WELL PROVEN PRODUCTS FOR TEXTILE STRUCTURES AND ACCOMPANYING DOCUMENTATION IMPORTANT TO ARCHITECTS

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Introduction

The classification of coated synthetic fibre fabrics as materials for membrane structures was made possible on the basis of research that was done on their physical and technical properties using new test dimensions.

The basis of this research was naturally the knowledge of the composition of these fabrics, taking into consideration both the base fabric and the coating materials.

Composition of the materials for Textile Structures

1. Fibres

From the variety of synthetic fibres that are available two types are now well proven;

polyester
glass

Both of these fibres differ considerably in their behaviour in regard to elongation and flammability. ***This paper will concentrate itself on polyester fibre based products.***

2. Base fabrics

The base fabrics differ in the number of threads per cm in both the warp (running) and weft (cross) direction, in the weave configuration, and in the titer (diameter) of the yarn.

3. Coatings

In order of importance, the coating materials are as follows;

plasticised polyvinychloride (PVC)
polytetrafluoroethylene (PTFE)
polyvinylfluoride (PVF)
polyvinylidenefluoride (PVDF)

This paper will concern itself with plasticised PVC on polyester base fabrics.

Fixed fabric constructions for textile structures

In order to have a range of fabrics with varying strength characteristics that would cover the various sizes and differing stress requirements of structures, six grades of coated fabric were chosen. These grades were designated; as Types I -VI.

The specifications chosen for these six grades were as follows;

Type I (POLYMAR 6505)	9/9 threads per cm 1100 dtex polyester warp & weft 1/1 plain weave total weight 850gsm tensile strength 3000/3000 N/50mm
Type II (POLYMAR 6506)	12/12 threads per cm 1100 dtex polyester warp and weft 2/2 panama (basket) weave total weight 900gsm tensile strength 4500/3800 N/50mm
Type III (POLYMAR 6601)	10.5/10.5 threads per cm 1670 dtex polyester warp and weft 2/2 panama weave total weight 1050gsm tensile strength 6000/5500 N/50mm
Type IV (POLYMAR 6602)	14/14 threads per cm 1670 dtex polyester warp and weft 3/3 panama weave total weight 1400gsm tensile strength 7500/6500 N/50mm
Type V (POLYMAR 6603)	18/18 threads per cm 1670 dtex polyester warp and weft 4/4 panama weave total weight 1600 gsm tensile strength 9000/8500 N/50mm
Type VI (POLYMAR 6605)	17/17 threads per cm 2200 dtex polyester warp and weft 4/4 panama weave total weight 2050gsm tensile strength 13000/11000 N/50mm

Examples of typical applications

Type I	Air supported halls of smaller size for swimming pools etc, and lightly pretensioned structures such as pagodas and sun sails.
Type II	Medium sized air supported structures, radomes, medium tensioned structures.
Type III	Large airsupported halls, larger pretension structures, e.g. Bicentenary Exhibition.
Type IV	Large scale pretensioned structures for exhibitions, sports stadiums, open air stages. e.g Expo 88.
Type V	Only for very large structures with very high pretensions. e.g shopping centre spire at Bochum, West Germany.
Type VI	For future constructions of a technically very ambitious level, having very high strength requirements.

As the European Community must adopt common standards by 1992 technical experts from the coating industry throughout Europe are currently meeting in order to work out a uniform standard for the fabrics to be used in textile structures. This aim is proving very difficult to implement as each nation wants to use its standards as the uniform standard. The most contentious issue will be which flammability standard is to be adopted, as there are important differences in relation to the ***real flare retardancy.***

What is clear thus far is that 2 new specifications will be added to the lower weight range, whilst in the upper weight range Type IV will be removed. The two new qualities in the lower range will also differ in yarn strength, and for the new Type I the total weight will be lowered to 670gsm.

In regard to the flammability test, the French test. (M2) and the German test (DIN 4102 B1) are very different. The French test with an electric burner demands a higher flame retardancy from the material than the German test. Trials are currently being conducted to find a lower level for the French test in order that the prices can be maintained at a reasonable level.

It must be said that generally the world wide differences in flame retardancy requirements represent an important price factor as for each country that demands its own standard, test certificates must be provided, at considerable cost.

Testing

In this paper the actual valid test parameters will be mentioned.

We basically differentiate between *short term tests* and *long term tests.* The short term tests will be known by most people as;

tensile resistance
elongation
tear strength
adhesion
resistance of the seams

These values will always define a fabric grade. These tests, and specifically the tensile resistance and resistance of the seam, are break tests which in the design'and engineering of a structure only give very basic information.

Between 1972 and 1980 in Germany a test program was established for Types II & III in order to study the *long term* behaviour of the material. Since the weakest point of any construction is the seam this work concentrated on weld types and strengths. From this research 4 seam types were classified.

a. double lap
b. four-fold flat needle stitched
c. high frequency welded
d. combination stitch (needle and HF)

A diagram is shown of each of these seams.

For Types II and III these seams have been defined in complete detail and are fixed for admission of projects to the Structures Authority.

The following long term tests have been conducted on these seam types;

a. creep behaviour, (uniaxially stressed tests)
b. time dependent rupture behaviour

The test 'b' is the one actually preferred. Here the aim is to ascertain how long the material and its seam (at temperatures of 23 deg.C and 70 deg.C and with various loads), resists rupture on the basis of 100% of the previously determined tensile strength value.

With this method you can obtain a 'line of durability', i.e. the resistance expressed as a percentage over time (see diagram). This long term test is carried out today at 70 deg.C, as translucent materials in high temperature regions of the world have been found to heat up to about 65 deg.C.

This 'durability line' is required by the German architects also to be carried out on fabrics with constructions other than Types II and III, or if the material itself has changed in construction, or if the seaming technique does not comply with the standards laid down for submission to the Structures Authority.

In calculating which material class to use for a structure reduction and safety factors must be calculated. The following factors are considered in regard to the reduction factor;

Factor A_1 – considers the reduction over time of the break values and represents the relation between short term and long term values for individual load periods.

Factor A_2 – is the reduction factor for ageing, and is dependant on the surroundings and impinging radiation, and the period of influence.

Factor A_3 – considers the temporary influence of increased ambient temperatures.

Factor A_4 – is the reduction factor for the influence of the manufacturing (fabrication) process.

The individual reduction factors are determined from various tests and the total reduction factor is thus:

$$A_{(total)} = A_1 \times A_2 \times A_3 \times A_4$$

The permissible strain is then given by the following formula;

$$N_{(adm)} = \frac{N_B}{A_{(total)} \times S}$$

N_B = short term strength

$A_{(total)}$ = total reduction factor

S = safety factor

For the safety factor a figure of 1.65 has been set.

Calculations using this formula have been carried out in Europe for a many years. These tests however must be re-examined when using the bi-axial testing method which loads the material simultaneously in both the warp and weft directions.

Specimens in the bi-axial test are not tested to break, but loads are applied to the specimen resulting from the above formula.

Accurate values can only be determined with this type of bi-axial testing equipment for sample sizes of at least 1 square metre. (See the attached diagram of the bi-axial test equipment).

The machine is made up of a number of hydraulic rams. Load is not applied over the total width of the specimen, but the specimen is divided into a number of strips of equal width on each side and all of the tongues on a particular side are loaded with the same force.

In the equipment at the University of Stuttgart the number of tongues on each side is 10. Each ram is positioned in a frame that can moves on bearings to ensure that the load is applied parallel to the threads of the material.

Each ram has a travel of 200mm. The maximum oil pressure is 100 bar. The area of the piston is 481 sq. mm. This results in a maximum load of 4810 N, which at a tongue width of 50mm corresponds to a maximum tension of 96.2 KN/m. All the rams on a side are linked to a common pressure line, and two sides can be actively worked via oil pressure steered through servo-valves.

With this equipment power-steered as well as way-steered tests can be carried out.

When measuring the elongation of a fabric, tension measuring strips are not used but rather the movement is measured. Aluminium clamps are screwed onto the membrane and the thread-parallel displacements can be measured in the warp and also the weft direction. From these results the elongation can be calculated.

It is possible to obtain with this method by applying various loads in the warp and the weft directions a bi-axial behaviour curve. Attached are such curves for a Type III fabric under different load conditions, i.e. 2:1, 1:1, and 1:2.

The architect or engineer will calculate the load which is expected to occur in the warp and the weft direction and with these the bi-axial test is carried out. The elongation can then be read from the corresponding bi-axial graph.

For temporary structures that are erected and dismantled several times, such as the travelling Bicentenary Exhibition, a cyclic bi-axial test can be carried out showing the long term stretch behaviour of the fabric.

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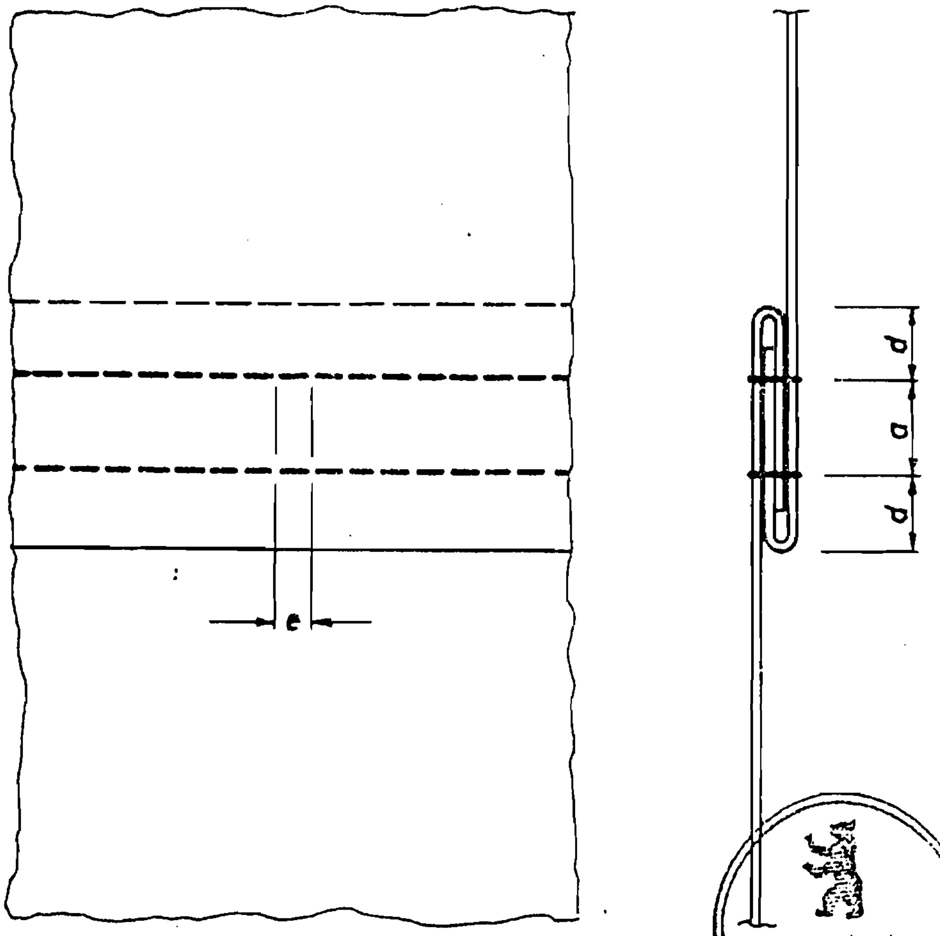

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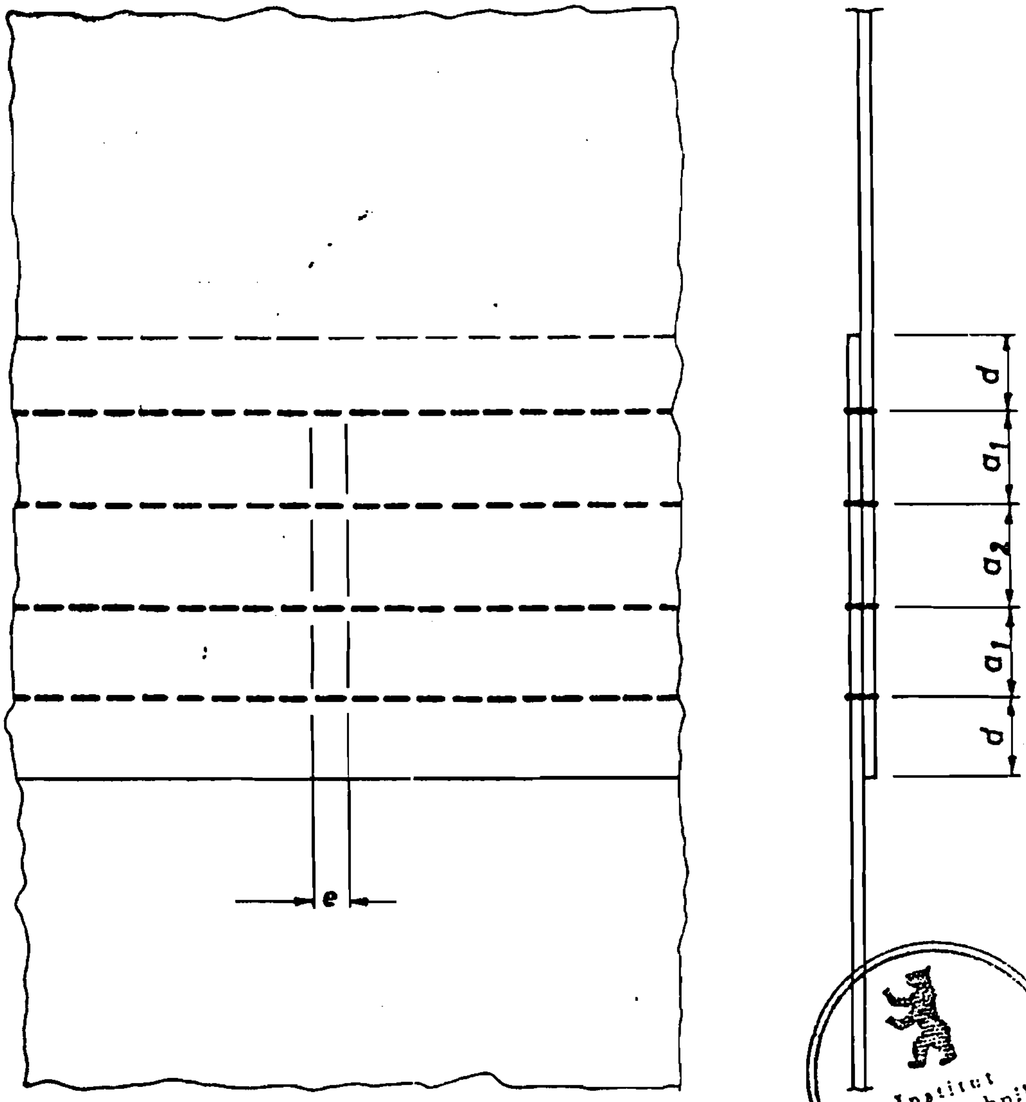
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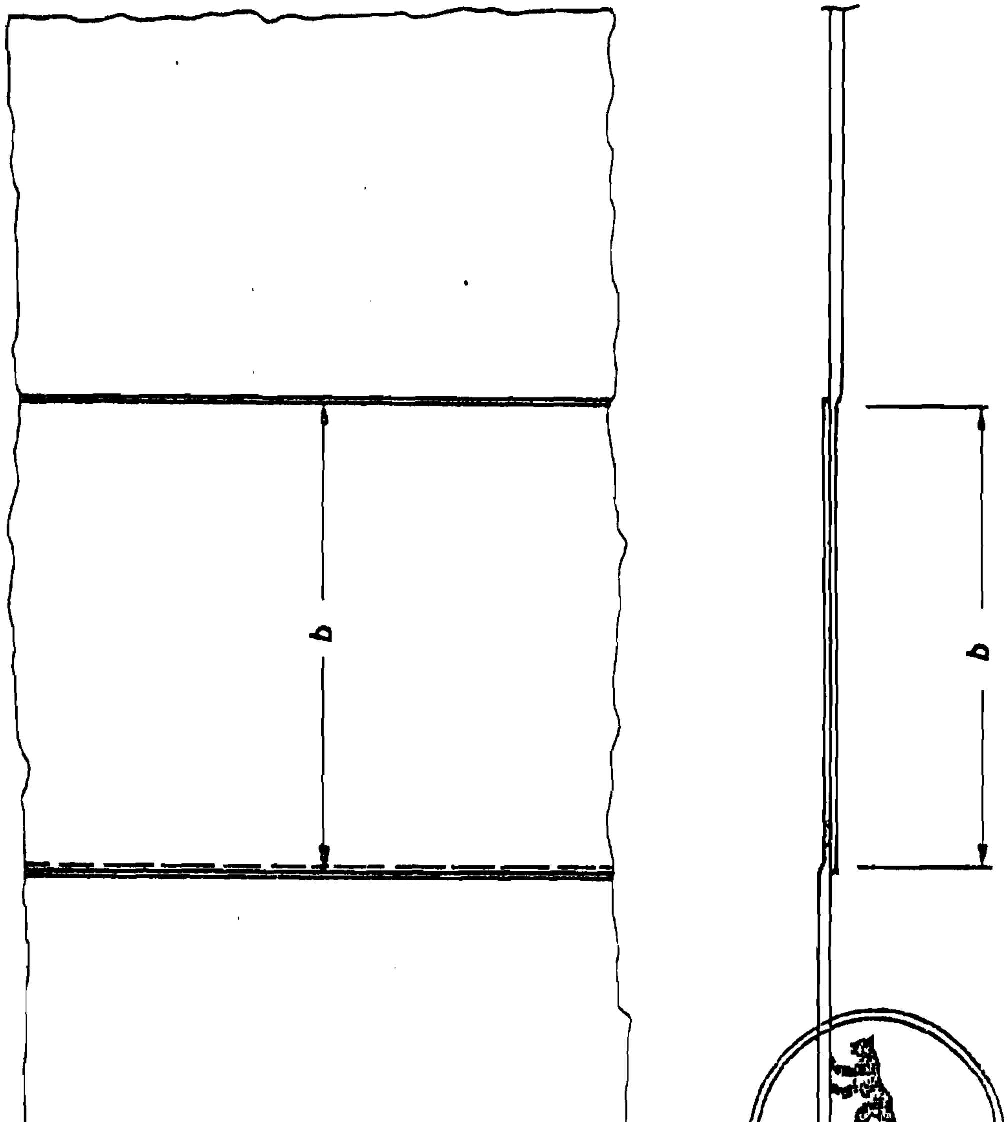

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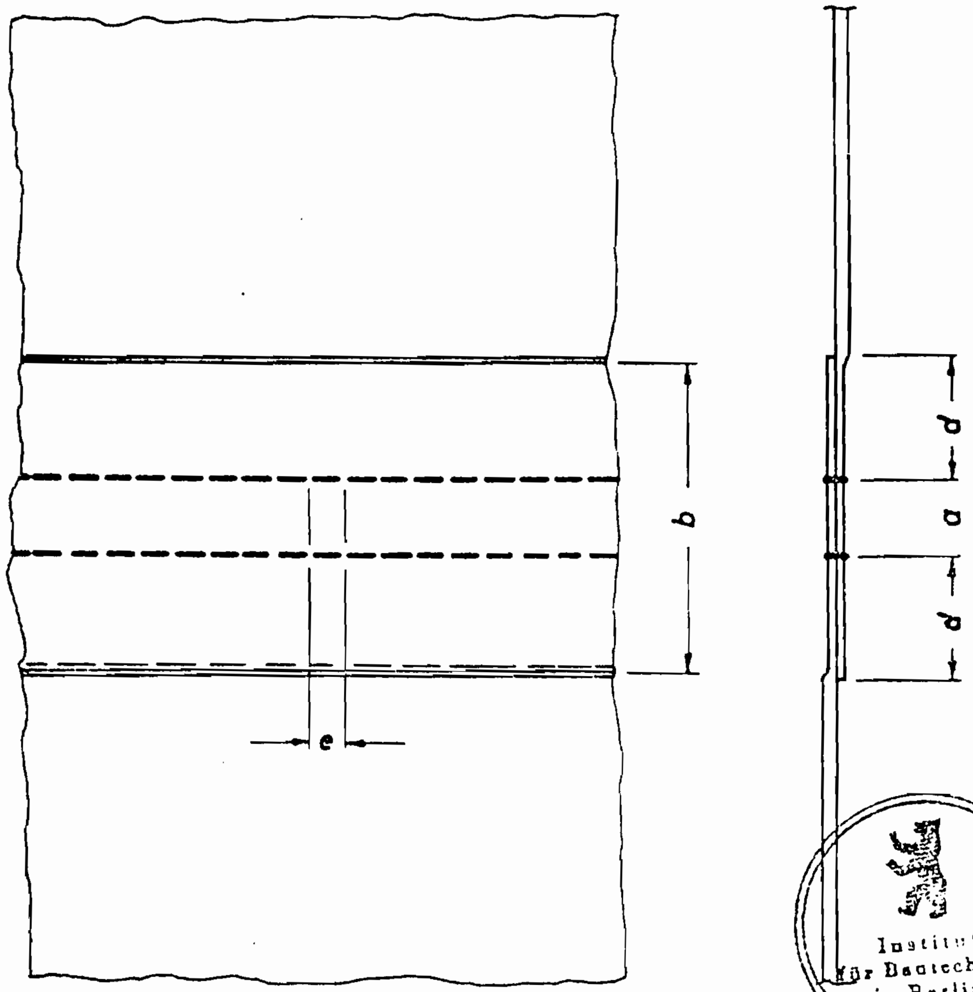
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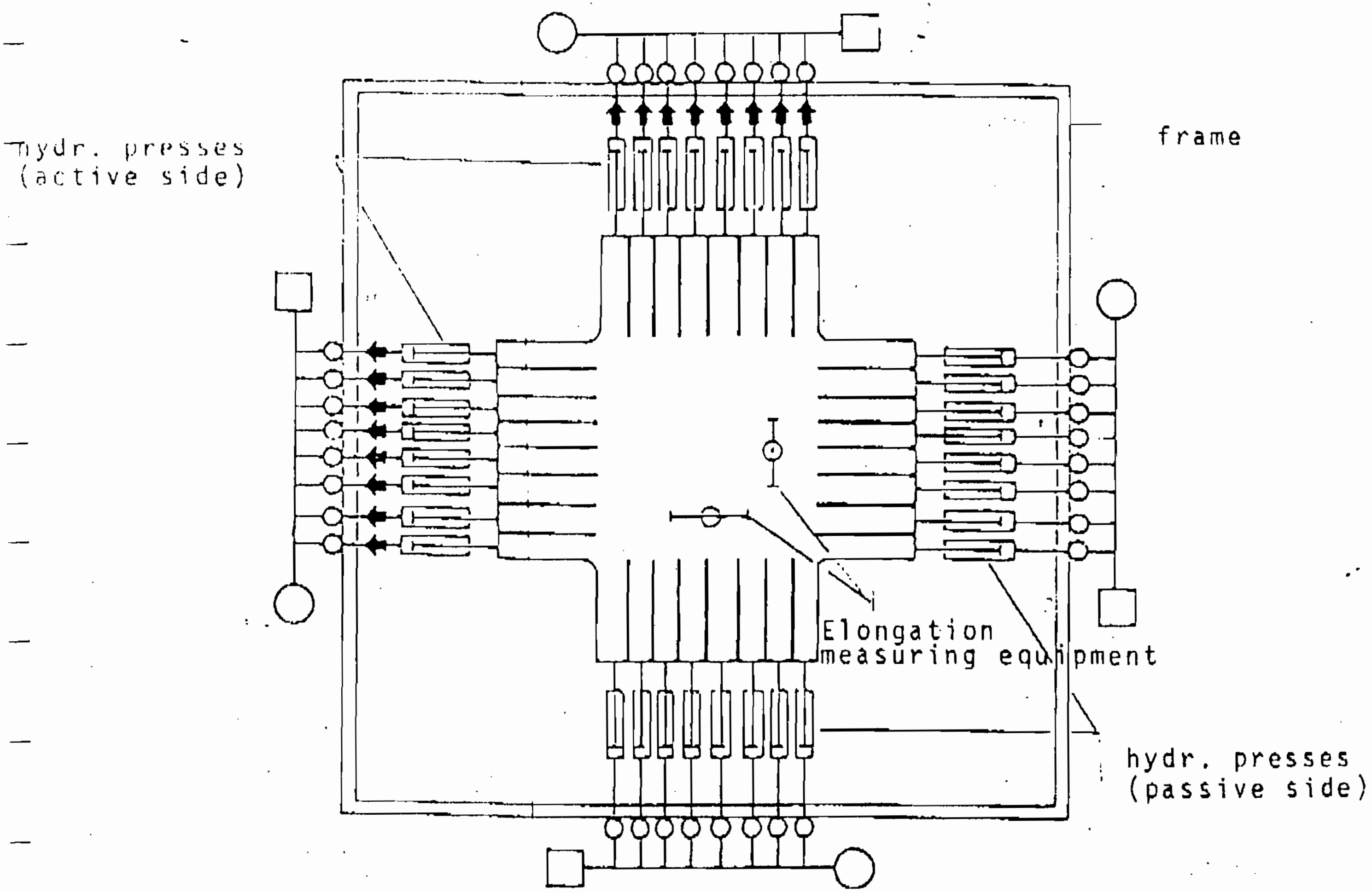
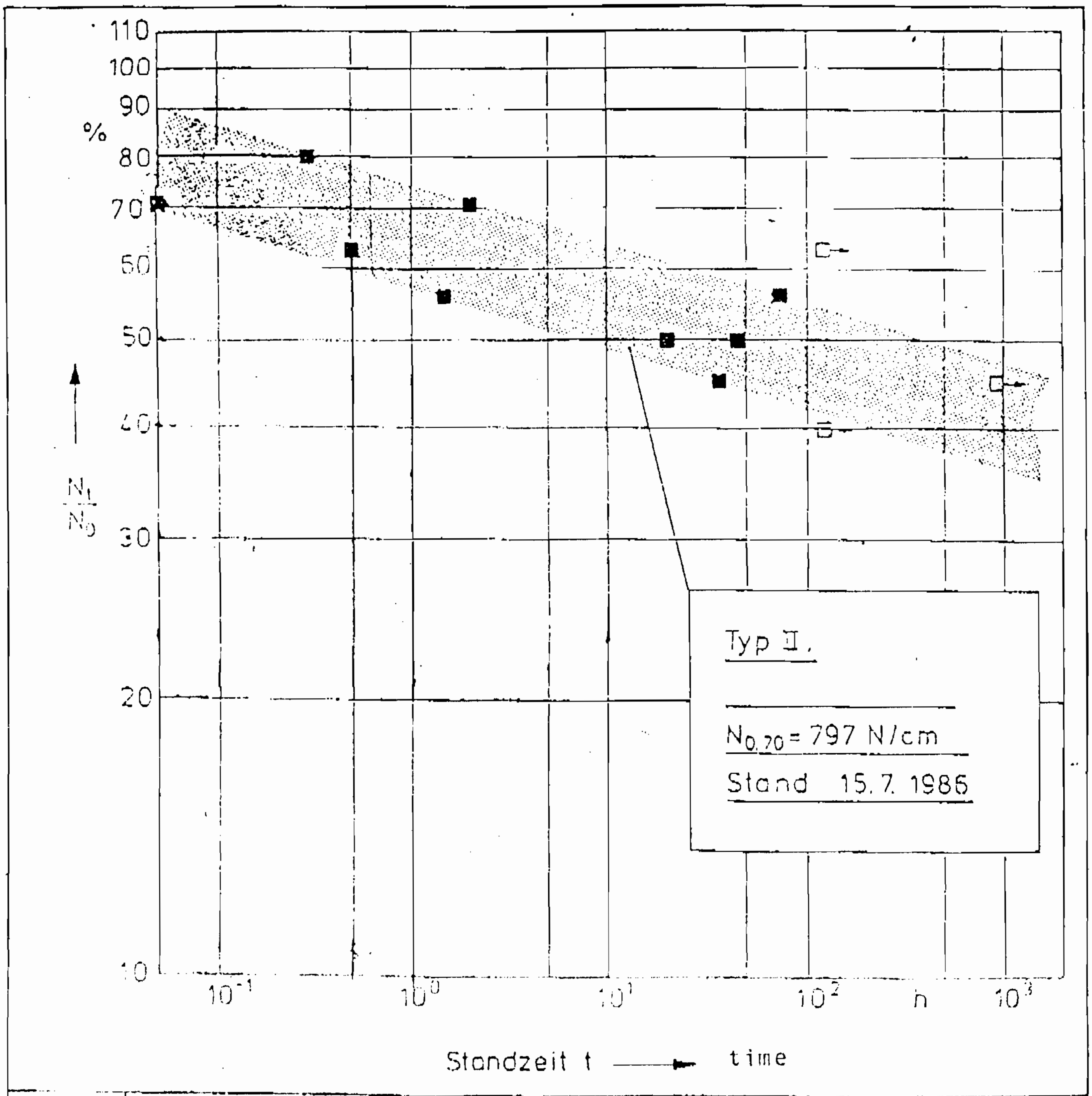
Scheme for the bi-axial test of fabrics

Photo 2





Typ II.

$N_{0,70}$ = 797 N/cm

Stand 15.7.1986

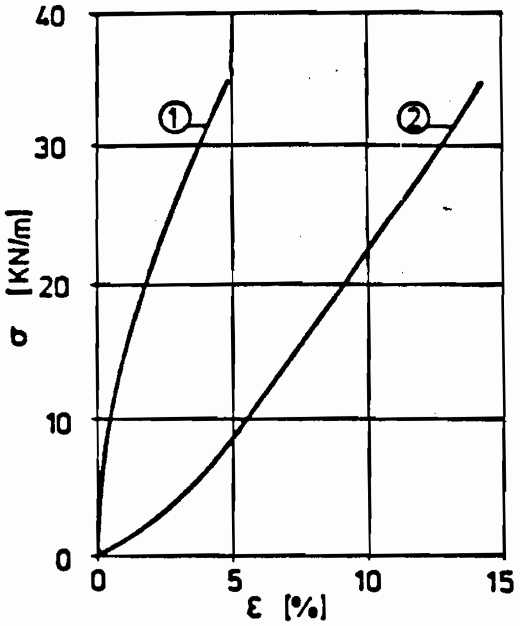
Time dependent rupture behaviour at 70° C of HF seam 60 mm width, weft direction, out of PVC coated TREVIRA high tenacity fabric, with acrylic lacquer

Spannungs-Dehnungs-Verhalten

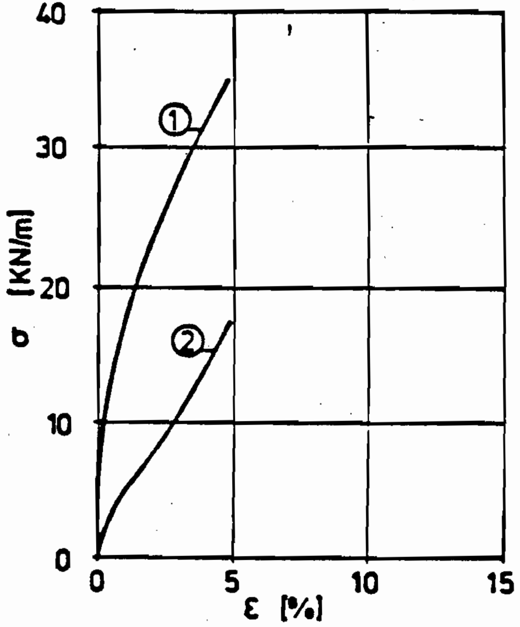
Stress-Strain-Behaviour

Tension-Allongement-Comportement

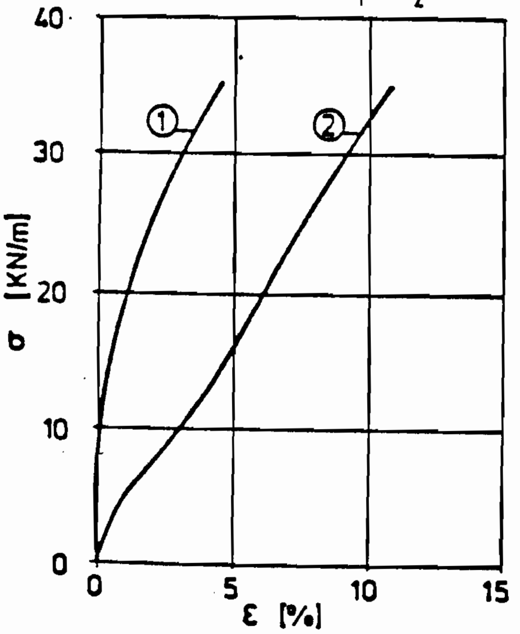
Uniaxial Test



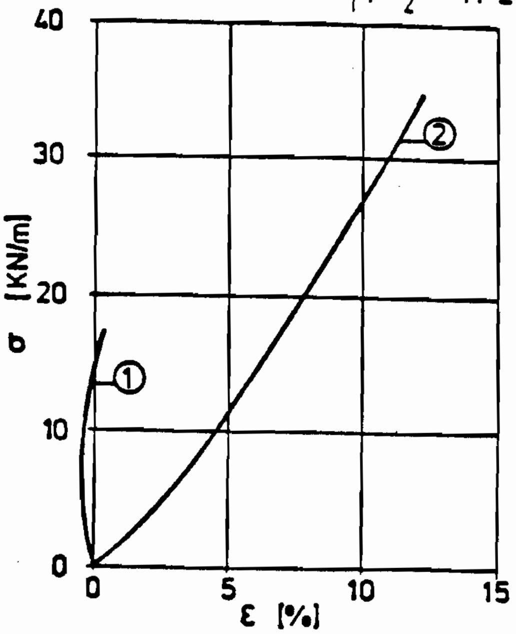
Biaxial Test $\sigma_1 / \sigma_2 = 2/1$



Biaxial Test $\sigma_1 / \sigma_2 = 1/1$



Biaxial Test $\sigma_1 / \sigma_2 = 1/2$



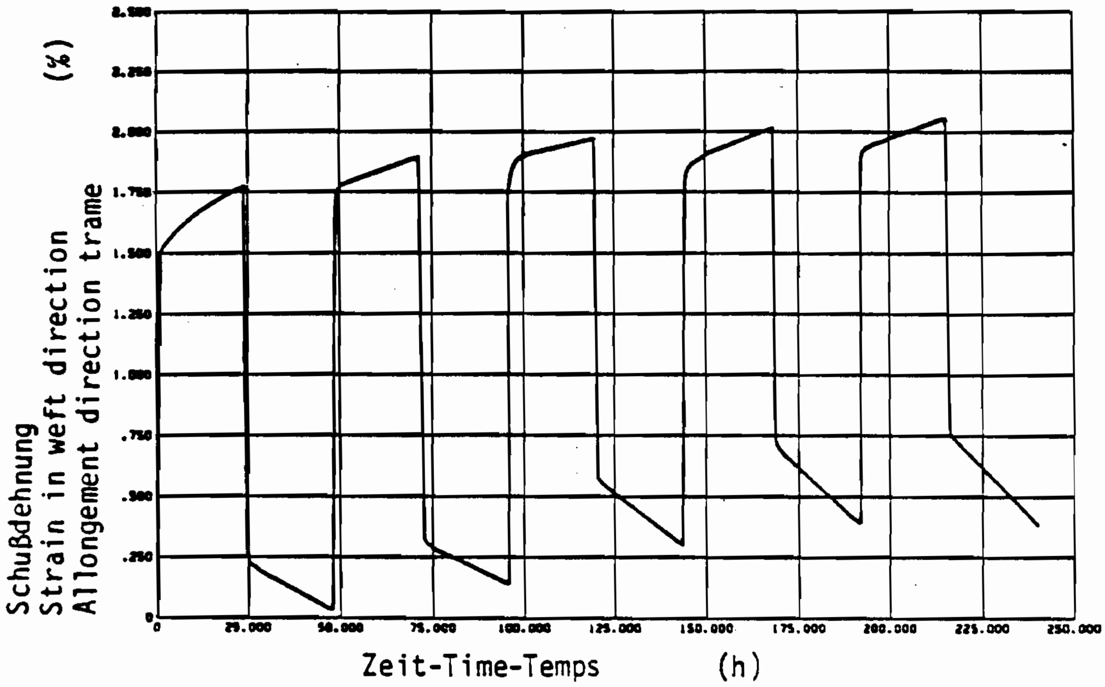
σ_1	..... Kettspannung	Stress in warp direction	Tension direction chaine
σ_2	..... Schußspannung	Stress in weft direction	Tension direction trame
ε_1	..... Kettdehnung	Strain in warp direction	Allongement direction chaine
ε_2	..... Schußdehnung	Strain in weft direction	Allongement direction trame

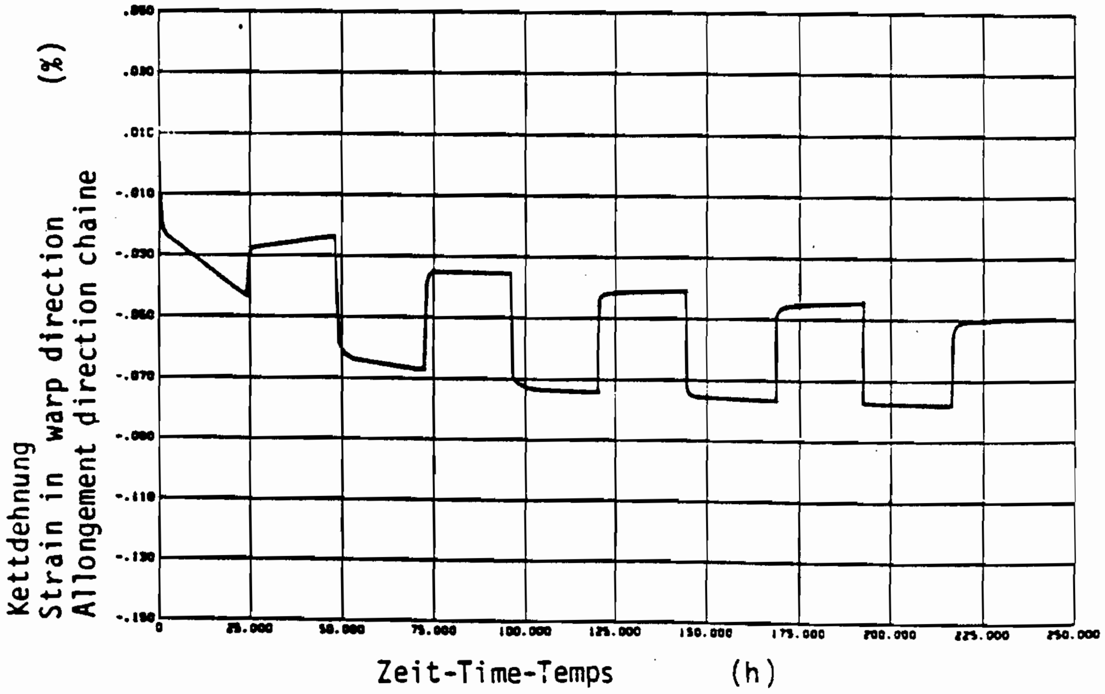
POLYMAR 6601

Biaxiales Langzeit-Verhalten	Biaxial Long-Time-Behaviour	Biaxial Long-Temps-Comportement

Belastung / Stress / Tension = 3 KN/m (1:1)

24 h Belastung-Stress-Tension / 24 h Entlastung-Discharge-Dêcharge





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