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METHOD OF CALCULATION OF STRESSES AND DEFORMATIONS IN A GEOTEXTILE UNDER LOAD

METHODE ZUR ERMITTLUNG VON SPANNUNGEN UND VERFORMUNGEN EINES GEOTEXTILS UNTER LASTEINWIRKUNG

METHODE DE CALCUL DES CONTRAINTES ET DEFORMATIONS DANS UN GEOTEXTILES SOUS CHARGE

This contribution presents a new method of calculation of stresses and strains in thermobonded and spunbonded non woven geotextiles under load.

This theorical study and the experience are in good agreement.

Thanks to this theory, lateral contractions that are observed during tensile tests in different widths can be explained.

1. INTRODUCTION

The target of this work is to try to clear up the internal behaviour of a non-woven geotextile, about displacements and stresses.
The non-woven geotextiles having a fibrous and very complex structure, we can expect the intervention of a great number of parameters (types of fibres, connection...).

A lot of authors have made researchs over this particular and delicate problem which concerns the determination of the "POISSON's ratio" of the geotextiles (or better the contact coefficient). Their results were very divergent.
In their studies, these authors have supposed that the nappe of geotextile was a continuous medium, what is very far from the reality and can explain the relatively unlikelihood of the results; indeed, certain values of the POISSON's ratio go beyond the value of 0,5 which is the maximum for a continous medium, from the second principle of thermodynamics.

To take into account this discreet structure of the non-woven geotextiles, we must imagine a specific model.
This study will be limited to the two types of the most used geotextiles, which are : the thermobonded and the spunbonded.

2. PROPOSED MODEL

So we purpose to make a model of the fibrous product.
This necessits a certain number of simplificated hypothesises.

2.1. Hypothesises of calculation

1) The geotextile is supposed to be homogen, with other words statisticly identical in every point (see proceeding of fabrication).
2) The filaments are continous (the study cannot be applied to geotextiles constituted with short fibres).
3) The filaments are rectilineal :
   - for the thermobonded, it exists a welding between the different filaments; we can consider that, between two points of the sample, we have a fictive fibre constituted with real knitted together filaments

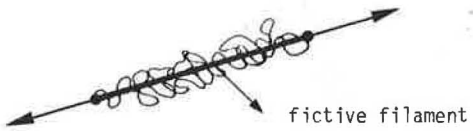


Figure 1 : model fo the filament

   - for the spunbonded, we suppose the same principle. The welding points are here constituted by the friction points.
4) The geotextile is supposed to be isotrop.
5) The geotextile is supposed to be bidimensionnal.
6) We leave out of count the secondary effects as time yield and relaxation.
7) The fibres work only in traction.

2.2. Look of the proposed model

Grounding ourself on the precedent hypothesises, we can establish the look of the model.
Being a fictive filament, coming from a sample, submitted to a tensile test "bread band" and which forms an angle β with the vertical axis oy. This filament binds an any point A to a point in the immediat neighbouring of the grip.

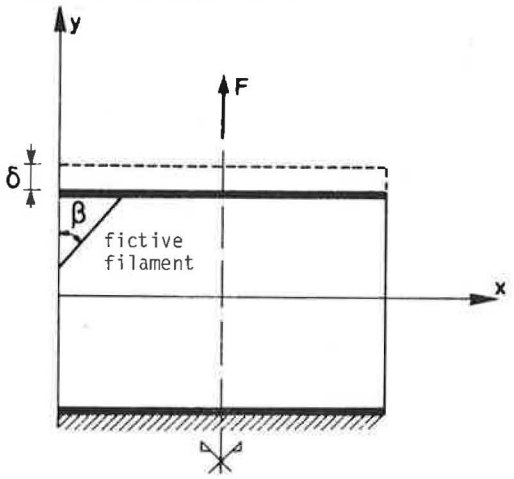


Figure 2 : discretization of the nappe

When the grips have a vertical movement, the point bond to the grips will have a vertical displacement of dh.

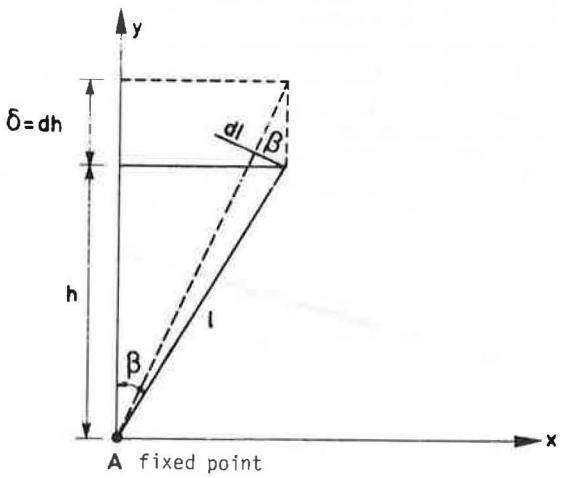


Figure 3 : elementary movement of the fictive filament

A is the point of reference and dh the displacement of the grip with regard to this point.
For a displacement dh, the filament lenghtens of dl :

$$dl = dh \cdot \cos \beta$$

The point A is supposed to be bond with all the points of the grip with a fictive filament. The movement of the point A will be the result of the combination of the tensions and the movements of all the filaments which bind it to the grip. All these filaments don't govern the movements of the point A. Indeed, if d_x represents the lateral movement of A, we'll have :

$$dl \sin \beta = dh \cos \beta \sin \beta$$

Deriving this function with regard to β, we obtain the angle of the fictive fibre which gives maximum d_x :

$$\frac{\partial d_x}{\partial \beta} = 0 \quad \text{gives } \beta = 45°$$

The fibres not resisting against the compression, the fibres directed to 45° condition the lateral contraction of the sample.
If the point A belongs to the border of the geotextile, we can suppose the configuration, represented at figure nr 4, to explain the lateral contraction of the sample.

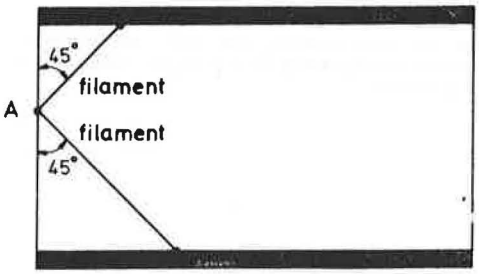


Figure 4 : point A belonging to the free border of a sample of traction "bread band"

The observations treated hereabove permit us to discretize the hole sample so :

- if we want to calculate the stresses and deformations in a point of the geotextile, we bind this point to four points of the grip with brackets directed to 45°;
- these brackets represent a band of filaments of a unitarian breadth;
- the resistances and the rigidities of the brackets can be so measured in numbers;
- every point is independant of his neighbour. The movement of each point can be studied separatively;
- the points to look over, which are in the neighbouring of the free borders of the sample, are bond, on one side to the points of the grips by brackets directed to 45° and, on the other side to the extremal points of the grips by brackets directed to more than 45°.

3. ELASTIC LINEAR BEHAVIOUR OF THE MODEL

This discretization having been made, we have been able to resolve this problem by using the method of the displacements, applied to the calculation of a treillis.
For a first approximation, we have supposed a linear behaviour of the brackets, taking the medium modulus of the geotextiles at the origin as the YOUNG modulus of the brackets.
Taking into account the considered discretization, we can understand that the points situated on the median, then on half-height of the sample and moreover, situated at more than h (height of the sample) of the free border of the sample, haven't lateral movement but only a ver-

tical movement. Indeed, these points are bond to the grips by four brackets equaly directed (45°). The four points of contact have a vertical movement. For reasons of symetry, the investigated point will have a vertical movement. For the points near the free borders, an horizontal movement can be detected on account of the symetry.

The table hereafter gives a view of the results of the movements of a point situated at 14 mm of the free border of the sample and on his median (test with 100 x 500 mm). In this case, the lateral contraction, experimentally measured is greater than that obtained by calculation. That can be explained essentially by the phenomenon of plastification of the brackets.
So we can suppose that we'll have a better correspondance with the experience by taking into account the non-linearity of the behaviour of the brackets and the geotextile.

Grounding ourself on the theorem of the virtual works and on the inner equilibrium, we can build the matrix of rigidity (Fig. 5).

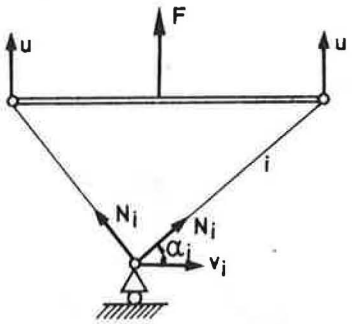
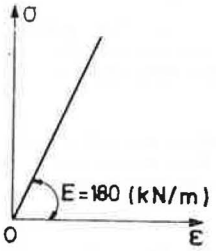
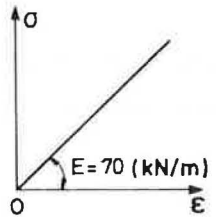
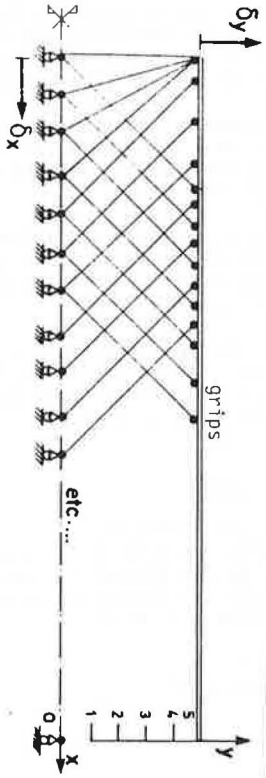
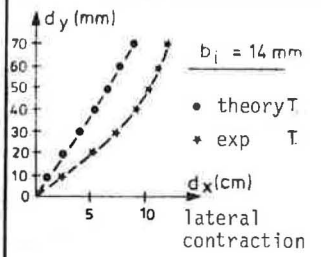
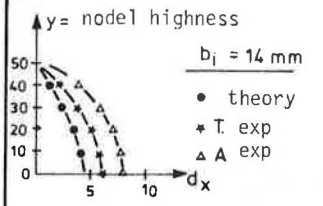
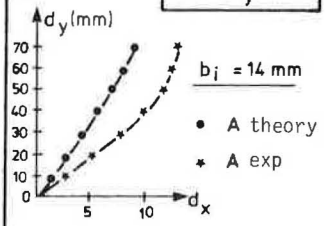


Figure 5 : method of the virtual works elements of the matrix of rigidity

TABLE 1

Material	Discretization of the model	Obtained curves	Remarks
- Thermobonded (T) linear behaviour of the brackets  - Spunbonded (A) linear behaviour of the brackets 		  for $d_y = 3$ cm 	- the linear theory, although it's far from the real behaviour of the geotextile, gives a good approximation of its behaviour - the results for a thermobonded are more significant. The thermobonded are nearer from the hypothesises of calculation of our model

4. ELASTIC NON-LINEAR BEHAVIOUR OF THE MODEL

Really, the behaviour of the geotextiles is not linear. It's possible to take into account this behaviour, thanks a multilinear approach of the relation tension-displacement.

$$K_T = \begin{bmatrix} \sum_{\text{brackets}} \frac{A_i\, E_t}{L_i} \cdot \sin^2 \alpha_i + N_i\, b_s & \sum_{\text{brackets}} -\frac{A_i\, E_t}{L_i} \cdot \sin \alpha_i \cdot \cos \alpha_i - N_i\, b_c \\ \sum_{\text{brackets}} -\frac{A_i\, E_t}{L_i} \cdot \sin \alpha_i \cos \alpha_i + N_i\, a_s & \sum_{\text{brackets}} \frac{A_i\, E_t}{L_i} \cdot \cos^2 \alpha_i - N_i\, a_c \end{bmatrix}$$

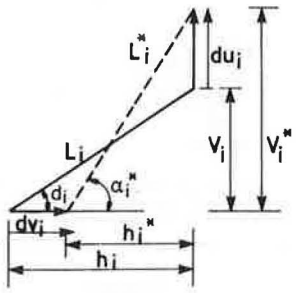


Figure 6 : elementary movement of a fictive filament

with (Figure 6) $a_s = \frac{h_i}{L_i^2} \cdot \sin \alpha_i$

$$b_s = \frac{1}{L_i} - \frac{v_i \sin \alpha_i}{L_i^2}$$

$$a_c = \frac{h_i}{L_i^2} \cdot \cos \alpha_i - \frac{1}{L_i}$$

$$b_c = -\frac{v_i}{L_i^2} \cos \alpha_i$$

Resolving numerically the system of linear equations for n brackets :

$$[k_T] \begin{bmatrix} du \\ dv_1 \\ dv_2 \\ dv_n \end{bmatrix} = \begin{bmatrix} dF \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

The table 2 sums up the results obtained in this case for a point situated on the median of the sample, at a distance of 14 mm from the free border.

For the points situated on more than h (height of the sample) of the free border, there isn't transversal movement.
We 'll note the good concordance between the theory and the experience.

Afterwords, the model has been applied to samples of 5 cm high into grips.
Grounding themself on the photographic proceedings HEARLE and STEVENSON had obtained a "POISSON's ratio" (with all the reserve affected to this term) or, more exactly, a lateral contraction of 1,5.

We have obtained 1,4 by calculation.

5. CONCLUSIONS

It's possible to conclude so :

1) on account of the discreet structure and the phenomenous of deformation, new orientation and sliding of the fibres - phenomenons which exist in a geotextile -, its behaviour differs from the theories established for continous elastic medium. We cannot speak about a "POISSON's ratio" but better about a coefficient of lateral contraction of the geotextiles;

2) consequently, the theories of soils reinforcement based on a "POISSON's ratio" of the geotextiles by using the theory of elasticity are very open to question;

3) we have explained the internal behaviour of a type of sample of non woven geotextile; this explanation can be applied to other types of samples and adequate models can be used;

4) the modulus of elasticity that we have attributed to the brackets are coming from a global test on the sample. This solution is open to question but it's the only one we know.

6. BIBLIOGRAPHY

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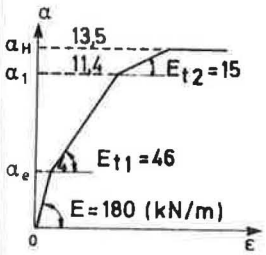
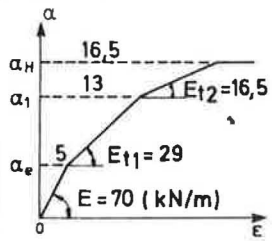
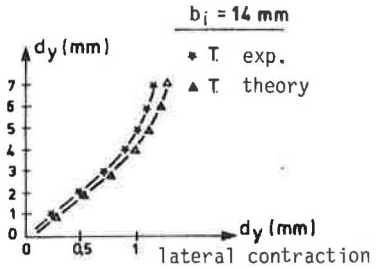
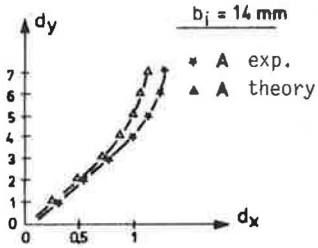
TABLE 2

Material	Discretization of the model	Obtained curves	Remarks
- Thermobonded (T) tri-linear  - Spunbonded (A) tri-linear  	See table 1	  	We note the better approach of the experimental results by our model. If you work with a non-linear system, the results of calculation are nearer from the reality