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# New methods of determining the stress-strain behaviour of woven and non woven fabrics in the laboratory and in practice

# Nouvelles méthodes pour déterminer le comportement sous tension des textiles tissés et non tissés au laboratoire et dans la pratique

RESUMé
Une attention toute particulière a été réservée ces dernières années à la mise au point de nouvelles méthodes spéciales de mesure dans l'intention de déterminer les rôles que peuvent jouer les nappes textiles dans le domaine du Génie Civil.

La mesure bi-dimensionelle des caractéristiques de tension et de contrainte (méthode de laboratoire).

En matière de stabilisation des sols, une nappe textile subit une charge bi-dimensionelle du fait que l'étirement dans un sens et le rétrécissement perpendiculaire au sens de l'étirement se trouvent empêchés par le poids du sol. Pour simuler cette situation, un manchon d'épreuve a été construit conformément à un prototype réalisé par L.R.P.C., à St. Brieuc. Les variations de la force de traction et de l'allongement de rupture mesurées sur des tissus révèlent que ces tissus présentent une excellente stabilité, et ce, même diagonale.

La mesure de l'allongement (sur le terrain)

. pendant la construction
Il a été mis au point un système avec lequel une "unité de mesure des contraintes", fixée au tissu, transmet (électriquement) des renseignements sur la question de savoir si et quand l'allongement du tissu -quel qu'en soit le pourcentage- dépasse certaines limites déterminées à l'avance.

. après la construction
Pendant la fabrication du tissu, un fil de couleur peut être tissé dans le tissu tous les 50 cm, ce qui crée optiquement dans le tissu une grille nettement visible. Des excavations entreprises localement permettent de déterminer la déformation de cette grille.

Fluage et détente

Le comportement des tissus réalisés en polymères, tels que le polyamide et le polyester, sous charge de longue durée est très important. Des recherches intensives ont donné des résultats intéressants pour le polyamide et le polyester (tant sous charge constante que pour un allongement constant) et révélé d'importantes différences en comparaison avec les tissus en polypropylène.

Cellule manométrique pour l'essai de matériaux de revêtement

Le comportement aux tensions et contraintes en flexion peut être mesuré dans une cellule manométrique sur une éprouvette de forme ronde tendue au moyen de griffes entre deux hémisphères. La résistance à la pénétration du matériau de revêtement se mesure en plaçant différents matériaux de support sous l'éprouvette de tissu.

## New methods of determination of the stress-strain behaviour of fabrics-woven and non woven in laboratoriy as well as in practice

In order to determine the functions that fabrics can fulfil in civil engineering much attention has been paid during recent years to the development of special measuring methods. The properties of various fabrics will be explained by means of laboratory investigations and practical tests. The possibilities to which this can lead for applications in civil engineering are at present the subject of study.

## TWO DIMENSIONAL MEASUREMENTS OF THE STRESS-STRAIN CHARACTERISTICS OF FABRICS (LABORATORY METHOD)

Since stress-strain behaviour is highly important, considerable attention has been paid to developing methods of measuring these properties.
A usual laboratory method employs a strip of material of 5 cm width, which is clamped on both sides in the jaws of a tester, the free length of specimen between the jaws being 20 cm. The strip is extended at such a uniform rate that rupture occurs after some thirty seconds. In this test there is a contraction of the test specimen, perpendicular to the direction of testing (especially for non-woven fabrics). For woven fabrics a measuring method of this kind allows only the determination of the strength in the direction of the warp and of the weft since a strip cut diagonally (fig. 1) cannot be clamped in position (no threads are clamped at both top and bottom).

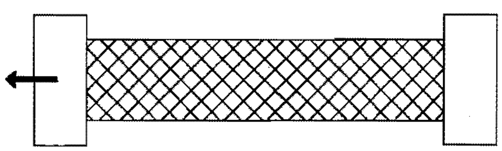

Fig. 1.
Strip, cut diagonally, between jaws.
No threads are clamped at the top and at the bottom.

This had led to a very limited diagonal strength being wrongly attributed to woven fabrics. In view of the two-dimensional conditions of loading to which such an insertion in the soil is subjected (stretching of the insertion while constriction perpendicular to the direction of elongation is prevented because the insertion is firmly fixed in position), it is also of importance to measure the stress-strain characteristics of the insertion in circumstances in which constriction is encountered. This is possible using the recently developed sleeve tester (this apparatus has been built on the basis of a prototype developed at the laboratoire Regional des Ponts et Chaussées, St. Brieuc, France).
In this apparatus the insertion, made up into a sleeve is inflated by water pressure, while clamps at top and bottom prevent the sleeve from shortening. The device is schematically shown in fig. 2. and is suitable for measuring the following characteristics:

- breaking strength
- elongation at break
- modulus E (at any specified elongation)
- coefficient of contraction (Poisson constant)

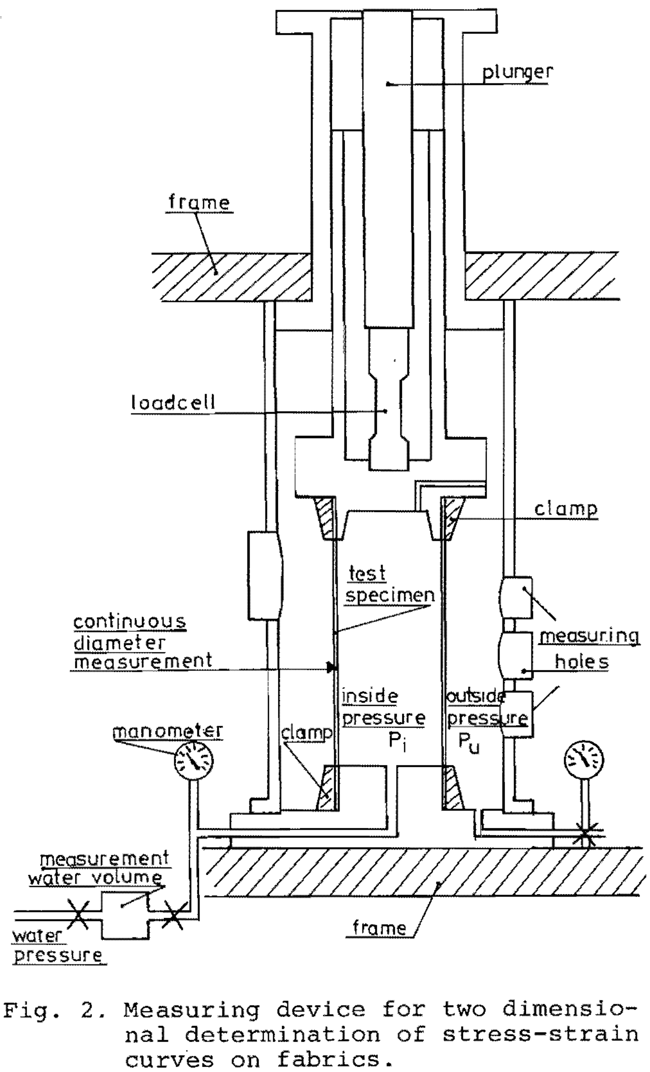


Fig. 2. Measuring device for two dimensional determination of stress-strain curves on fabrics.

For measuring these characteristics the material has to be sewn or glued in the shape of a tube.

In fig. 3 such a tube is shown together with a chosen cylinder coordinate system. We can define the following parameters:

- . vertical elongation $\varepsilon z$
- . tensile force in vertical direction $\sigma z$
- . elongation in tangential direction $\varepsilon_{\theta}$
- . tensile force in tangential direction $\sigma_{\theta}$

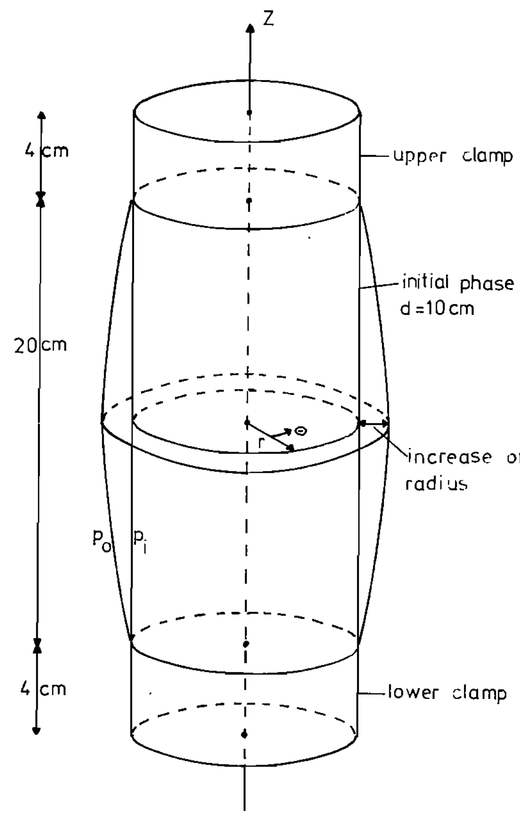


Fig. 3. Cylindrical test specimen (sleeve)

The device has been built in such a way that four different types of experiments can be carried out. For each type of measurement one parameter remains unchanged, the other three being measured.
The most feasible method seems to be the test in which the elongation $\varepsilon z = 0$.

Results for woven STABILENKA fabrics

Figs. 4 and 5 give the measured variation of tensile strength and extension for a low modulus fabric (A) and a high modulus one (B).
With respect to tensile strength the fabrics possess a great degree of isotropy, the strength being about equal to the 5 cm strip strength as woven fabrics possess hardly any contraction.
In respect of the extension there proves to be a ratio of 1.5 in the extension in a diagonal direction and in that of the warp and the weft. The strength of woven fabrics may be arbitrarily chosen between 1 - 200 kN/m' or higher. The elongation characteristics of fig. 5 broadly show the situation of all woven fabrics. However this two dimensional measuring method clearly demonstrates that woven fabrics possess an entirely acceptable diagonal stability.

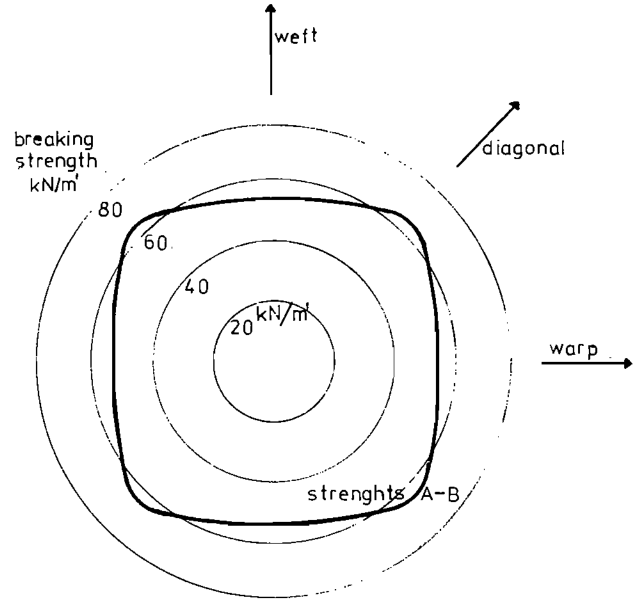


Fig. 4. Breaking strength as a function of the direction of testing for a polyamide (A) and a polyester (B) woven fabric.

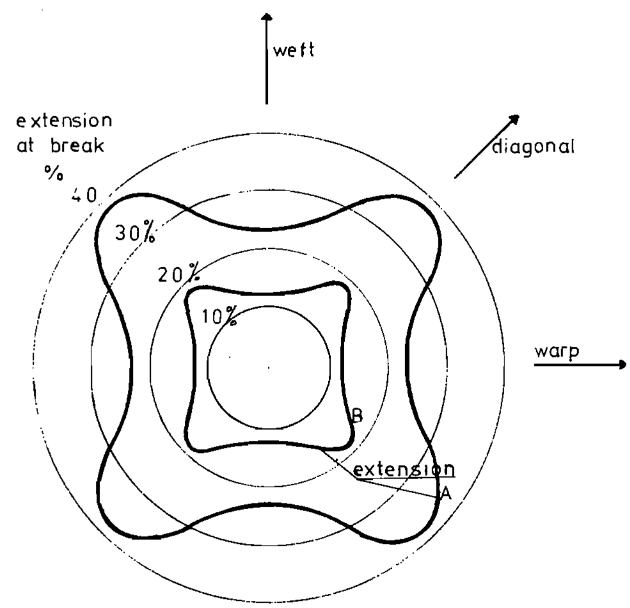


Fig. 5. Elongation at break as a function of the direction of testing for a polyamide (A) and a polyester (B) woven fabric.

Results for non woven fabrics

Non wovens mostly show a considerable coefficient of contraction. This causes an important difference between the results of strip testing (1 dim) and sleeve testing (2 dim). In fig. 6, the stress-strain curves of two different non wovens, A and B, have been drawn.

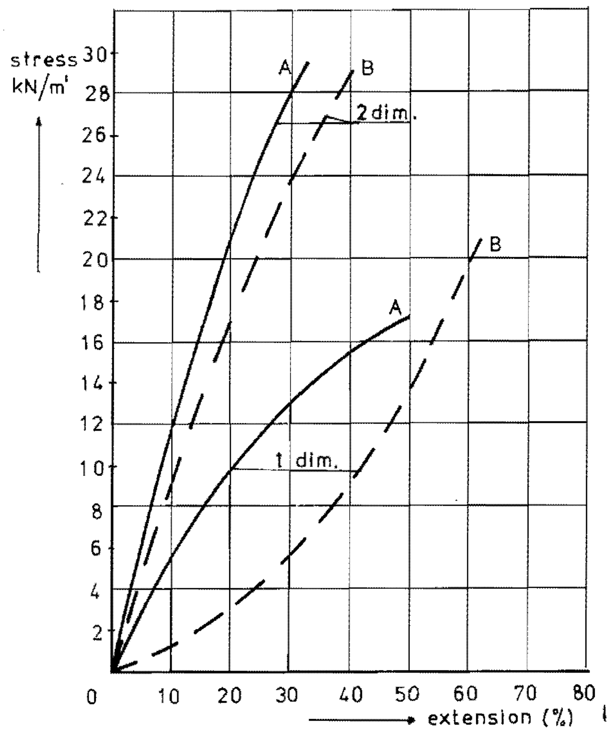


Fig. 6. Stress-strain curves (one and two dimensional) for two different polyester non woven fabrics.

In comparison with one dimensional testing it can be roughly said that the results of two dimensional testing show:

- a higher stress at break (increase 30-50 %)
- a lower strain at break (decrease 30 - 50 %).
- a Poisson constant of 0.25 - 0.50.

This means that these non wovens possess a much higher modulus E than the results of one dimensional testing would suggest.

ELONGATION MEASUREMENTS (IN THE FIELD)

The measurement of the state of strain of a fabric embedded in the soil is no easy matter.
In the course of our trials two methods of measurement were developed to enable the elongation during a load situation at least to some extent to be measured.
The first method is suitable for the measurement of elongation under a soil load for woven fabrics as well as for non wovens.
The second method needs local excavation before the deformation can be determined and is only applicable for woven fabrics.

During construction

A system has been developed by which a "strain gauges unit" fixed to the fabric, gives information if and when the elongation of the fabric, irrespecitve of the percentage, exceeds certain predetermined limits.
The principle is schematically represented in fig. 7.

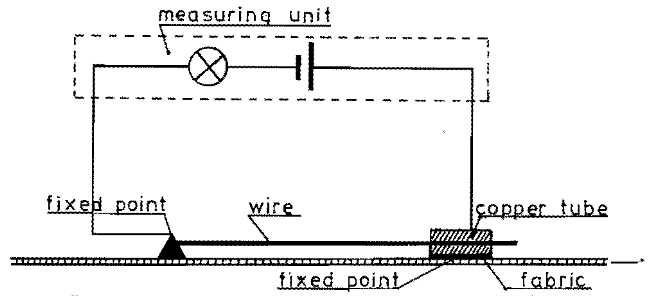


Fig. 7. Principle of "strain gauges" measuring unit.

By means of these units, built into several trial embankments, an insight has been gained into when and to what extent deformation of the subsoil and the subsequent deformation of the insertion occurs.
As the information supplied by one unit is qualitative rather than quantitiative, it is nessesary to fix a fair number of units to the fabric.
From the results obtained from all these units it is usually possible to reconstruct a rather accurate picture of the deformation under the embankment.

After construction

During production of a woven fabric a coloured thread can be woven into it at fixed equal distances. When this is done in both warp and weft directions a clearly visible grid network is produced in the fabric.
The deformations in the subsoil will cause deformation of the two dimensional grid network. During local excavation (local because of the need to prevent relaxaton of the mainly elastic elongation of the fabric) the deformation of the grid network can be determined.
During experiments, described in the paper "Reinforcement with fabrics, a new technique to improve the stability of embankments on weak subsoil" by MM Volman, Krekt and Risseeuw the above-mentioned method of a visible grid network combined with "strain gauges" has been used to determine the deformation of the reinforcing woven fabric under the embankment.
The results, gathered by excavation trench for trench, have been given in fig. 8.
With this method clear and rather accurate information leads to knowledge of which strain and, by means of the two dimensional stress-strain curves, to which stress the fabric has been exposed. After total excavation of the trial embankment and after relaxation of the woven fabrics the strains are less than 3 % (Fig. 8), so the deformation of the fabric during about 2 months seems to be elastic for the greater part.

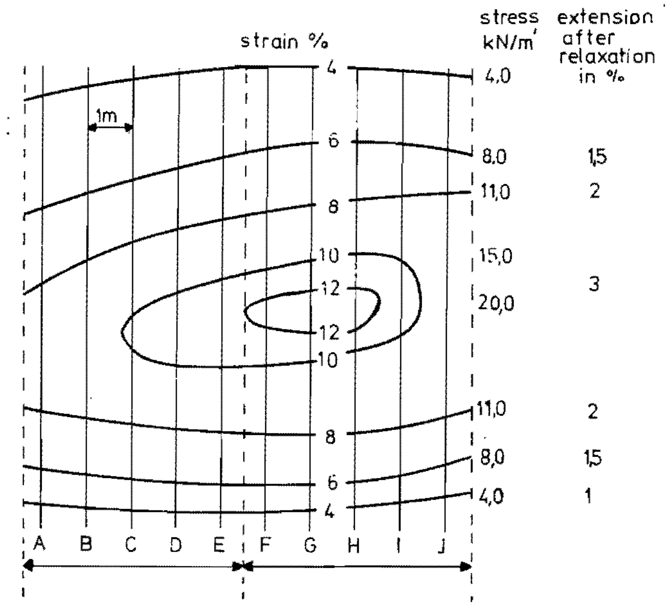


Fig. 8. Stress, extension and relaxation data of a polyamide fabric under an embankment.

## CREEP AND RELAXATION

In the above we have been concerned at all times with the breaking strength, measured (one or two dimensionally) for e.g. 30 sec. or at most some minutes, which leads to the standard or norm strength. However in the case of prolonged loading (for years) only part of this standard strength may be reckoned with, since we have to do here with materials which are more or less visco-elastic and are therefore subject to creep (this is the increase of elongation as a function of the time under prolonged loading).

Extensive investigations have shown, that woven fabrics (results of fabrics A and B, the same fabrics as used in fig. 4, 5 are given in fig. 9) can tolerate a constant force of approx. 60 % of the standard strength for several years before break occurs.

80 % of the elongation (see fig. 9 ) that the samples undergo develops during the first 10 minutes after application of the load i.e. during the construction phase, the subsequent elongation (creep) amounts to only one to a few percent of the installed length.

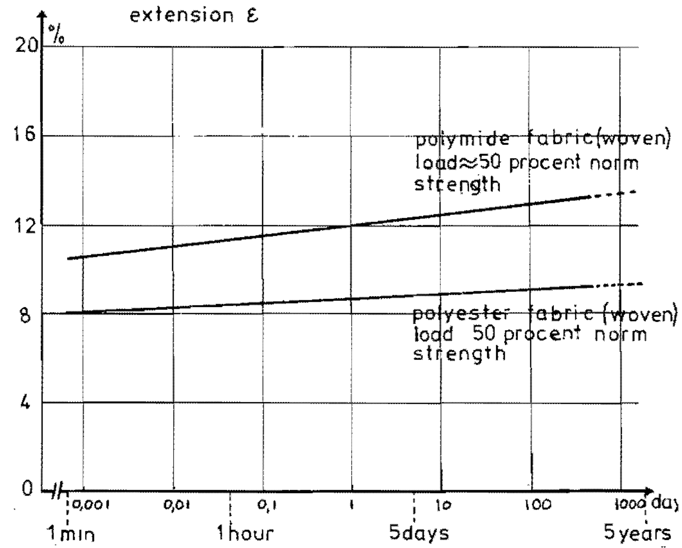


Fig. 9. Creep of polyamide and polyester woven fabrics as a function of time (logarithmic scale)

In this paper no attention has been paid to the properties of polypropene strip fabrics.

As a result of the fact that the stress-strain properties of polypropene strip fabrics are rather irregular, i.e. irregular between different types of PP as well as between the yarns of one kind, it is very difficult to draw stress-strain curves or creep results exactly. In any case, it can be said that the creep of polyester is somewhat less than that of polyamide, the creep of both being less than PP creep.

When, in a given situation, constant elongation is present instead of constant load, the tension will decrease with that constant

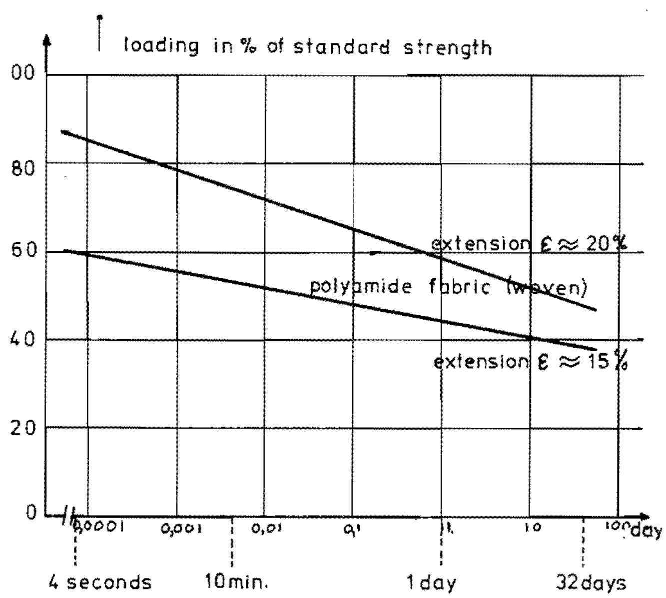


Fig. 10. Stress relaxation of a polyamide woven fabric.

elongation, or in other words, relax. Relaxation (this is the decrease of tension as a function of the time under constant elongation) follows about the same time scale as creep, i.e. an action of tension, once produced, lasts for years for the greater part (see fig. 10).
In such a case loading of for instance to some 80 % of the standard strength is permissible because this condition of loading is less serious for the material than a high constant load.

PRESSURE CELL FOR TESTING LINING MATERIALS

Testing materials in the laboratory in such a way that the materials are exposed to a deformation that approximates best to the deformation the insertion undergoes during practical use, must be the aim of application research. For instance in civil engineering this means that one has to take into account the fact that a deformation in the plane of the insertion in practice is mostly combined with soil deformation perpendicular to that plane. This is usually caused by a very irregular subsoil or by very local differential settlements. In order to have the ability to create a kind of 3 dimensional deformation an apparatus has been constructed in which the stress-strain behaviour under all directional loading can be measured on a round sample, clamped between two semipheres. The apparatus has schematically been drawn in fig. 11.

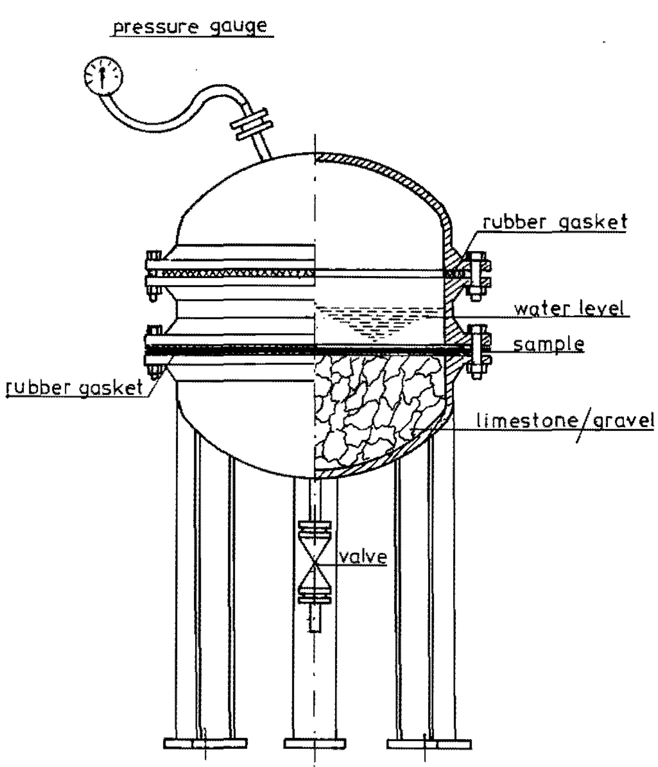


Fig. 11. Pressure cell for testing lining materials

The bottom part of the round spherical steel vessel with inside diameter of 60 cm can be filled for instance with clean sand, (rounded) gravel or (sharp) limestone.
A round sample with a matching pattern of holes for the bolts is placed between the flanges (see fig. 11) and over the sand or stone bed. By means of water pressure the sample can be deformed and pressed upon the filling material.
In this pressure vessel the following characteristics of an insertion can be tested:

- the stress-strain behaviour under all directional loading
- the penetration resistance against sharp limestone or other hard objects in the subsoil.
- the properties of an overlap construction.

With regard to the stress-strain and penetration resistance measurements the results show clearly that on clean sand all liners perform satisfactorily. But placed upon a subsoil in which stones with sharp pointed sections are to be expected. only liners with a heavy high tenacity fabric will stay undamaged.

Depending on application and the circumstances in which the insertion will be applied in practice, these and all the other test results can help you to choose the material that performs best in a given situation.

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