THE MEMBRANES USED FOR THE LIGHTWEIGHT STRUCTURES WITH CABLES AND MEMBRANES

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ABSTRACT
The lightweight structures with cables and membranes into construction practice, was an important stage in the management of complex structural form, so that they lead to optimum economical results. The investigations are necessary to determinate the mechanical characteristics of structural membranes. For this reason, this article is about practical determination of these characteristics by experimental testing.

INTRODUCTION
The characteristic demands for structural membrane foils [7] and the material choosing is conditioned by a great number of factors such as:
* Criteria of strength,
* Criteria of rigidity,
* Resistance to alteration,
* Thermal insulating properties,
* Acoustic properties,
* Optical properties.

MATERIALS AND METHODS
1. Classification of structural membrane foils
The membrane is the result of several cut foils joining. Two kinds of materials are used for the foils: isotropic and anisotropic, [1], [2], [7].

A. Isotropic materials
The isotropic materials are the foils made of metals (steel, aluminium), polyesters, polyethylene, polyvinylchloride (PVC), polyvinylfluoride (PVF or Tedlar).

In practice, the most used are the foils made of metals due to their durability and resistance in time (practically, they don't present creeps and they don't relax). The disadvantage is their great sensibility to deformation before the site works, so special cutting problems occur here. The isotropic foils are one-layer or multi-layer materials like a co-operative assembly (Fig.1).

Fig.1. The isotropic foils
B. Anisotropic materials

These materials, with properties orientated orthotropic or by more direction, are made especially by ondulated or profiled sheet metal and by reinforcing the isotropic foils with fibbers - the so-called composite materials. (Fig. 1, 2), [3].

![Composite material](image)

**Fig. 2. Composite material**

Fibber used for reinforcing:
- a) organic: flax, hemp or cotton,
- b) mineral: glass, carbon or graphite fibbers,
- c) synthetic: polyesters (Trevina, Diolen), polyethylene (Fabrene), poiyamides (Perlon, Nylon), polyacrylonitrile (Dralon), aramides (Kevlar).

The isotropic connection layer or the top layer (the coating) is made also by synthetic rubber (Neoprene), polyurethane, poiytetrafluoroethylene (Teflon), [4], [5], [6], [7]. Using the metal and glass fibbers, the tensile strength increase to unexpected high values. The testing of a Kevlar fibber reinforced and PVC coated membrane showed a 6.9 kN/cm tensile strength.

2. Experimental essays for structural

The mechanical characteristics needed for a proper design of membranes depend on lot of factors, such as: the nature of the material, the speed and the time of loading, the climatic conditions, the presence of the joints, the aging of the foil, the storage conditions (for example, damages caused by the folding of the material or a not proper storage).

2.1. The tensile strength

The design standards for cable and membrane structures (Germany, USA, Hungary) give a formula for the calculus of the tensile strength:

\[ R = \frac{\bar{R}}{k} \]  

where:
- \( R \) is the average value of tensile strengths obtained with rapid essays,
- \( k \) is the product between \( k_1, k_2, k_3, k_4, k_5 \),
- \( k_1 \) is the influence of the aging of the material; \( k_1 = 1.2 \) for an average life less or equal with 10 years, \( k_1 = 1.4 \) for an average life longer then 10 years,
- \( k_2 \) is the influence of long term loading; \( k_2 = 1.0 \) if the solicitation from long term loading is less then \( 0.15\bar{R} \) and \( k_2 = 2.0 \) if the solicitation is between \( 0.15\bar{R} \) and \( 0.5\bar{R} \),
- \( k_3 = 1.2 - 1.4 \); represent the variation of \( R \),
- \( k_4 = 1.25 \); represent the influence of assembling inaccuracies,
- \( k_5 = 1.3 - 1.5 \); represent the influence of the calculus model.

The tensile strengths are obtained using the following tests:
- uniaxial test,
- biaxial test,
- "membrane" type test,
- "cylinder" type test.

* The uniaxial test

The used standard is STAS 9051/2-79 (Elastomers or plastic materials coated textile fabrics - determination of tensile breaking strength and tensile breaking elongation). This standard stipulates that the measurements must be taken on five samples, both on the warp and fill directions. The sample width is 50 mm. [7], [8].

The introduction of material in the testing machine is made by using special equipment (Fig.3).

![Fig.3. Equipment for testing](image)

* The biaxial test

In this case the tensile test is made by simultaneous solicitation of the material after two orthogonal directions in the plane of the sample. The solicitation is applied on both directions in different ratios.

The sample has a central square form test region and the prolongation on both directions has a clamping role. Figure 4 presents the dimensions of a sample used in Germany. The testing is made with specialized equipment, [10].

![Fig.4. Sample form used in Germany](image)
Figure 5 presents such testing equipment that belongs to the Mechanical Department of Technical University of Cluj-Napoca, made by the authors of this work.

**LEGEND:**

1. Tensioning screw  
2. Material sample  
3. Jaws for fixing the material  
4. Dynamometric spring  
5. Frame  
6. Comparing watch  
7. Loading lever  
8. Gas butner heater

*Fig. 5. Testing equipment used in Technical University of Cluj-Napoca*

Other biaxial measurements are obtained from:

- Membrane type test  
The membrane is subjected to a uniform pressure. The membrane has its edges fixed on a circular plane outline (Fig.6)

*Fig. 6. Membrane type test*

- Cylinder type test  
The samples have a cylindrical shape with the ends fixed in special parts (Fig.7).

*Fig. 7. Cylinder type test*
2.2. The tear strength

The used standard is STAS 6144-86 "Tear strength determination" for any type of tissues. The samples are made with wings. Five measurements are taken on both warp and fill directions. Other countries use four more test types: tongue (Fig.8.a), paws (Fig.8.b), pendulum (Fig.8.c), trapezium (Fig.8.d).

![Fig.8. Sample for the tear strength](image)

The knowing of tear strength is important in choosing of foils.

2.3. Adhesion strength

For the testing of elastomers and plastic material coated textile fabrics the standard is STAS 9051/3-85. The adhesion strength is the average force required for a continuous propagation of the separation line between the coating and the fabric (Fig.8).

![Fig.8. Sample for adhesion strength](image)

2.4. Compression strength

This strength means the modifying of foil's thickness $t$, because of an orthogonal loading on the material's surface (Fig.9). The compression strength curve is obtained by representing the variation of foil's thickness in respect with the applied load.

The tangent line to the beginning part of the curve represents the compression modulus.

![Fig.9. Sample for compression strength](image)
2.5. Stress determinations in soap films

Introducing the metal trame shown in figure 10 in a soap solution the mobile side A-B displace upwards. The value of $F$ force is known from physics; it is proportional to A-B side's length

$$F = 2\alpha l$$

Where: $\alpha$ is a constant value depending on the liquid's nature, it is measured in $N/m$.

![Fig.10. Soap films test](image)

The superficial stress has an energetically interpretation. Thus, if the A-B side displace with $\Delta s$ downwards, the surface's increasing (considering both sides) is

$$\Delta A = 2l \Delta s$$

The work done by $F$ force is

$$\Delta W = F \Delta s = 2\alpha l \Delta s = \alpha \Delta A$$

This work is transformed in surface energy

$$\Delta W = \Delta E_s$$

From (4)

$$\alpha = \frac{\Delta W}{\Delta A} = \frac{\Delta E_s}{\Delta A}$$

So to change the soap film surface's with one is necessary a work equal with $\alpha$.

3. The characteristic demands for polymers coated fabric's

3.1. Testing of non-coated fabrics

These tests were made in order to make a comparison between the coated and non-coated fabrics to see exactly what's the coating influence, [14], [15].

As shown in figure 11, on the fill direction the material's curves are very appropriate. This means that the coating has an insignificant contribution to the stress taking over. On the other hand this means that coating didn't modify the fill. On the warp direction the curves have different aspects. The US line shows at the beginning a stretch of the coated fabric and till $\varepsilon \approx 1.1\%$ US is
parallel to BS. This means that a stretched fill behave like a warp. The coating process modifies the fill comportment. [16], [17], [18], [19].

![Fig.11. Testing curves](image)

### 3.2. Strength characteristics

The tensile breaking strength and the tensile breaking strain can be determined by short time essays, which are considered being instant. Usually, the strengths are not measured in \( \text{daN/cm}^3 \) because of non-homogeneity of the material and the difficulty in finding a real cross section. The tensile strength is obtained from axial measurements and is measured in \( \text{daN/cm} \). The sample’s width is 50\( \text{mm} \). [18].

**CONCLUSIONS**

* The tensile strength for isotropic foils is 0.10 – 0.80 \( kN/cm \). For the PVC coated fabrics, the tear strength is different for the warp and fills direction. So, for the warp direction this strength is 0.15 – 1.30 \( kN/cm \). The tensile breaking elongation is 10 – 60%.

* The tear strength for PVC coated fabrics is 0.10 – 0.80 \( kN \).
* The initial elastic modulus for PVC coated fabrics is 1 – 7 \( kN/cm \).
* Other required characteristics for projecting the anisotropic PVC coated fabrics are:
  - the weight for 1\( mm \) thickness is 10 \( kN/m^2 \),
  - the coefficient of thermal extension is \( \alpha = 2 \cdot 10^{-3} ^\circ C \),
* After repeated essays on the PVC coated fabrics the conclusions are:
  - On the fill direction the comportment is almost elastic, the charge-discharge curves are nearly identical. The lost energy after every cycle is small in respect with the useful energy. The remanent deformations are small. This behavior shows that the forces and strains are taken instantly by the material and the damping is very small.
  - On the fill direction the behavior is of viscous-elastic type. The hysteresis curves are bigger and the remanent deformation increases more then on the warp direction.
REFERENCES


