, humidity,... Materials can grow fungi or start to rot.

The polycottons are stained. The polycottons of 200 g/m² and 350 g/m² show a mediocre growth (30% to 60%), while the heaviest polycotton of 440 g/m² shows a significant growth of more than 60%.

All the other materials show no growth after 56 days of burial.

The polycotton materials show a slight decrease in tensile strength after soil burial. The tensile strength of the other materials is not affected by the soil burial. A reference cotton fabric already degraded after 7 days of burial (tensile strength loss of more than 80%).
The elongation strength after soil burial is decreased in a similar way as the tensile strength. The elongation strength of the polycottons is decreased; the largest decrease is observed in the warp direction of the 200 g/m² polycotton.

In the weft direction on the other hand, the elongation strength has increased significantly; this phenomenon is also observed in the weft direction after ageing of the fabric. The other materials show no differences before and after soil burial.

The Luxembourg outdoor testing showed substantial fungi growth on the polycotton tent after three months already, whereas the other tents (PE and PVC/PES) remained unaffected.

**MAIN FINDINGS**

- Only polycotton fabrics show significant fungi growth; the other materials were unaffected.
- A slight decrease in tensile strength of the polycotton was found – the other materials are unaffected.
- Polycotton fabric can undergo an antimicrobial/antifungi treatment to solve this problem.
- Products made from natural materials (e.g. cotton) should not be stored in hot and very humid conditions.
A polycotton fabric (PES/CO) of 350 g/m² was investigated after it has been used as roof over a family tent in the Philippines for less than 6 months.

The fabric had completely turned brown on one side. Due to the hot and humid climate the sample was covered by fungi. It was also observed that the fungi corroded the cotton fibres, resulting in a 70% strength loss of the fabric.

It may be concluded that the artificial ageing has a good correlation with the ageing in the field. The fabric is affected by fungi growth and loses much of its original strength (tensile/tear). The influence on the water vapour permeability is minor.
11 - Cost / Repairability / Cleanability

**Cost.** In view of the large-scale distribution of the (family) tent, its cost price has to be kept as low as possible. In general, the cost price of e.g. polycotton or PVC/PES tents is directly influenced by the fabric's weight.

The cost price of a polycotton fabric is almost identical to the one of a PVC coated PES of the same weight.

The presence of additional functionalities in the fabric, e.g. flame retardant, will increase the price. A flame retardant PVC coated PES will be more expensive than its non-flame retardant counterpart.

The tested lightweight camping materials (PU/PES and Sil/PA) are far more expensive than the other tested materials.

The costs of the fabric may fluctuate according to the quality. For example, a PE-sheet containing more UV-stabilizers (which is not visible by the naked eye) is more expensive but at the same time it has a much longer lifespan. Prices can be augmented by 50%. Therefore it is complex/impossible to compare prices without technical information.

**Repairability** also increases a tent’s lifespan. The fabrics used for the lightweight camping tents (PU/PES, Sil/PA) are so thin that sewing a tear is very delicate. The repairability of these materials is very poor. The heavier weight polycottons can be sewed but every sew has a negative influence on the fabric properties, such as tensile strength, waterproofness,...

The PVC coated PES can be welded\(^1\) via a thermal treatment. After melting the PVC coatings, the fabrics are joined together and cooled down. A uniform coating layer is thereby produced by which the rupture completely disappears. If the welding is done correctly, the impact on the tent properties is limited. The drawback is that the ‘welding equipment’, i.e. a means to heat the fabric, needs to be available.

Stitching PE fabrics causes leaking (punctured fabric).

<table>
<thead>
<tr>
<th></th>
<th>PES/CO</th>
<th>PVC/PES</th>
<th>PE sheets</th>
<th>PU/PES Sil/PA</th>
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</tr>
<tr>
<td>glueing</td>
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<td>+</td>
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</tr>
</tbody>
</table>

Although glueing is a preferred technique for practical reasons (universally applicable) the glue itself has the drawback of easy deterioration under the influence of UV-light and moisture.

**Cleanability** of the tent fabric is another important issue, especially in tents used for hospitals, wards,... A full coating layer creates a smooth surface of the tent fabric, which benefits the washability. PVC coated PES and LDPE coated HDPE (as used in the PE-sheet) are the best options. Outdoor testing in the Netherlands showed that the polycotton tent contaminates more easily.

Disinfecting (hospital) tents with a chlorine solution on a regular basis is believed to deteriorate the fabric. To test this effect, the tent fabrics are soaked in a 2% chlorine solution for 10 minutes and for 1 hour to evaluate the effect of disinfectants on the tent walls. Afterwards they are rinsed and dried. The tensile strength was again measured but no differences were observed. All textile materials in our test withstand the exposure to the chlorine solution.

Although short term exposure clearly has no effect, the test results are not conclusive for a longer term exposure to a chlorine solution.

\(^1\) - textile welding is a completely different technique than steel welding requiring other equipment!
<table>
<thead>
<tr>
<th>properties vs material</th>
<th>Polycotton 200</th>
<th>Polycotton 350</th>
<th>Polycotton 440</th>
<th>PE-sheet 165</th>
<th>PU/PES 55</th>
<th>Sil/PA 53</th>
<th>PVC/PES 240</th>
<th>PVC/PES 340</th>
<th>PVC/PES 450</th>
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<td>380</td>
<td>410</td>
<td>1100</td>
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<td>tear strength (warp)</td>
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<td>67</td>
<td>91</td>
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<td>resistance to UV-light</td>
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<td>++</td>
<td>++</td>
<td>- to +++ according to the quality</td>
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<td>fungi resistance</td>
<td>-</td>
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<td>FR treated +</td>
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<td>+++</td>
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<td>++</td>
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<tr>
<td>interior light quality</td>
<td>++++</td>
<td>+++</td>
<td>++</td>
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<td>local repairability</td>
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<td>+</td>
<td>+</td>
<td>++</td>
<td>-</td>
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This table is based on standard materials in non high-end applications.

*Overview of the main properties of the tested tent fabrics*
CONCLUSIONS

- Comparative tests of several types of polycotton materials, PVC coated polyester materials, PE fabric (tarpaulin sheeting) and some other state-of-the-art tent materials were performed. A universal, low cost, long lifetime tent material adapted to all climate conditions does not exist. Each fabric is characterized by its own specific properties. The comparative tests show that PVC coated polyester material is the most all-round material.

- Extensive tests performed on a large set of state-of-the-art materials show that polycotton has poor mechanical and outdoor stability properties. This result is confirmed by NGO’s describing the limited lifetime of such shelters in the field (often less than 3 months). In fact all the tested polycotton materials, which are nowadays typically used for small shelters (i.e. <50 m²), did not comply with the specifications as stated by most NGO’s.

- Ideally, the desired shelter properties should be pointed out for each type of application and external condition, and compared with existing tent materials to choose the most appropriate fabric. Based on the tests, a combination of multiple tent materials is recommended, for example, a roof manufactured in waterproof PVC coated PES, a floor of PVC coated PES or PE sheet, and a polycotton wall to maintain breathability. Indeed, variations can occur since e.g. the opacity of heat and light is related to the colour of the fabric, the burning behaviour can be improved by adding flame retardant additives, UV-resistance can be ameliorated through additives, anti-microbial and anti-fungi treatment is possible,...
OVERVIEW OF THE RESULTS OF OUTDOOR TESTING PERFORMED IN LUXEMBOURG

comparison of 3 different cladding materials (polycotton, PE and PVC/PES)

Nov. 2013: installation of the polycotton and PVC/PES tents
Feb. 2014: installation of PE tent

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PVC/PES tent cladding is still intact after 27 months
Polycotton tent is destroyed after 7 months
PE tent is destroyed after 8 months

fungi growth after 3 months
Holes in polycotton fabric after 4 months
Failure after 8 months
Failure after 7 months
Structure failure after 21 months without damage to claddings
Holes in PE fabric after 4 months
PVC/PES cladding still intact

PVC
polycotton
PE
MEMBRANES FOR SHELTERS

a comparative study to assist humanitarian workers in selecting suitable textile materials