MEMBRANE STRUCTURES ASSOCIATION OF AUSTRALASIA
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COATED FABRICS, RECENT DEVELOPMENTS AND MARKETS OVERSEAS

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MEMBRANE MATERIALS FOR FABRIC STRUCTURES
PROPERTIES AND APPLICATIONS

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Summary

The utilisation of different combinations of coatings and base fabrics for textile structures is examined.
While the main benefit derived from commercial PVC coated fabrics would be their good weldability,ease of handling and their advantageous cost/benefit ratio,PTFE coated glass fabrics present a true alternative with regard to their excellent weatherability and unsurpassed flameproof behaviour.
With the recent development of PVDF coated polyester fabrics it was intended to combine the favourable weathering properties of PTFE with the good high frequency weldability of PVC at a reasonable price between the former and the latter material.

Format of the Paper

1. Introduction

As basic construction materials in the building industry, laminated fabrics combine the advantages of high tensile strength with minimal surface weight and on the whole excellent flexibility.

The main areas of application of these "slack and pliable" bonded fabrics are roof and air-inflated structures that are stretched and supported by mechanical or pneumatic means.

The above-mentioned specific properties of laminated fabrics make a larger variety of construction possibilities available to the builder than could otherwise be envisaged using traditional building-materials in the modest price range.

Although we can already look back on decades of experience gained working in textiles, and judge them, taken as a whole, in a very favourable light, the textile industry has nevertheless failed to develop, especially in West Germany, to the extent it was expected to, considering the encouraging upwards trend of the sixties and seventies.

There are various reasons for this. One of the main reasons is certainly that not enough has been taught, or is being taught at German universities today, apart from a few centres of learning, about the textile industry and the properties of textiles as basic building-materials.

Other reasons are, alongside the bad economic situation in general and the resulting economy measures in the public sector, the difficulties above all of guaranteeing sufficient thermal insulation during roof construction. On the positive side, however, practicable suggestions have been put forward in the meantime by the industry, which, in certain areas e.g. warehouses, can be carried out at relatively minor expense.

In many cases the builder has been put off by the far too time-consuming business of applying for and obtaining planning permission, something which is especially true of West Germany today, and opted for conventional building methods, instead of the largely more attractive and favourably-priced alternative, namely textile construction.

In order to improve this situation, both fabric workers and drapers in Germany have worked towards standardising the most usual membrane qualities, and their load-bearing and joining elements, and towards gaining the approval of the building authority.

Most of this approval has already been given and full approval will be obtained when current investigations produce the necessary proofs.

The necessity to standardise particular types of foundation fabrics not only applies to the generally known PVC laminated polyester fabric, but also to the recently developed, more sensitive membrane materials with new types of coating and fibres.

On the basis of their very special properties, necessary for a meaningful completion of the PVC-laminated polyester fabric pallet, these materials are worthy of our attention, and will now be looked into in more detail.

2. Materials

If one first considers those materials that principally recommend themselves because of their wide range of properties as textile building materials for laminated fabrics, then we must mention here the fibres: polyester, polyamide, glass and aramide, as they are all important to the production of foundation fabrics.

The limited weathering properties of unprotected polyester, polyamide and especially aramide fibres, make it essential for coating from the outset, that the fibres which determine tensile strength are protected from harmful exposure to the atmosphere. Similarly, glass fibres should also be protected from the damaging effects of humidity.

Apart from the price, it is above all the particular properties you require (shape stability, tensile and crease resistance etc.) that govern the choice of fibre. Picture 2 shows the varying stress/ deformation ratio of the abovementioned fibres, as well as the ratio between the specific tensile strength properties and the weight.

While polyester and nylon display a marked non-linear deformation tendency under stress, the corresponding curves for glass and aramide are approximately linear. The specific tensile strength of Kevlar is almost twice as much as that of glass fibres, and approximately 2.7 times the strength of polyester or nylon.

If we look at the various forms of coating, then polyvinyl chloride takes first consideration, since it plays a dominating role as a coating material in the textile industry today.

Chlorosulfinated Polyethyl, too, has now established itself, especially in the United States, as a coating material.

Regarding weathering properties, fluoropolymers show chemical and temperature stability while they also have outstanding properties such as anti-adhesive and dirt-repellant characteristics: properties which are far superior to those of other polymer materials.

Silicon rubber and alastomer and thermoplastic polyurethane are also becoming more interesting when used as coating materials for textile supporting bases. In contrast to the coating methods previously mentioned, however, they only play a subordinate role.

In reference to the said coating methods, Table 1 gives a survey of the processing possibilities as well as the technical properties.

It is especially true in the textile industry that only those coating methods can become established, by which it is possible to produce, at reasonable expense, stitched seams that will exploit tensile strength to a very high degree.

Further criteria for choosing the form of coating are, apart from the cost involved, flame-resistance and resistance to harmful atmospheric conditions.

Taking as a base the price-profit relationship as well as the special properties of the afore-said fibrous materials and coating methods, it is the following combinations that have made their mark in the textile industry:

In first place the PVC-coated polyester and in certain cases also polyamide fabrics. Then there are, especially in the United States, the CSM-(Hypalon) coated polyester or polyamide fabrics, and also PTFE coated glass fabrics.

In the future, PTFE-coated aramide fabrics could also start being used to a greater extent than they have been, especially in industrial complexes, where certain requirements would have to be met, e. g. chemical stability and flame-resistance.

New developments which are especially investigated in our company in order to improve weatherability of membrane fabrics show that mainly coating systems of thermoplastic fluorpolimer could be employed. This has, for instance, in comparison to PTFE coated glassfabrics, the advantage that such fabrics can be welded by HF and the manufacture of such qualities could thus be considerably cheapened.

First results with these PVDF coated polyester fabrics, with regard to the weatherability (artificial weathering) and especially in consideration of the long-term strength of welded seams at 70°C, prove the correctness of these theoretical considerations.

Weathering tests in different climates should, at the moment, confirm the results which were obtained under laboratory conditions.

After all final tests with positive results, we would regard PVDF coated polyester fabrics as a membrane fabric for textile structures which is suitable to fill the big gap concerning properties and price levels between PVC coated polyester fabrics and PTFE coated glass fabrics.

3. Properties of coated fabrics

If one makes a direct comparison of the principal properties of PVC-coated polyester fabrics, PTFE-coated glass fabrics and PTFE-coated Kevlar fabrics (Table 2), it will be seen that, apart from the favourable price, the chief advantages of PVC-coated polyester fabrics lie in their outstanding flexibility, high crease-resistance and excellent processability and manoeuvreability.

The advantages of PTFE-coated glass or Kevlar fabrics on the other hand lie, because of their special properties when used as coating materials, in their outstanding ageing stability, their anti-adhesive or anti-soiling behaviour, and also their very favourable flame-resistance.

Flame-resistance tests conducted in keeping with DIN 4102 standards show the PTFE-coated glass and Kevlar fabrics to be in Class A 2 (non-flammable), while PVC-coated polyester fabrics can be positively placed in Class B 1 (low inflammability).

A direct comparison between PTFE-coated glass fabrics and PTFE-coated Kevlar fabrics shows that, taking into account crease-resistance properties together with processability and manoeuvreability, PTFE-coated Kevlar-fabrics are definitely superior to PTFE-coated glass fabrics.

This applies even when very expensive glass fabrics are used, such as those where glass fibres with individual capillary diameters of 3 μ (Beta glass) have been employed. This Beta yarn now plays a leading role in the production of glass fabrics in the textile industry.

On the other hand, PTFE-coated glass fabrics display a far better transparency than PTFE-coated Kevlar fabrics.

Because the transparency of aramide fibres is comparatively poor, fabrics made up of these fibres can only be coated by means of heavy pigmentation and are therefore extremely non-transparent.

Tables 3 to 5 give a survey of the technical data of those fabrics mostly used in the textile industry: PVC-coated polyester fabrics, PTFE-coated glass fabrics and PTFE-coated Kevlar fabrics, as produced by VERSEIDAG.

The PVC-coated polyester fabrics I - IV shown in Table 3 have now become standardised in Germany. With regard to fabric structures made by different producers. Type V fabric can be considered as it has approximately the same tensile strength as fabrics I - IV but can also be used for different purposes.

As you can see from the table, types I - V can determine the ultimate choice of fabrics that can be used for various purposes because they have the tensile strength properties required.

The last line of the table shows that the welding strength of these fabrics is calculated at 70°C, using standard seams in the test. This finding is particularly significant of late, as it has shown that tests of this nature carried out at higher temperatures already tell us a great deal, not only about the welding strength of the material but also the stress on the welding seam after long and repeated use. Therefore, further such tests would help to gain PVC-coated polyester fabrics a place in the framework of the identity test of the membrane material.

PVC-coated polyester fabrics are used for a whole variety of coverings, ranging from the light-weight awning made from the type I fabric shown in Picture 3, and attractive architectural structures like the swimming-baths roof in Düsseldorf-Flingern (Picture 4) made from the type II fabric, to purely industrial buildings, like for example, the roof structure covering the basin water-works at the mouth of the River Emscher (Picture 5), where the fabrics used here were similar to type II. Look at the outer covering of the cooling-tower in Bouchain in France (Picture 6). Here the fabrics were a variation on the type IV fabric, though with extra coating.

As in the case of PVC-coated polyester fabrics, a specially tailored fabric can be made with PTFE-coated glass fabrics for a given purpose, depending on the actual claims of the membrane. In this connection it should be pointed out that DURASKIN B 18059 GF and DURASKIN B 18049 are used worldwide.

As far as the various applications of PTFE-coated glass fabrics are concerned, we already have years of experience at our disposal. In the USA in particular, the advantages of PTFE-coated glass fabrics for the purpose of covering large areas were already recognised and put to use at a very early stage.

One of the most well-known examples is the 40.000 square metre roof erected on the Pontiac Stadium in Detroit in 1975 (see Pictures 7 and 8).

The largest roof in the world, the Hadj-Terminal roof in Jeddah measuring 420.000 square metres, was likewise built from PTFE-coated glass fabrics. It was erected by means of single square sections measuring 2.000 square metres in area and 20 metres high.

The biggest roof structure in West Germany to date, that of the Eispalast in Dortmund, which has an area of approximately 2.500 square metres, was achieved with the quality type B 18059 GF (see Picture 9).

As far as we know, only one type of PTFE-coated Kevlar fabric with the same quality of tensile strength as DURASKIN B 18059 GF has been developed. We must wait and see if membrane materials of this type gain a wider market before we can feel justified in extending the type pallet. To gather information about this material, an experimental roof was erected on the industrial premises of VERSEIDAG in Krefeld, with which it was possible to test the weathering strength and also the effects of special loads on the material, using practical conditions.

The choice of building materials, and actual building, is only possible when there is very accurate knowledge of the properties of the materials to be used.

Apart from knowledge of deformation behaviour, there must naturally be also sufficient knowledge of the stress and load properties. These particular properties of the various membrane materials will now be looked at more closely and in greater detail.

3.1. Deformation Behaviour From Mono-axial and Bi-axial Loading

Before calculating the length that each roll of fabric is to be cut into, so that no creasing will occur while it is being mounted subject to the required stretching of the membrane, it is necessary to estimate how much the membrane can be expected to stretch, taking into account the loading factors mentioned.

Investigations into mono-axial tension to date, most of which have been published, only describe the behaviour of a material given a particular stress level which, in practice, seldom occurs. This method of testing is relatively cheap, but nevertheless suited to showing the principal characteristics of stress-deformation of membrane materials.

Picture 2 shows power-stretch diagrams of the warp and weft directions for various types of membrane with relatively the same tensile strength. The curves only measure up to a maximum load of 2000 N/5 cm, in order that the power-stretch lines in relation to the loading of the membrane materials can be better portrayed.

A comparison of the PVC-coated polyester fabrics (type IV), the PTFE-coated glass fabrics (B 18059 GF) and the PTFE-coated Kevlar fabrics (B 18109) shows that the deformation behaviour of coated fabrics under loading depends less on the stress-deformation characteristics of particular reinforcing fibres than on the structure of the fabric itself especially in the weft direction (see also e. g.3,7). The various fibre modules, as illustrated in Picture 2, appear with the power-stretch lines of coated fabrics in the various loops of the curves, for only bigger loads. Stress-deformation under low loads is more interesting in practice because it is determined by deformation that is triggered off by wavering of the warp and weft threads. Since the weft threads of coated fabrics are generally wound stronger than the warp threads, they must first be pulled straight before they will be capable of bearing weight.

During this loading phase a considerable part of the tension applied must be replaced by coating. If the deformation increases i. e. the warp threads are stretched more and more, the coating will cause it to drop to the more negligible amount of the tension, and convey this tension in the warp direction of the fabric.

The mono-axial power-stretch diagrams, as illustrated here, tell us very little about the actual deformations that can occur in a building material under near-normal bi-axial loading. Reasonably accurate information can only be obtained from the bi-axial power-stretch diagrams, as illustrated in Pigtures 12 and 13 by 1/1 and 1/2, with reference to the loading factors (Load in warp direction divided by load in weft direction).

Because of the importance of this information, these experiments will be continued in the interests of getting the general approval of the building authority at the very highest level. The loading factors 1/1, 1/2 and 2/1 will come into play.

As a comparison of Pictures 12 and 13 with Picture 11 will confirm, the deformation tendencies of bi-axial loaded membrane materials are, in part, considerably less than the corresponding deformation tendencies of mono-axial loaded membranes when the loading is the same.

This deformation behaviour is characteristic of all membrane materials made from heavily coated fabrics. It is caused by the fact that deformations in the fabric are precluded by the combined influence of the warp and weft threads. This can have the effect of causing the material to become shorter in the warp direction, which happens as a result of the weft threads stretching and the warp threads crinkling, particularly under minor strains from loading. It will lead to the possibility of negative fabric deformations becoming apparent, in spite of the positive aspects of tension loading. It will usually be seen that under bi-axial loading increased at regular intervals, the altered thread ends, that are largely responsible for deformation in the first place, will sooner rectify themselves when treated with smaller loads than with mono-axial ones. This deformation behaviour is therefore "stiffer".

The information obtainable from short bi-axial experiments on membrane materials where deformations will occur as a result of actually stretching the membrane out on the erection site is relatively accurate. This is confirmed by Picture 14, which shows the creeps of a PVC-coated polyester fabric, a PTFE-coated glass and Kevlar fabric. All three fabrics show that those creeps which occur (i. e. slight increases in length through stretching) as a result of regular loading over a period of time, are negligibly small compared to those caused by stretching from heavy loading. As thorough tests, especially with PVC-coated polyester fabrics, have shown, these creeps occur largely independently of the level of loading.

3.2. Tensile Strength of Membrane Materials & Stitched Seams

Information obtained from testing permissible load-levels of membrane materials i. e. load-bearing properties over a set period of time, is largely based on the materials tensile strength properties. Consequently, tests as to why membranes show negative signs of behaviour under as near realistic conditions as possible, where the tension is precisely applied, have a very special significance.

In close relation to the negative behaviour of the fabric is above all the failure to act positively of what is generally the weakest constituent of a building part - namely, the stitched seam.

Detailed studies of the tensile strength of fabrics and binding materials are already available, particularly as regards PVC-coated polyester fabrics (1-6, 8, 9).

Picture 15 shows in a direct comparison, the relative longterm creep strength (in reference to various short-term creep strengths) of a Kevlar fabric, a PVC-coated polyester fabric and a PTFE-coated glass fabric.

Since the failure to behave legitimately of coated fabrics depends in the first place on the behaviour of the loadbearing fabric threads, one can assume that relative longterm creep strength measurements of different types of fabric though of the same fabric materials are practically identical under mono-axial loading. This was confirmed in the case of PVC-coated polyester fabrics (3).

A direct comparison of the various membrane materials shown in Picture 15 reveals that the relative long-term creep strength of Kevlar fabrics as of glass fabrics are nearly identical. Moreover, PVC-coated polyester fabrics have a more constant tensile strength. This favourable behaviour can be ascribed, among other things, to the fact that in polyester fabrics inconsistencies in the distribution of tension, caused by the effects of long-term loading, can be more easily ironed out than in Kevlar and glass fabrics, through the effects of relaxation.

It is particularly important in the case of PTFE-coated glass fabrics that special precautions are taken during manufacture, transport and erection to ensure that the material is not damaged in any way, for example, through creasing.

With a view to making a better assessment of the damage, that is never completely inevitable, to the tensile strength and therefore stability of membrane materials, tests were carried out using already damaged samples of the quality B 18049 GF and comparing them directly with the type II fabric (see Picture 16). The tensile strength was measured both after an incision was made and an additional dynamic load was applied. (Pre-load 10 % +- 5 % of the KZ-F, Frequency 5 Hz, Load Alternation Count 10). The results showed that the degree to which the tensile strength had been impaired was less in the case of PTFE-coated glass fabrics than PVC-coated polyester fabrics, even taking into consideration the relatively smaller tear. This was in reference to the initial damage as well as to the additional dynamic load applied. When one considers that building parts made from PVC-coated polyester have rarely ever had to be completely discarded, except in a few cases, as a result of a small tear caused by external influences growing into a larger one, it can be safely assumed that at least a comparable guarantee is also in evidence in the case of building parts made from PTFE-coated glass fabrics.

Since crease-strains can never fully be avoided, especially at the finished-product level and when a building part made from membrane materials is being erected, more consideration should be given in the future to admissible load-levels. The problem of loss of tensile strength through creasing could then be solved by establishing which loads are permissible, and which are not. This is particularly relevant to PTFE-coated glass fibres.

Such crease-stresses can be artificially brought about by means of a Flexfold test. This consists of rolling a weight of 10 lbs ten times over the tear. The test is used especially in the United States. In Germany, damage can be artificially applied to samples by a flap experiment in accordance with DIN 53361 (Crease-flap).

Similar tests on various quality PTFE-coated glass fabrics (10) show that the tensile strength can decrease under the pressure of crease-stresses up to 15 %, irrespective of the type of stress.

The weakest features of a building part are, in general, the points where the various fabric sheets join. The carrying capacity of these joints are, in places, 2 - 3 times as bad as the carrying capacity of the fabric as a whole. Therefore, very accurate knowledge must first be acquired of the tensile strength of the joints, so that the permissible loading limits of the membranes' component parts can be reasonably well calculated.

The prerequisite for the best possible exploitation of the tensile strength of a fabric is a stitched seam that is adapted to the material and the tensile strength of the fabric. Nowadays, often for reasons of easier finishing, weld seams are still made with over-lapping ends which, in relation to the high tensile strength required, are simply not long enough. If there are no other reasons to govern the choice of a particular fabric, then this is an unnecessary and also uneconomic waste of material.

Picture 17 shows, as an example, the relative long-term creep strength of a 70 mm wide weld seam of the quality B 18059 as well as a 80 mm wide weld seam of the PVC-coated polyester fabric type III (2, 4), corresponding to the permissible seam for this type of fabric.

Here it becomes clear that, in spite of the fact that teflon or glass fabrics are less sensitive to changes in temperature than PVC or polyester fabrics (which was only to be expected), the relative creep strength of the quality B 18059 GF at room temperature, and particularly at 70°C, is much worse than the corresponding relative seam strength of the fabric type III. The reason for this unfavourable behaviour becomes clear when one looks at the short-term tensile strength of the weld seam both at room-temperature and at 70°C.

This tensile strength is, in both cases, related to the corresponding short-term tensile strength of the fabric as a whole. In the present case a shorter overlap at the weld seam was opted for, so that, in spite of nearly double the tensile strength in the glass fabric, its capacity to be exploited was much less than that of the polyester fabric. Nevertheless, the absolute tensile strength of the weld seam of the PTFE-coated glass fabric is, in spite of the overlap being too short, higher than the corresponding long-term creep strength of the 80 mm wide weld seam of the type III fabric. If the same seams were made in the case in point, then the use of a lighter PTFE-coated glass fabric (e. g. DURASKIN B 18049 GF) would have been far more economical.

Even the surrounding conditions must be given consideration. As they can be influential in reducing the tensile strength of a fabric, acceptable load-levels must again be assessed. With PVC-coated polyester fabrics in particular one can draw on years of experience and find the corresponding data, not only about materials that have been extracted from building parts, but also about materials that, for example, were exposed to years and years of atmosheric conditions.

Certainly with more recently developed products it is impossible to give accurate information about the influence of weathering.

One relies far too much on experiments done in haste in artificial conditions to be able to make a proper evaluation of atmospheric influences. Picture 18 shows an experiment of this kind with a PTFE-coated Kevlar fabric. While the tensile strength of the unprotected grey fabric decreased by approximately 70 % within 6 weeks due to the very poor UV-stability of aramide, the corresponding decrease for the PTFE-coated Kevlar fabric was only about 9 %, thus putting this fabric in the same league as PVC-coated polyester fabrics when tested under the same conditions.

Picture 19 shows the relative tensile strengths, tear propagation resistance and adhesive properties of membrane materials some of which were exposed to weathering conditions up to as much as 11 years.

Test samples were taken, which had been exposed to atmospheric conditions below 45° facing South, in experiments with and without additional mechanical loads. Specimens extracted from building parts were also used in these experiments.

It shows that the highest recorded decrease in tensile strength of 35 % over that period (11 years) is very little, even for a relatively thin-coated PVC-coated polyester fabric corresponding to fabric type I, then in use.

According to recent available sources, PTFE-coated glass fabrics are, by virtue of their weathering, their tear resistance, their resistance to further tearing and their adhesive properties far superior to other building materials. Tests performed on our premises on the quality B 18059 under the supervision of the Institute for the Processing of Synthetic Materials in Aachen show, after more than two years weathering under a constant load of 15 % of the short-term creep strength, no worsening of the properties. On the contrary, in many cases measurement values were as much as 40 % on previous ones.

The PTFE-coated Kevlar quality B 18109 displays, when compared directly with corresponding PVC-coated polyester fabrics, no significant difference as regards its weathering properties.

And so it can be concluded that, given the right formulas for coating and the right type of production, the coated membrane materials currently on the market display excellent, even outstanding, resistance to weathering and especially the PTFE-coated glass fabrics.

Manufacturing firms are asked to step up measures to ensure high quality production and to keep fluctuations in quality to a minimum. They are also asked to eradicate errors at source. This would apply not only to the factory-floor but also to retailers. Furthermore, existing products must be developed more and more to reduce existing insufficiencies, and new products or product combinations (e. g. of coating and fabric) should be checked to see that they are fully suitable as textile building material.

In this way it should be possible by linking up with the developments of the sixties and seventies to promote coated fabrics even further as building materials in the textile industry, and thereby give them the attention the deserve.

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Class	Chemical Classification	Tradenames	Density g/cm	Coating Processes	Fabrication Processes	Specific Temp (dry) in C short-time	Specific Temp (dry) in C extended	Chemical Constancy (reference value) Solvent	alkalies	acids	oil/petrol	steam	oxidations	weathering resistance	Behaviour in fire
Fluoro plastics	PTFE/Polytetrefluoroethylene.	Teflon Hostaflon	2.15 2.2	Dispersion coating.laminating	only welddable with auxiliary welding substances	300	260	A	A	A	A	A	A	++	doesn't burn
	TFEP/Tetrafluoroethylperfluoropropylene cop.	Teflon	2.1-2.2	Dispersion coating.laminating welded-coating**	welding	240	200	A	A	A	A	A	A	++	low inflammability.Self-extinguishing
	TFA/PFA/Perfluoroalkoxy. Cop.	Hostaflon TFA.Teflon PFA	2.1 2.2	Dispersion coating.laminating welded-coating**	welding	280	250	A	A	A	A	A	A	++	low inflammability/self extinguishing-
	PVDF/Polyvinylidenfluoride	Vider Solef	1.78	Dispersion coating.laminating welded-coating	welding	180	130	A	A	A	A	A	A	++	low inflammability/self-extinguishing
	ETFE/Ethylenetetrafluoroethylene Cop.	Tefzel Hostaflon NT	1.7 1.77	laminating welded-coating	welding	220	150	A	A	A	A	A	B	+	low inflammability/self-extinguishing
	PVF/Polyvinylfluoride	Tedlar Dyflor	1.45	laminating welded-coating	welding	150	100	A	A	A	A	B	A	++	burns self-extinguishing
Thermo-plastics	PVC/Polyvinylchloride	e.g.solvic vestolit vinnol Lonza Hostalit	ca. 1.16	welded-coating coating	welding adhesion	70/80	50	C	B-C	B	C	B	B	+	low inflammability.Variable.self-extinguishing
thermoplastics elastomers/elastomers	CR/Polychloroprene	Neoprene Baypren	1.23	coating. welded-coating. laminating	adhesion vulcanisation	120	80	C	A	B	A	C	A	+	low-inflammability
	CSM/Chlorosulphinated polyethylene	Hypalon	1.25	welded-coating laminating	adhesion vulcanisation welding *	150	130	C	A	A	B	B	A	++	self-extinguishing.low inflammability variable
	Si/Silicon-Rubber	Wacker Silicon,Silopren,Silastic,CE-Silicon Rubber	1.25	Coating welded-coating	adhesion	300	180	B	C	C	A	C	A	++	low-inflammability.inflammable
	PU/Polyurethene	Impranil, Adiprene Estene	1.25	coating welded-coating laminating	welding * adhesion vulcanization	90-140	70-100	A-B	B	B	A	C	A	+	inflammable low-inflammability/variable

Tab. 1 Key:

* In non-interlaced condition. e.g. for thermoplastic elastomers

** coating with extruder

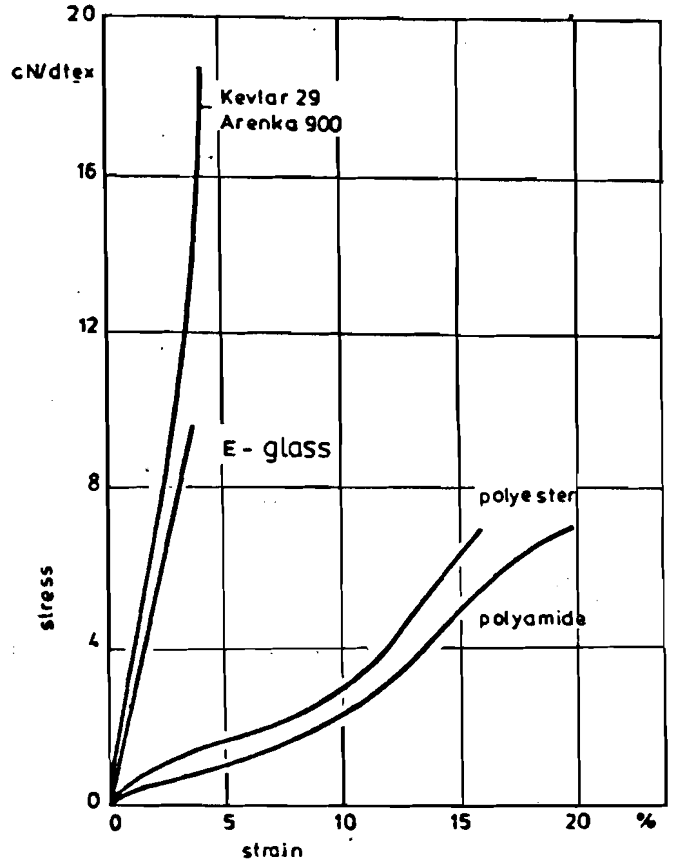
A no influence (Very suitable).

B Slight to average influence (suitability to be tested for individual cases).

C strong influence (not suitable)

++ very good weathering resistance

\+ weathering resistance through additives weathering resistance variable



stress-strain behaviour of fibers

ITE
2

alternatives of structural fabrics	technical interesting combinations	commercial combinations
grey cloth polyester (PES) polyamide (PA glass aramide	PVC-PES/PA PVC-aramide PVC-glass CSM-PES/PA PTFE-glass PTFE-aramide PVDF etc.-PES PVDF etc.-glass Si-glass Si-PES PU-PES/PA	PVC-PES/PA CSM-PES/PA (USA) PTFE-glass PTFE-aramide
coating systems polyvinyl chloride (PVC) chloro-sulfinated polyethylene (CSM) fluoro polymers (e.g. PTFE, TFA/PFA, PVDF, PVF, ETFE) silicone (Si) polyurethane (PU)		

picture 1

Comparison of properties
of DURASKIN(R) - qualities

	PVC-coated polyester-fabrics	Teflon-coated glass-fabrics	Teflon-coated Kevlar-fabrics
abrasion resistance	+	++	++
resistance to ageing	+	++	++
anti-adhesive behaviour	0	++	++
flameproof properties	+	++	++
elongation at point of burst	15 % - 20 %	3 % - 12 %	2 % - 7 %
chemical resistance	+	++	++
dimensional stability	++	++	++
flexibility	++	0	0
absorption in normal climate	2 %	0 %	0 %
crease resistance	++	0	+
corrosion resistance	+	++	++
resistance to light	+	++	+
light transmission	+	+	-
tensile strength	++	++	++
soil-repellance	0	++	++
resistance to low temperatures as far as / hight temperatures up to	- 30°C / + 70°C	- 80°C / +250°C	- 80°C / +160°C
processing-fabrication and characteristics in use	++	0	+
heat isolation	0	0	0
tear resistance	++	+	+

++ excellent
\+ good
0 sufficient
\- bad

tabular 2

PVC-coated polyester fabrics of VERSEIDAG for textile structures
- DURASKIN(R) -

quality	I	II	III	IV	V
VS-quality No.	e.g. B 1292 B 1251	e.g. B 1211 B 1272	e.g. B 1232 B 1215	e.g. B 1233 B 1485	e.g. B 1234
grey cloth					
type of yarn	polyester yarn DIOLEN(R) 174 S or TREVIRA(R) high tenacity				
yarn (dtex)	1100	1100	1670	1670	2200
weave	plain 1/1	basket 2/2	basket 2/2	basket 3/3	basket 3/3
ends/picks (cm) warp	9	12	10,5	14	14
ends/picks (cm) weft	9	12	10,5	14	14
weight (g/m²)	210	275	370	490	650
coated fabric					
total weight (g/m²)	800	900	1050	1300	1450
weight distribution from right side to left side	3/2	3/2	3/2	3/2	3/2
tensile strength (N/5 cm) warp direction	3000	4400	5750	7450	9800
tensile strength (N/5 cm) weft direction	2750	3950	5100	6400	8300
tear resistance (N) (trapezoid method) warp direction	310	520	800	1200	1700
tear resistance (N) (trapezoid method) weft direction	350	580	1050	1500	1900
adhesion (N/5 cm)	150	150	125	150	150
stress of a welded seam on standard seam at 70°C (N/5 cm)	width = 3 cm 2400	width = 4 cm 2850	width = 4 cm 3350	width = 6 cm 4600	width = 6 cm 4600

tabular 3

PTFE-coated glass-fabrics of VERSEIDAG

for textile structures

- DURASKIN(R) GF -

quality	B 18039 GF	B 18089 GF	B 18049 GF	B 18059 GF
grey cloth:				
type of yarn:	for all qualities ECB-Beta-glass (ECB 150) of Owens-Corning-Fiberglass			
yarn (dtex):	340x2x2	340x2x3	340x4x2	340x4x3
weave:	plain 1/1	plain 1/1	plain 1/1	plain 1/1
threads/cm warp:	13,0	10,5	9,0	7,5
weft:	13,0	10,0	9,0	7,5
weight (g/m^2):	365	440	510	625
coated fabric:				
total weight(g/m^2):	800	1100	1275	1550
weight diviation on both sides %:	50/50	50/50	50/50	50/50
total thickness(mm):	0,6	0,8	0,8	0,9
tensile strength (N/5 cm) (dry) warp direction min.	3500	4000	5000	7300
weft direction min.	3500	3500	4500	6500
tensile strength (N/5 cm) (wet) warp direction min.	2500	3400	4300	6200
weft direction min.	2500	3000	3800	5500
tear resistance trapezoid method (N): warp direction min.	300	300	400	500
weft direction min.	300	300	400	500
adhesion (N/5 cm): min.	120	120	120	120
translucency at 550 nm (%):	15 ± 3	15 ± 3	13 ± 3	7 ± 2
reflection at 550 nm (%) min.	67	67	67	67

tabular 4

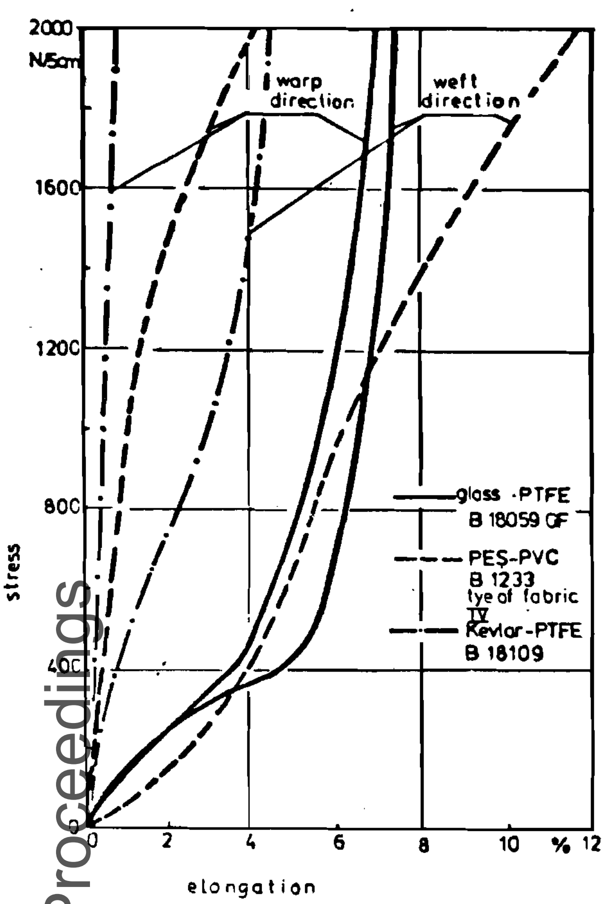
PTFE-coated Kevlar-fabric of VERSEIDAG

for textile structures

- DURASKIN(R) B 18109 -

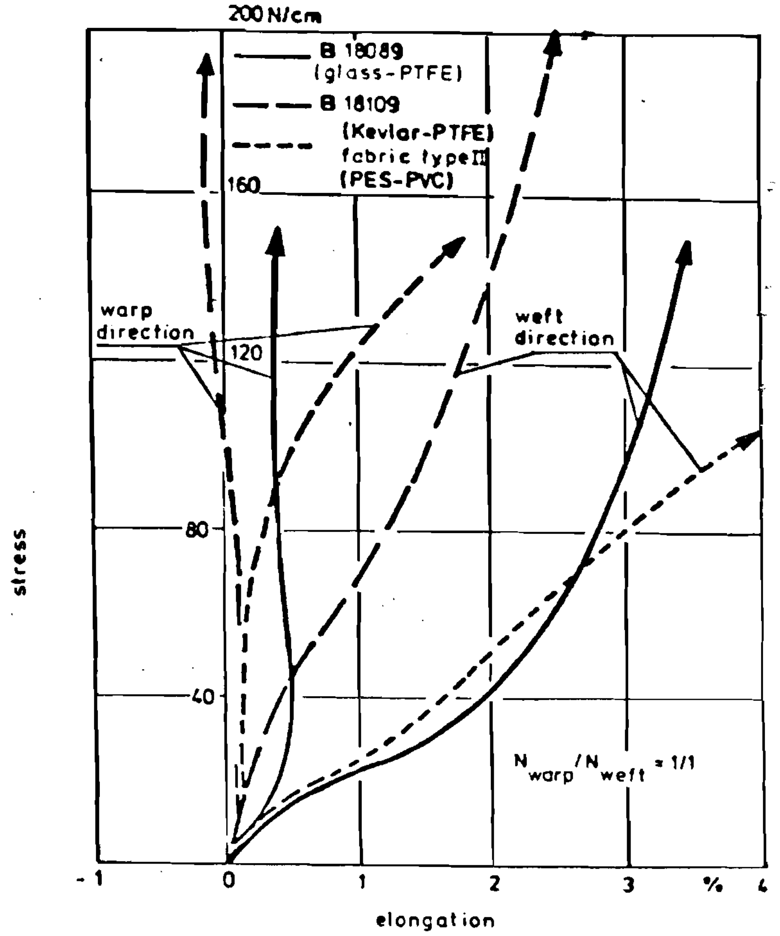
grey cloth:	
type of yarn:	Kevlar 29
yarn (dtex):	1670
weave:	basket 2/2
ends/picks: warp	11,5
weft	11,0
weight (g/m^2):	380
coated fabric	
total weight (g/m^2):	1200
weight deviation on both sides in %:	50 / 50
tensile strength (N/5 cm): warp direction	7000
weft direction	7000
tear resistence (N): trapezoid method warp direction	600
weft direction	500
adhesion (N/5 cm):	120
strength of a standard welded seam at 70°C (N/5 cm):	width = 40 mm 4000

tabular 5



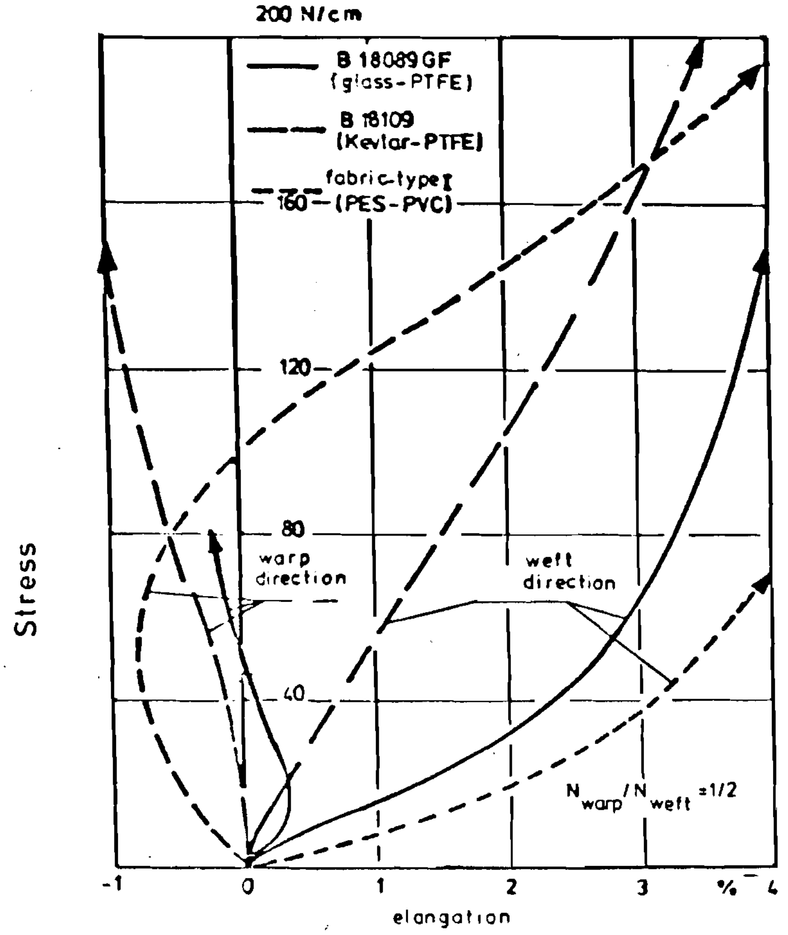
stress-elongation curves of PTFE coated glass and Kevlar fabrics as well as PVC coated polyester fabrics

ITE 11



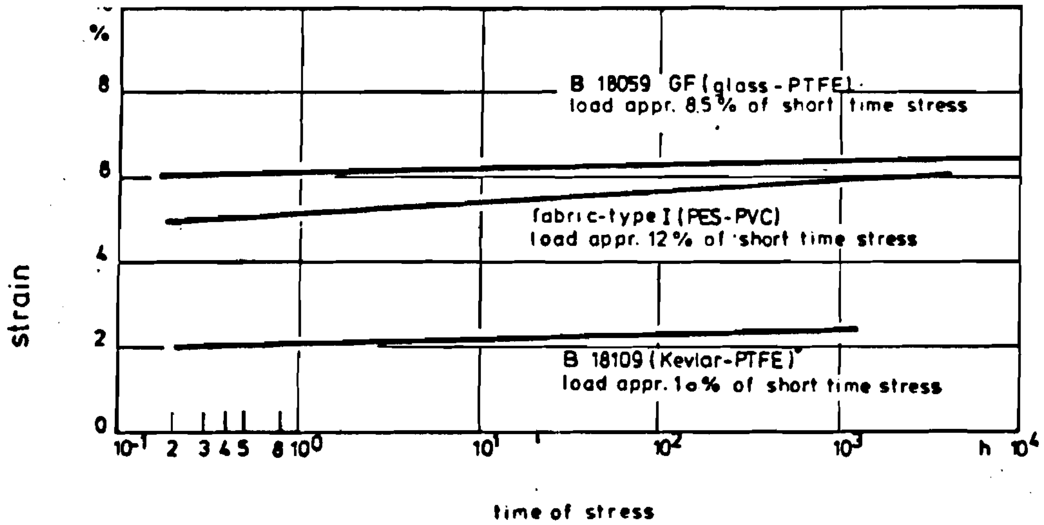
biaxial stress-strain-behaviour of structural fabrics

ITE 12

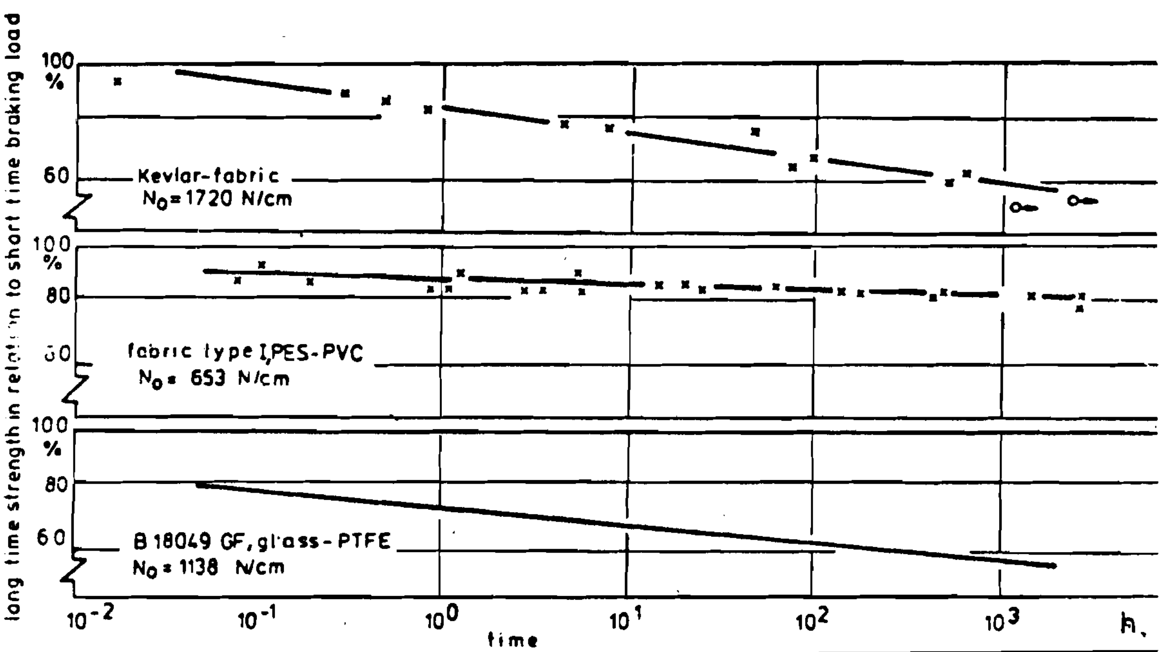


biaxial stress-strain-behaviour of structural fabrics

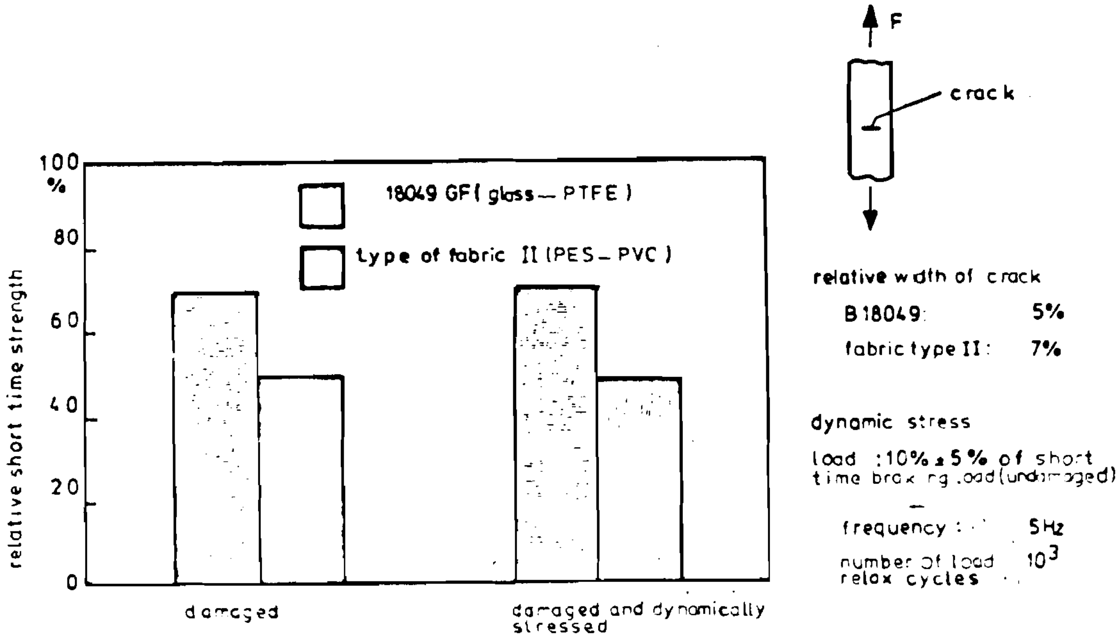
ITE 13



	long-term-elongations of structural fabrics (weft direction) under permanent load at room temperature	ITE 14

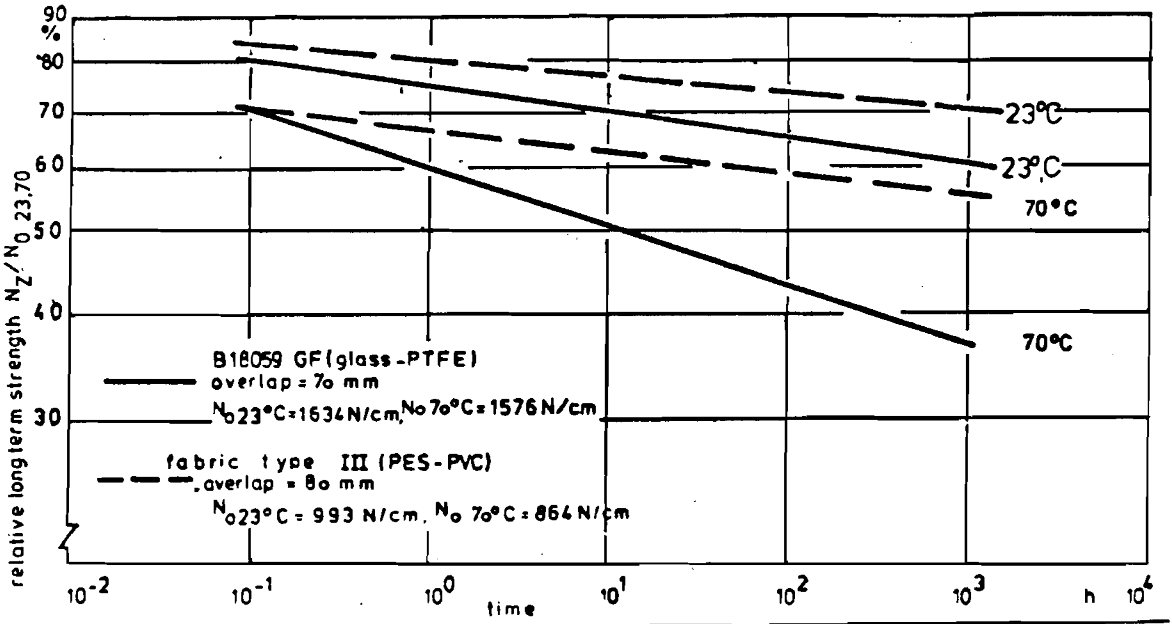


	relative long time strength of structural fabrics (warp direction) at room temperature	ITE



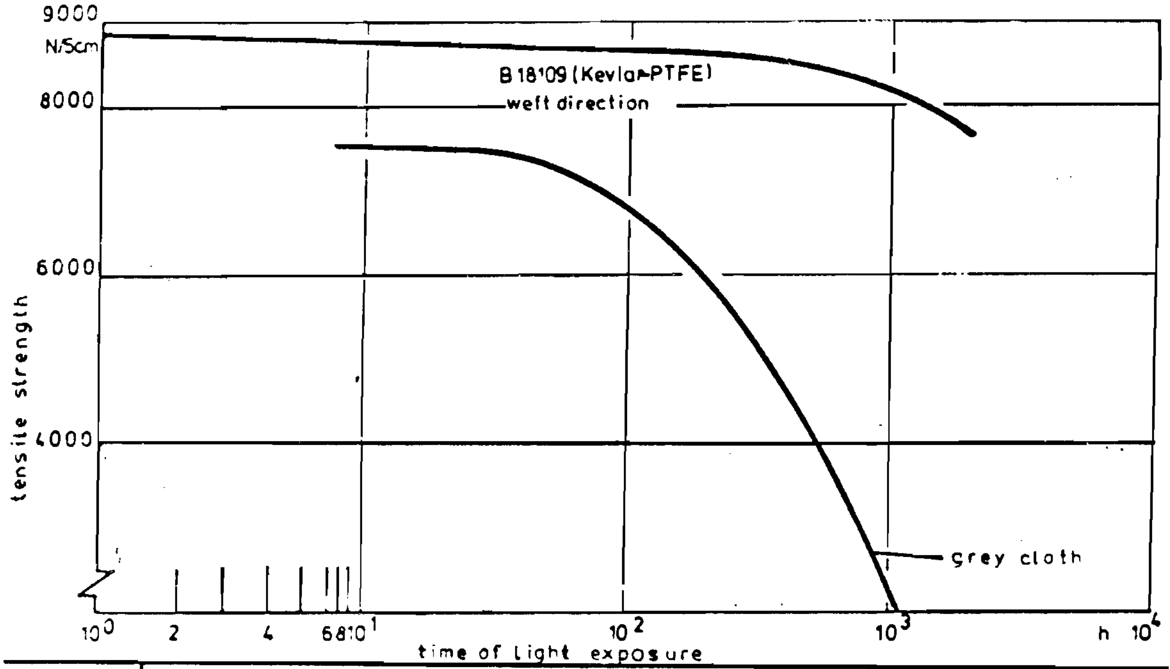
influence of pre damaging and dynamic loads onto the tensile strength of structural fabrics

ITE



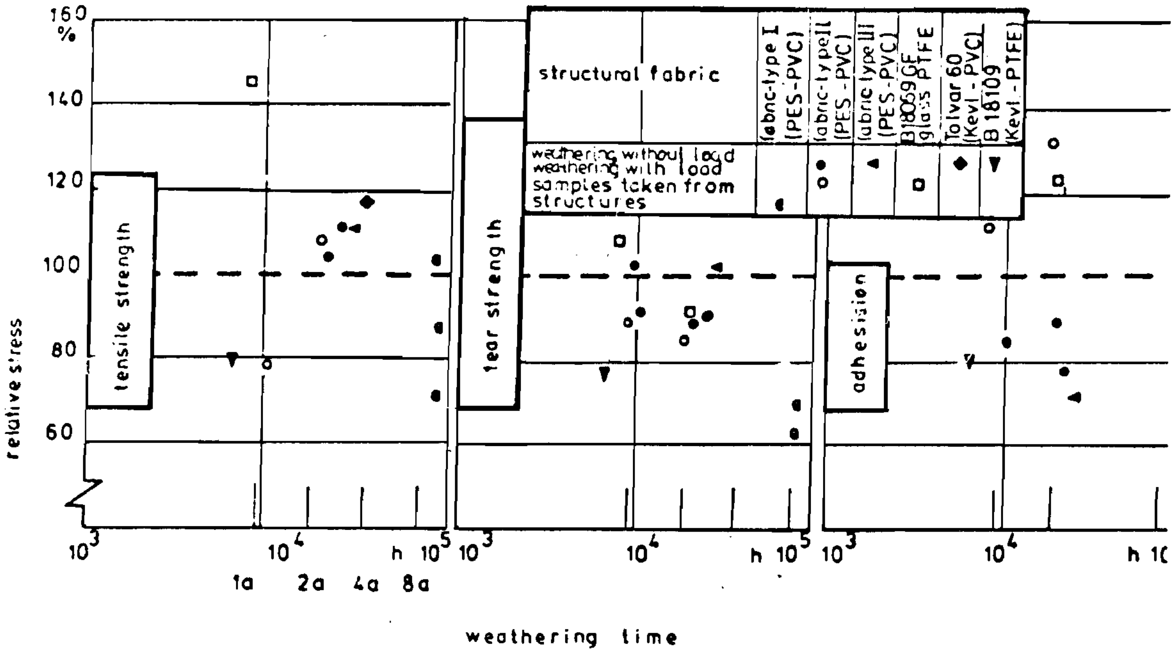
long term strength of welded seams of structural fabrics at room temperature (23°C) and 70°C (weft direction)

ITE



influence of UV-rays on the stress behaviour of Kevlar-fabrics

ITE 18



weathering influences on the mechanical properties of structural fabrics

ITE 19