MECHANICAL PROPERTIES OF SUBSTRATE OF SPACE EXPOSED HST BLANKET MATERIAL

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ABSTRACT

The substrate of the HST inner buffer blanket is manufactured from a glass fibre reinforced epoxy coated with a DC 93500 silicone coating and a sandwich core of kapton and DP46971 polyester adhesive. Tensile specimens with a gauge length of 15 mm and a width of 5 mm are cut from the longitudinal and long transverse direction of the exposed part of the blanket. Identical testpieces are cut from that part of the inner buffer that was not exposed to the atox environment (still rolled up on the drum).
The mechanical properties are measured using a Lloyd LT500 tensile tester using a crosshead speed of 10 mm/min.

Keywords: Blanket, Substrate, inner buffer, RTV-S 691, Tensile testing, Mechanical properties.

1. INTRODUCTION

After retrieval of the Hubble Space Telescope solar array it was recognised that severe discolouration of the blanket material had changed the appearance significantly. The light yellow coloured substrate had changed to dark brown after the ca. 4 years of low earth orbit exposure.
The intention of the present investigation is to measure the mechanical properties such as the Young's Modulus, Ultimate Tensile Strength (UTS) and Elongation ($\epsilon=\Delta l/l$) of this exposed substrate. Comparison with unexposed substrate measuring the same properties under identical conditions will be presented. Unfortunately no comparison could be made with not flown substrate material of the same batch. Instead, comparison is made with substrate material flown on the HST solar array, but not exposed to atomic oxygen, UV, etc. A part of the inner buffer of the solar array remained on the drum after deployement of the panels. These regions of the blanket are not fully identical to the exposed parts. To give a better protection to the environment an extra layer of DC93500 silicone adhesive was applied on the exposed parts, thus increasing the thickness of the substrate.

2. MATERIAL

The investigated substrates consist of several layers. The centre core is a sandwich of an insulation foil (2x kapton 100H) and two kapton 50H foils glued together with DP46971 adhesive. Glass fibre matting filled with DC93500 silicone with a thickness of 50 μm is applied to both sides of the kapton H with an adhesive layer of DP46971 with a thickness of 12.5 μm. This gives a total thickness of 180 μm as is illustrated in figure 1. On the exposed part an extra layer of DC93500 silicone was applied giving a total average thickness of 222 μm of substrate.
The difference between the exposed and the unexposed region of the inner buffer substrate can be seen in figure 2. On the un-exposed substrates small dots of DC93500 were applied only to areas where two

glass fibre bundles cross, while on the exposed substrate the complete surface is coated.
Tensile samples were cut with a pre-shaped cutting tool giving a standarised sample dimensions with a total length of 40 mm. The gauge length of the tensile samples is 15 mm with a width of 5 mm (see figure 3).
For each direction (longitudinal and long transverse) five spaecimens were cut, making in total twenty tensile specimens (ten exposed and ten unexposed).
Specimens for the Young's Modules measurements were sized as 12 x 3 mm.

3. TEST SETUP.

The tensile testing was performed using a Lloyd Instruments series 500 Materials Testing Machine, the testing machine is controlled by a remote computer using the Lloyd Instruments dedicated data analysis programme Dapmat 3.0. The pre-cut tensile samples were prepared for testing by bonding silicon carbide paper to the grip areas using a cyanoacrylate adhesive. The samples were gripped in Lloyd Instruments HT41 pneumatically operated jaws, the gripping faces of the jaws are also covered with silicon carbide paper, this is to ensure that there is no slipping of the test specimens for the duration of the testing sequence. The tensile tests were performed using a test speed of 10mm/min.

4. RESULTS AND DISCUSSION

The Young's modulus is measured between -150 °C and +150 °C and is shown in figure 4. The Young's modulus of the non-exposed sample is in general somewhat lower that of the exposed sample. The Young's modulus is defined as the slope of the stress vs. strain where the stress is the load per surface area. In this calculation, the add-on silicone layer at both sides of the substrate, which makes ca. 20% of the thickness of the blanket, plays a major role in the calculated value of the Young's modulus.
At ca. -100 °C a steep change in modulus is apparent for the non-exposed part. This is due to the glass transition point for the adhesive. The environmental effect on the blanket material changes the material properties in such a manner, probably by cross linking, that this effect is reduced to a small step for the exposed substrates.
To measure the UTS and the elongation, the specimens are tested to break. A broken tensile specimen is shown in figure 5, where the broken glass fibre matting is visible.
A number of stages can be seen in the tensile curves. The tensile curves are given in figures 6a to d. In one occasion a crack was present in the kapton layers and this specimen shows a specific tensile curve. This exposed longitudinal sample failed at the plateau after the first stage (figure 6a). We can see that the complete tensile curve consists of a linear hookian part and a plateau. These are the characteristics of the outer part (glass fibre + adhesive) of the substrate. The flat plateau appears always at the same position when the load is taken per sample width, irrespective of the added surface layer of silicone. The average value at the plateau is 4.5 N/mm for the exposed as well as for the unexposed in both the longitudinal and long transverse direction.
After an elongation of about 5%, when most of the exterior of the substrate is failed and the kapton core is taking the load, stage three shows up. This stage is a reasonable straight line and represents the elastic elongation of the kapton + polyester adhesive. It is not surprising that the values for the longitudinal and long transverse direction are identical if one observes the glass fibre matting after removal of the silicone adhesives and the interior layers. As can be seen from figure 7, the direction of the glass fibre is invariant to respectively the longitudinal and long transverse direction, also the properties of the kapton core are isotropic. Finally the kapton core fails at ca. 9.2 N/mm in all cases. A second plateau can be seen after the kapton failure at approximately the same level as the first. This plateau is probably due to the remains of some glass fibres pulling. The final elongation at break is rather random between 8.5 and 21%.

5. CONCLUSION

From these measurements one can conclude that the mechanical properties of the blanket material does not change significantly. The UTS and elongation were not influenced by the exposure to atomic oxygen, UV, etc. The darkening of the substrate increases the Young' modulus at temperatures above -100 °C slightly. At low temperatures (lower than -100°C) a large change is found where the cross linking took place which stiffened the silicone.

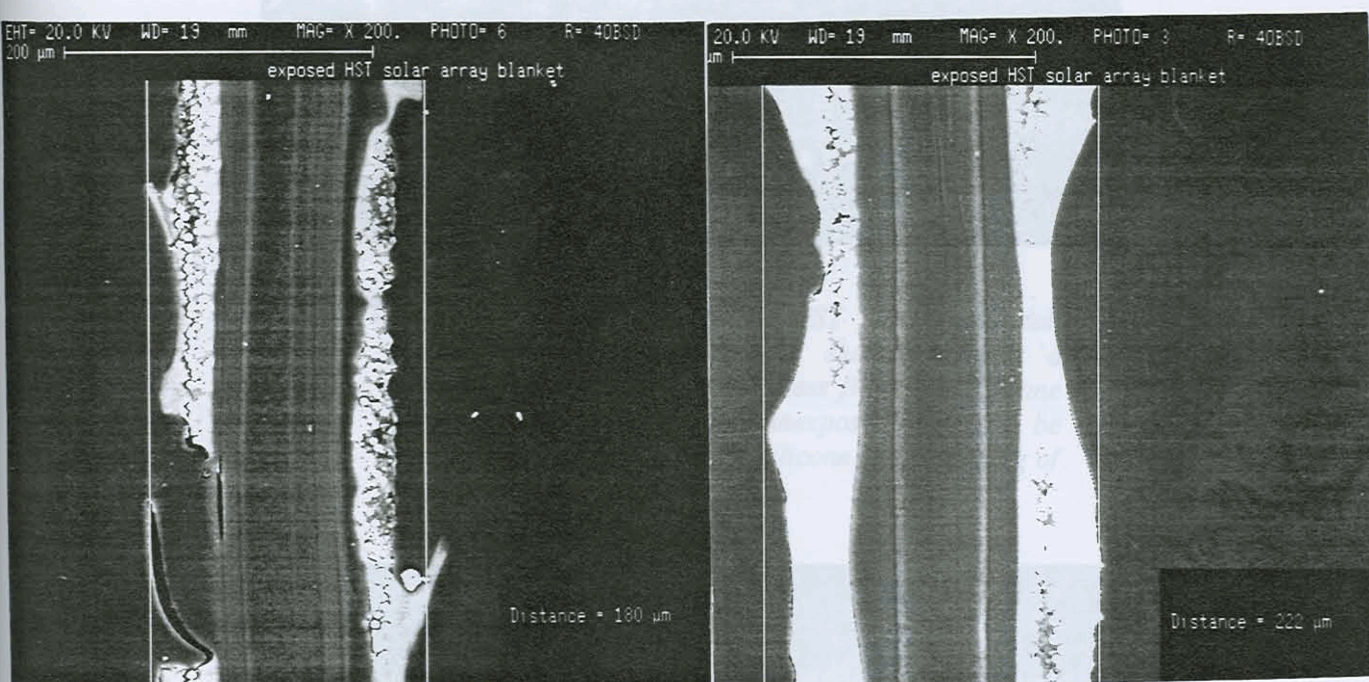

Figure 1. *Cross section of the unexposed and exposed area of the solar array blanket material. The centre core is a sandwich of an insulation foil (2x kapton 100H) and two kapton H foils glued together with DP46971 adhesive. Glass fibre matting filled with DC93500 silicone with a thickness of 50 µm is applied to both sides of the kapton H with an adhesive layer of DP46971 with a thickness of 12.5 µm. This gives a total thickness of 180 µm as is illustrated in the left picture.*
On the exposed part an extra layer of DC93500 silicone was applied giving a total average thickness of 222 µm of substrate.(right picture)
Magn. x200

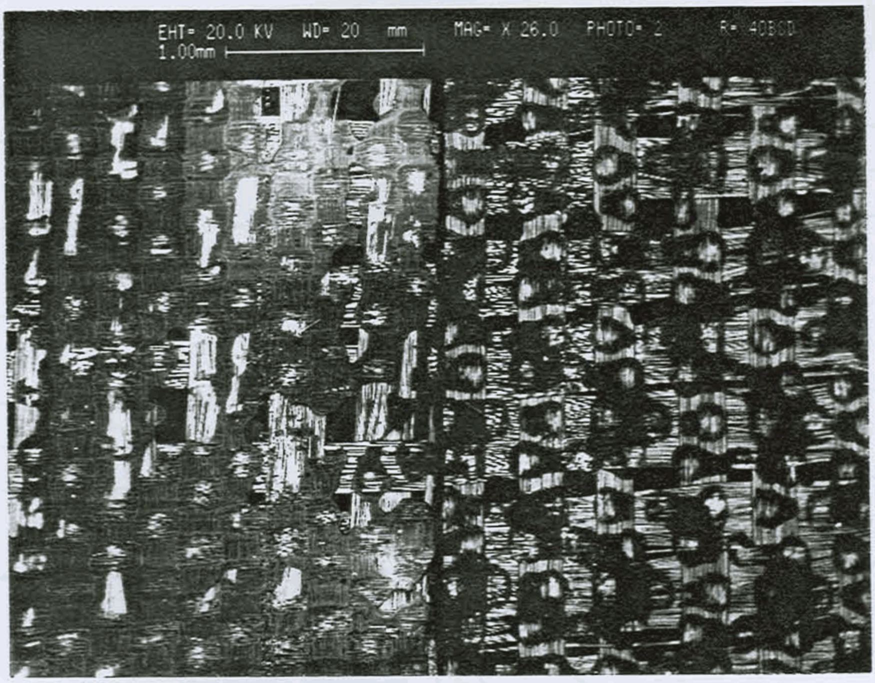

Figure 2. *A backscatter image of the HST blanket material. Left is the exposed region showing almost a continuous covering of the glass fibre with silicone DC93500. At the right the unexposed region can be seen, showing only dots of silicone at the crossing of two glass fibre bundles.*
Magn. x26

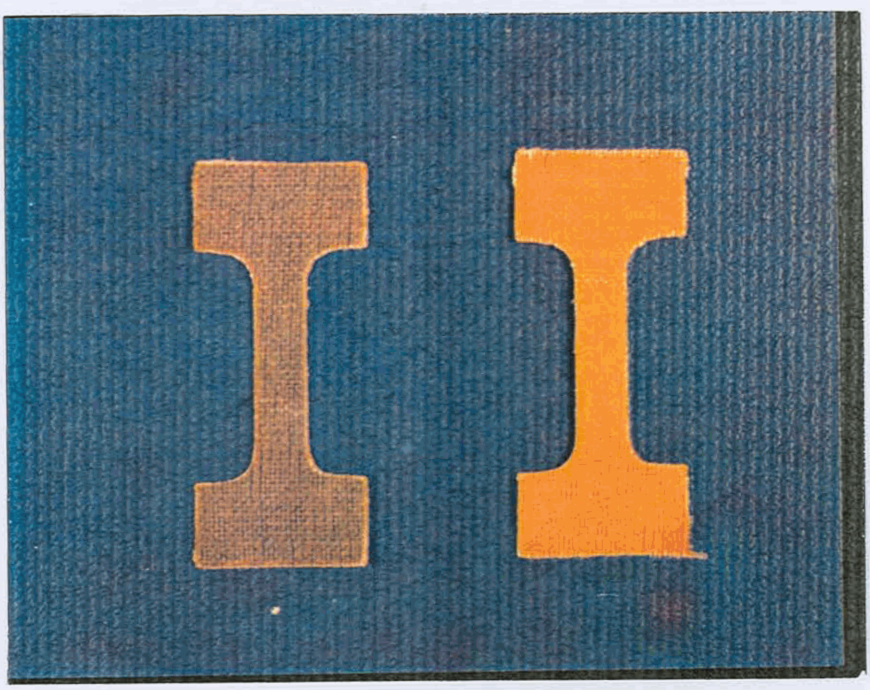

Figure 3. *General view at the tensile test samples cut from the HST solar array substrate.*
Magn. x1.4

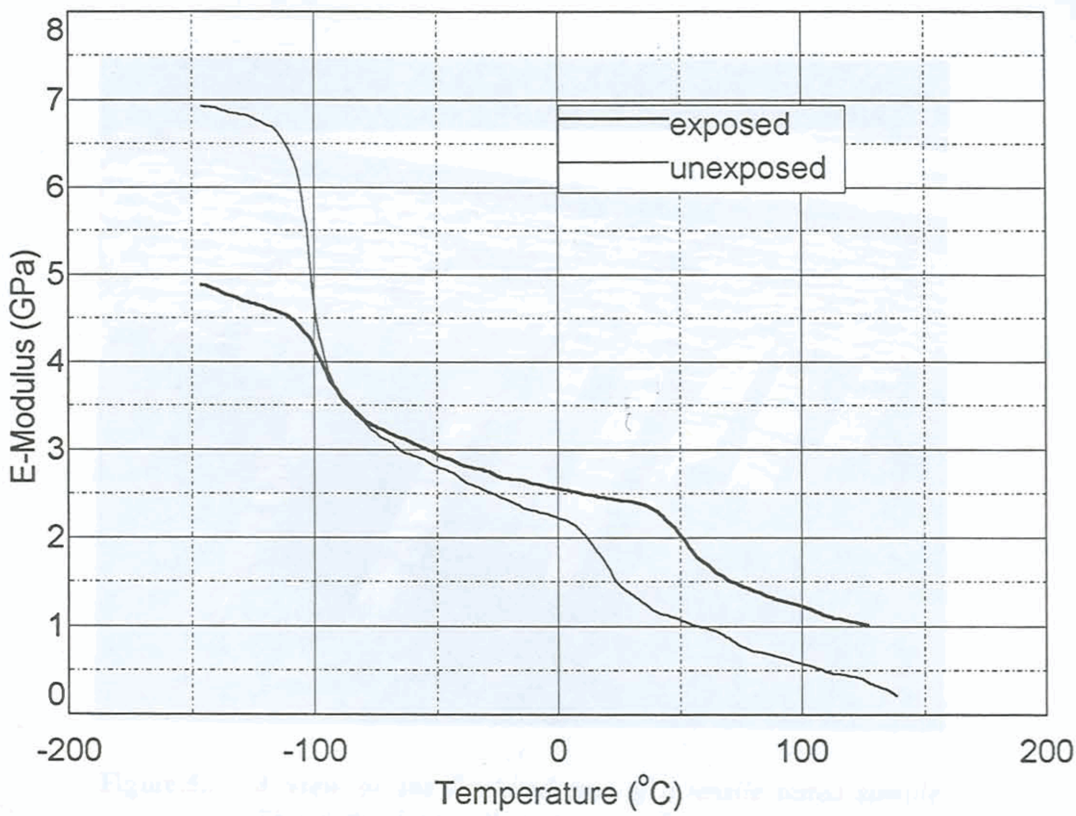

Figure 4. *Young's modulus measured between -150 °C and +150 °C using the DuPont dynamic mechanical analyser. The thin curve shows the unexposed sample (cross section 0.,58 mm²). The thick curve shows the exposed sample (cross section 0.68 mm²).*

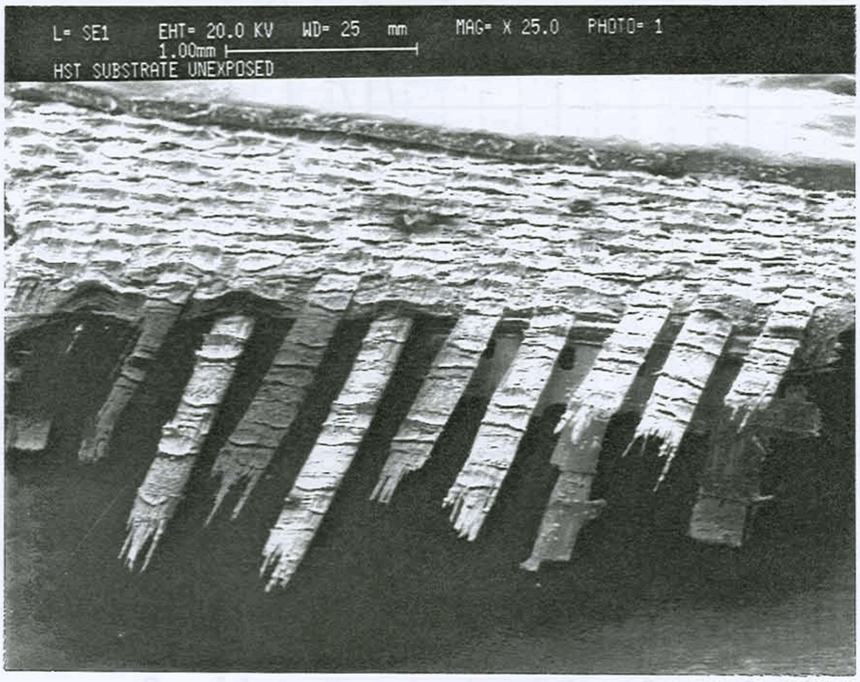

Figure 5. *A view on the fractured area of a tensile tested sample. This particular tensile test was performed on an unexposed area of the HST solar array substrate. The fractured surface of the exposed area looks identical. (the smooth coating at the top left is an aluminium tape to hold the specimen in position).*
Magn. x25

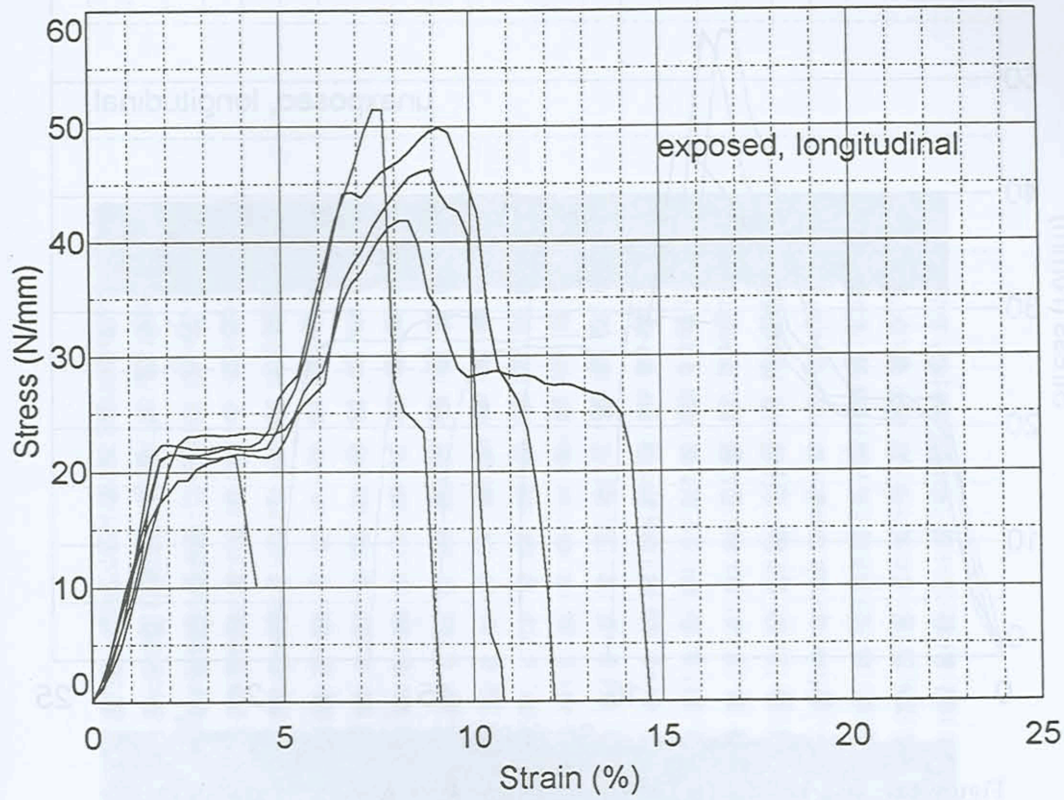

Figure 6a. *Compilation of the five tensile tests performed on the exposed substrate in the longitudinal direction. One of the tensile test specimen had a surface crack and shows only the first part of the tensile curve.*

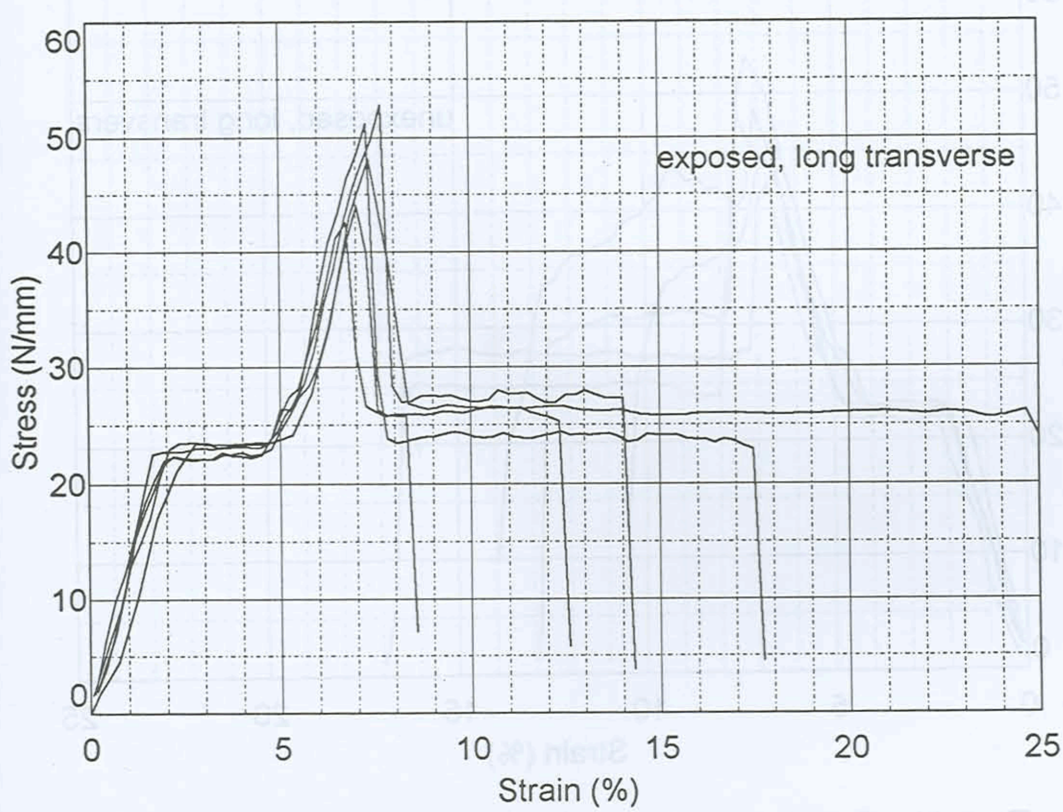

Figure 6b. *Compilation of the five tensile tests performed on the exposed substrate in the long transverse direction.*

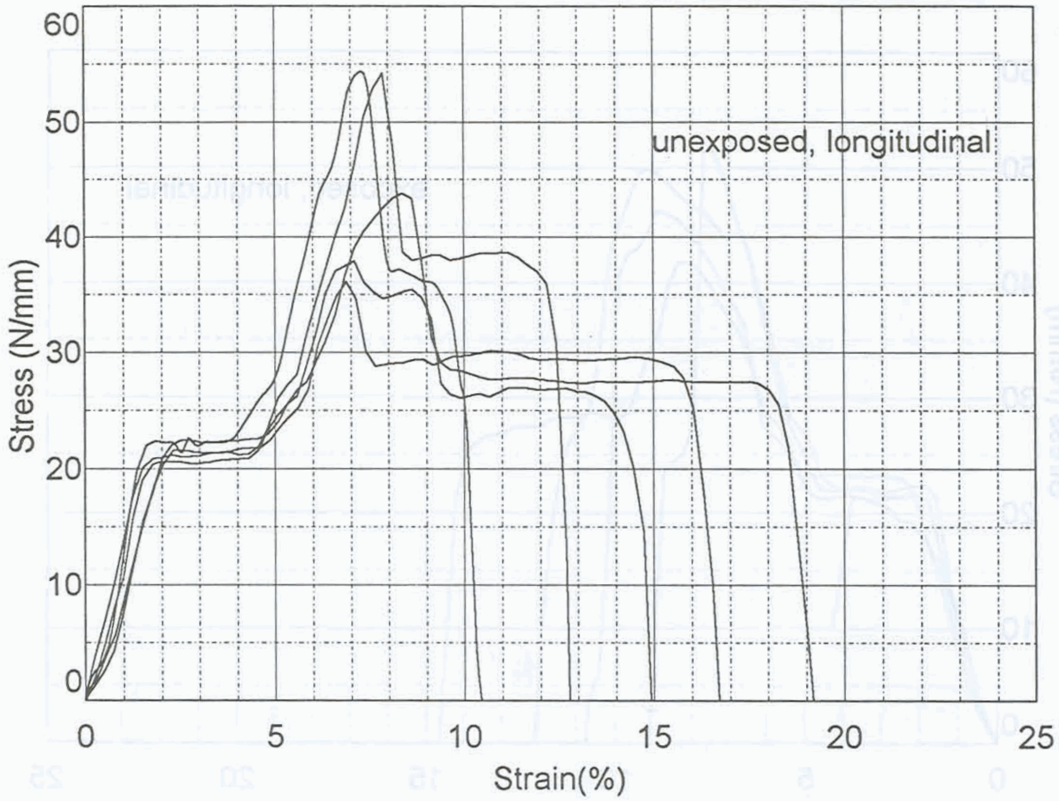

Figure 6c. *Compilation of the five tensile tests performed on the unexposed substrate in the longitudinal direction.*

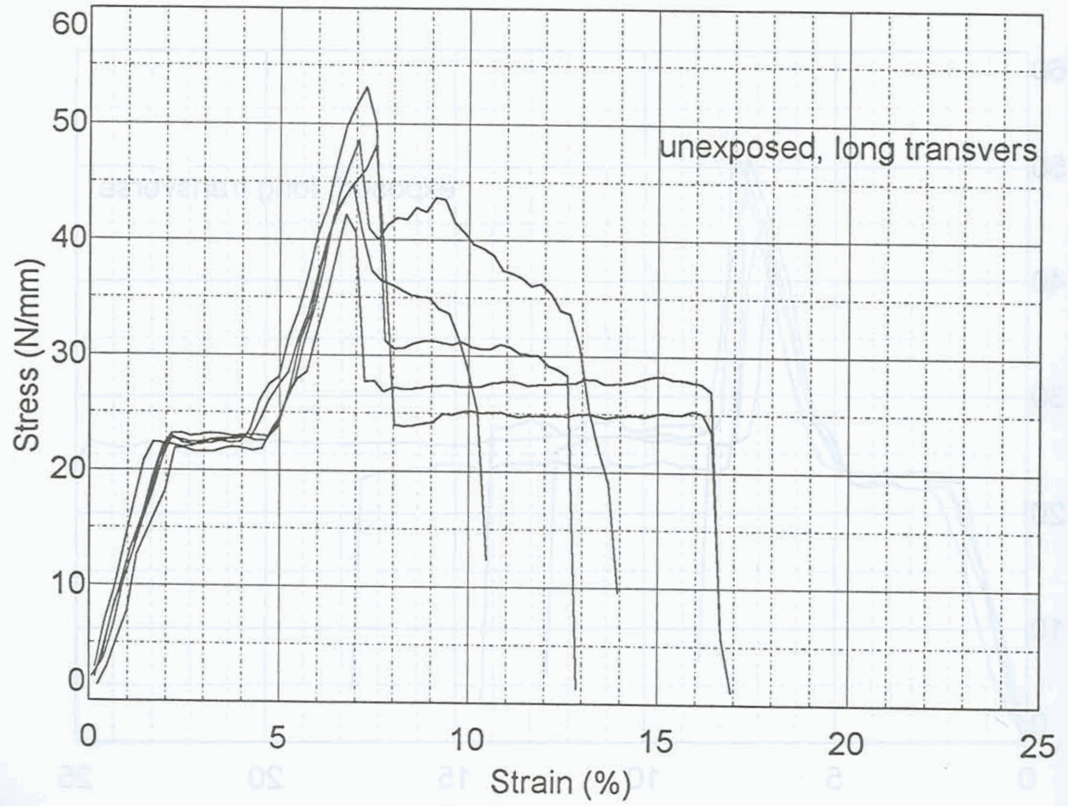

Figure 6d. *Compilation of the five tensile tests performed on the unexposed substrate in the long transverse direction.*

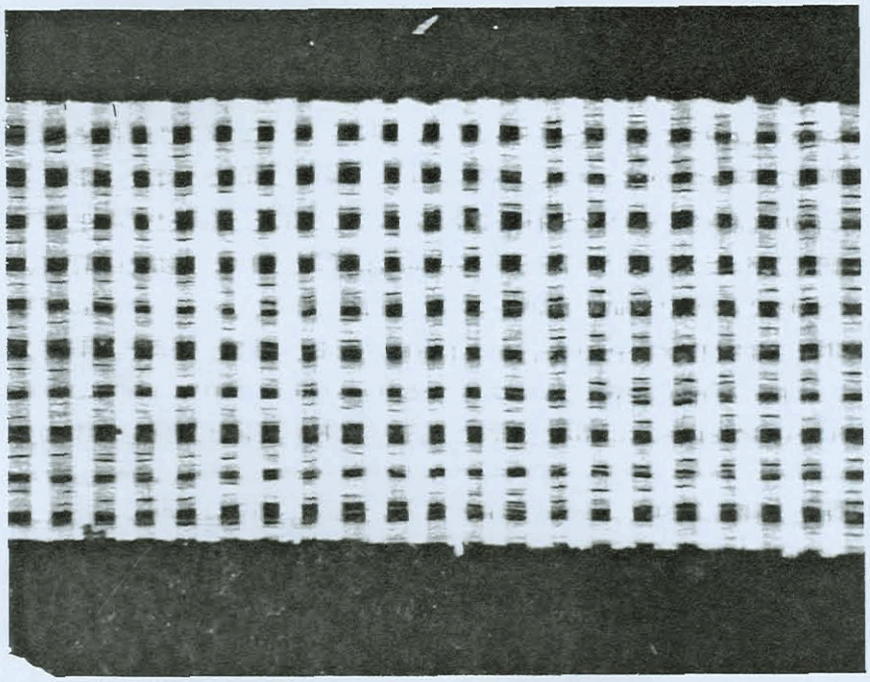

Figure 7. *Glass fibre matting after removal of silicone layers and interior core. It shows that the direction of the glass fibre bundles is invariant with repect to the longitudinal or long transverse direction*
Magn. x12