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Physical Characteristics of Geotextiles Definition Dimensions

Charactéristiques physiques des géotextiles Valeurs de définition

The paper brings forth a point of view on the geotextiles physical characteristics definition taking into account the elements with a specific textile nature that help establishing the value of these parameters.Considering the non-woven geotextiles strong compressibility the inclusion of this parameters,expressed by varying the non-woven fabrics thickness under loading,as a possible mean to be used in defining the characteristics comprised in the present paper is necessary. The final part exemplifies some of the stated characteristics for the MADRIL geotextiles made in Romania.

The paper conclusions underline the fact that the geotextiles specific anisotropy imposes the selection of the computing elements values on the basis of statistically processed laboratory tests.

L'article soumet à l'attention un point de vue sur la définition des caractéristiques physiques des géotextiles en tenant compte des éléments à spécifique textile qui concourent à l'établissement des valeurs des paramètres respectifs. En tenant compte de la compressibilité accentuée des géotextiles non-tissés on impose l'inclusion de ce paramètre aussi par la variation de l'épaisseur des géotextiles non-tissés sous charge, comme hypothèse pour définir les caractéristiques physiques renfermées dans l'article. Dans la partie finale on illustre par des exemples, pour les géotextiles de production roumaine MADRIL, quelques caractéristiques de celles énoncées déjà.

Dans les conclusions de cet article, on met en évidence le fait que l'anisotropie spécifique aux géotextiles impose le choix des valeurs des éléments de calcul à base de détermination de laboratoire expliquées du point de vue de la statistique.

1. INTRODUCTION

The use of textile materials in geotechnique imposes, besides defining them by means of values accepted for the textile testing, the establishment of notions that should offer the possibility of creating some corkespondences between the two types of porous materials: geotextiles and soils.

Starting from this idea the authors point of view concerning the definition of geotextiles as building materials elements is presented taking into consideration the component elements (textile fibres and yarns) characteristics.

2. DEFINITION HYPOTHESIS

- geotextiles (woven or non-woven textiles) made of one or more than one polymers having strict manufacturing formulas;
- the circular fibres or yarn section;
- the initial thickness t_i considered $\sigma_i = 0.5$ kPa for non-woven and at $\sigma_i = 1.0$ kPa for woven fabrics;
- the reference unit 1 cm^2 or 1 cm^3;
- having in view that thickness represents an important characteristic especially with non-woven geotextiles the registering of thickness variation as hypothesis in defining the physical characteristics of this geotextile type is to be considered.

Figure 1 presents the thickness variation curve form for non-woven geotextiles made by needlepunching, the curve being drawn on the basis of a series of laboratory determinations performed in accordance with the STAS methodology (1).

Thus, three domains can be detected in this parameter variation, as it follows:

- the A domain (low loads) in which the thickness variation observes a law of the form

$$T_A = tg\,\alpha_1 \log\sigma + n_1 \Big|_{\sigma_i = 0.5\text{ kPa}}^{\sigma_1} \qquad (1)$$

- the B domain (average loads - usually having the values 3 kPa$<\sigma<$300 kPa) in which the variation of T observes a hyperbolic law of the form

$$T_B = \frac{k^2}{\log\sigma}\Big|_{\sigma_1}^{\sigma_2} \qquad (2)$$

- the C domain (high loads) in which the thickness variation observes a law of the form

$$T_C = tg\,\alpha_2 \log\sigma + n_2 \Big|_{\sigma_2}^{\sigma_{max}} \qquad (3)$$

where, σ_{max} represents the loading for which $T=f(\sigma)$= = constant.

The values of the terms α_1, n_1, k, α_2, n_2 from the expressions (1), (2) and (3) can be determined by

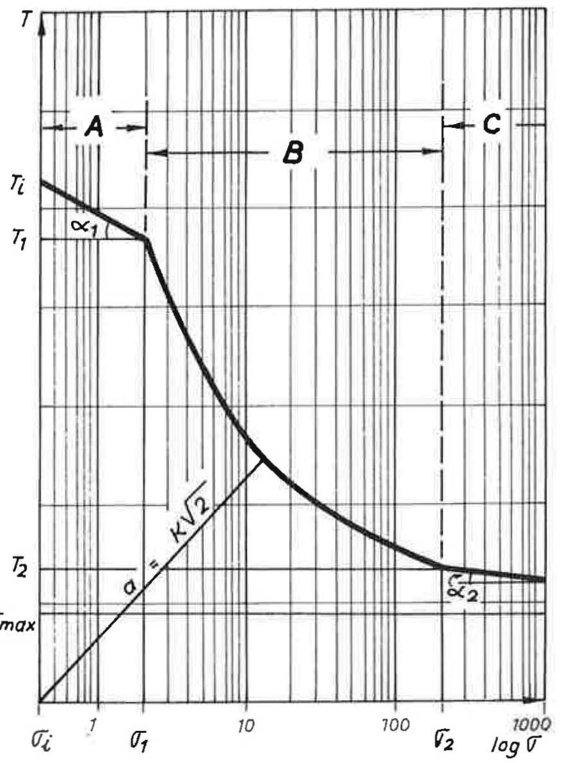

Fig.1. The variation of the non-woven geotextile thickness depending on the σ loading.

laboratory tests depending on the geotextile mass, the fibres characteristics and the technological parameters of the textile fabrication.

3. PHYSICAL CHARACTERISTICS

3.1. Nominal Volume (V_u)

The nominal volume represents the volume of one cm^2 of geotextile when the σ_i loading is applied to it

$$V_u = T_i \qquad (4)$$

T_i being the thickness at the initial loading.

For the case when $\sigma \neq \sigma_i$ the expression (4) becomes

$$V_\sigma = T_\sigma \qquad (4')$$

where T_σ is the geotextile thickness in the case of a certain "σ" loading (for the non-woven geotextiles, see figure 1).

3.2. Nominal Mass (μ_s)

The nominal mass represents the mass of one cm^2 of geotextile

$$\mu_s = 10^{-4}\, M \qquad (g/cm^3) \qquad (5)$$

M being the mass per unit area expressed in g/m^2.

3.3. Specific Mass (μ_{sp})

The specific mass represents the mass of one cm^3 of geotextile when the σ_i loading is applied to it

$$\mu_{sp} = \frac{\mu_s}{T_i} \qquad (g/cm^3 \qquad (6)$$

Note: Although the specific mass thus defined is in fact the geotextile specific weight the authors will keep the name of "specific mass" so that no confusions will be possible between it and the polymer specific weight (γ_p).

3.4. Nominal Volume of Fibres or Yarns (v_f)

The nominal volume of fibres or yarns represents the volume of the fibres or yarns having a mass equal to the geotextile nominal mass

$$v_f = \frac{\mu_s}{\gamma_p} \qquad (cm^3) \qquad (7)$$

γ_p being the specific weight of the polymer the fibre or the yarn is made of.

3.5. Specific Volume of Fibres or Yarns (V_f)

The specific volume of fibres or yarns represents the volume of the fibres or yarns comprised in one cm^3 of geotextile when the σ_i loading is applied

$$V_f = \frac{\mu_{sp}}{\gamma_p} \qquad (cm^3) \qquad (8)$$

For $\sigma \neq \sigma_i$, V_f becomes $V_{f\sigma}$ (the fibres or yarns volume in the case of a certain loading)

$$V_{f\sigma} = \frac{\mu_s}{T_\sigma \gamma_p} \qquad (cm^3) \qquad (9)$$

3.6. Nominal Length of Fibres or Yarns (l_f)

The nominal length of fibres or yarns represents the fibre or yarn length having a mass equal to the geotextile nominal mass

$$l_f = 10^5 \frac{\mu_s}{\lambda} \qquad (cm^{-1}) \qquad (10)$$

λ being the fibres or yarns fineness (linear density of fibres or yarns) expressed in Tex (3).

3.7. Specific Length of Fibres or Yarns (L_f)

The specific length of fibres or yarns is the fibre or yarn length having a mass equal to the geotextile specific mass

$$L_f = 10^5 \frac{\mu_{sp}}{\lambda} \qquad (cm^{-2}) \qquad (11)$$

If for the non-woven geotextiles L_f is defined as the length of fibre comprised in a certain volume of the geotextile this characteristic has the meaning of denseness.

3.8. Specific Denseness (∂)

The specific denseness represents the length of fibre (l_f) comprised in the nominal volume (V_u)

$$\partial = L_f = 10^5 \frac{\mu_s}{T_i \lambda} \qquad (cm^{-2}) \qquad (12)$$

If $\sigma \neq \sigma_i$ then the denseness at a certain loading will be expressed as:

$$\partial_\sigma = 10^5 \frac{\mu_s}{T_\sigma \lambda} \qquad (cm^{-2}) \qquad (13)$$

For woven geotextiles the denseness (∂_w) can be expressed according to the textile regulations (2), namely:

$$\partial_w = 10\, \frac{N}{l} \qquad (yarns/10\ cm) \qquad (14)$$

where: N = number of yarns; l = length of the sample (in cm).

In the case of woven fabrics ∂_w has two values, one for each of the two winding directions: warp and filling.

3.9. Nominal Side Surface of Fibres (A_l) - for Non-woven Fabrics

The nominal side surface of fibres represents the surface of fibres having a length equal to the nominal length

$$A_l = \pi d_f \times l_f$$

where d_f = the diameter of fibres

$$d_f = 2\sqrt{\frac{\lambda}{10^5 \pi \gamma_p}} \quad \text{(cm)}$$

$$A_l = 2\mu_s \sqrt{\frac{10^5 \pi}{\lambda \gamma_p}} \quad (\text{cm}^2) \qquad (15)$$

3.10. Specific Surface of the Geotextile (A_g) - for Non-woven Fabrics

The geotextile specific surface represents the side surface of the fibres comprised in one cm^3 of fabric when the σ_i loading is applied to it

$$A_g = 2\mu_{sp} \sqrt{\frac{10^5 \pi}{\lambda \gamma_p}} \quad (\text{cm}^{-1}) \qquad (16)$$

For $\sigma \neq \sigma_i$ A_g becomes A_σ

$$A_\sigma = 2\frac{\mu_s}{T_\sigma} \sqrt{\frac{10^5 \pi}{\lambda \gamma_p}} \quad (\text{cm}^{-1}) \qquad (17)$$

In the case when the specific surface A_g is related to the fibres specific volume (V_f) the specific volumetric surface of the geotextile (A_f) is obtained

$$A_f = \frac{4}{d_f} \qquad (18)$$

In the case when the specific surface A_g is related to the fibres specific weight the specific surface of the geotextile mass (A_μ) is obtained

$$A_\mu = 2\sqrt{\frac{10^5 \pi}{\lambda \gamma_p}} \quad (\text{cm}^2/\text{g}) \qquad (19)$$

$$A_f = \gamma_p \cdot A_\mu \qquad (20)$$

3.11. Fineness Index of the Non-woven Geotextiles (F)

The fineness index of the non-woven geotextiles is defined as the inverse of the section of fibres the non-woven fabric is made of

$$F = 10^5 \frac{\gamma_p}{\lambda} \quad (\text{cm}^{-2}) \qquad (21)$$

The denseness dependence on fineness index is expressed by

$$\partial = V_f \cdot F \qquad (22)$$

3.12. Specific Porosity of Non-woven Geotextile (n_i)

The specific porosity represents the ratio between the pores volume of a non-woven fabric and the fabric volume when σ_i loading is applied.

$$n_i = (1 - \frac{\mu_{sp}}{\gamma_p})\ 100 \quad (\%) \qquad (23)$$

For a certain $\sigma \neq \sigma_i$

$$n = (1 - \frac{\mu_s}{T_\sigma \gamma_p})\ 100 \quad (\%) \qquad (24)$$

The porosity dependence on denseness is expressed by

$$n = (1 - \frac{\lambda\, \partial_\sigma}{10^5 \gamma_p})\ 100 \quad (\%) \qquad (25)$$

3.13. Specific Void Ratio (e_i) - for Non-woven Geotextiles

The specific void ratio represents the ratio between the pores volume of a non-woven fabric and the fabric fibres volume when the σ_i loading is applied

$$e_i = (\frac{\gamma_p}{\mu_{sp}} - 1) \qquad (26)$$

For a certain $\sigma \neq \sigma_i$

$$e = (\frac{T_\sigma \gamma_p}{\mu_s} - 1) \qquad (27)$$

and

$$\frac{n(\%)}{100} = \frac{e}{1 + e} \qquad (28)$$

3.14. Openings Dimensions of the Woven Geotextiles

In the case of woven fabrics the porosity problem is dealt with differently from the non-woven fabrics one.

The openings are not to be found in the material mass but are formed by the warp yarns intersection with the filling yarns.

Analysing the regular case of the woven fabrics with a cloth texture the fact can be admitted that the openings are of a rectangular form. If: N_w = number of warp yarns; N_f = number of filling yarns; b_w = the warpwise length of sample; b_f = the fillingwise length of sample; λ_w = the warp yarns fineness; λ_f = the filling yarns fineness; w = the distance between two warp yarns; f = the distance between two filling yarns

$$w = \frac{b_f}{N_w} - 2\sqrt{\frac{\lambda_w}{10^5 \pi \gamma_p}} \quad \text{(cm)} \qquad (29)$$

$$f = \frac{b_w}{N_f} - 2\sqrt{\frac{\lambda_f}{10^5 \pi \gamma_p}} \quad \text{(cm)} \qquad (30)$$

From the values thus calculated for w and f the lowest one is to be considered as characteristic dimension of the openings.

The characteristic dimension of woven fabrics openings can as well be defined by the characteristic surface of the openings (Ω)

$$\Omega = w \cdot f \quad (\text{cm}^2) \qquad (31)$$

using the values w and f from the relations (29) and (30).

3.15. Openings Quantum (Porosity) of Woven Geotextiles (n_w)

The woven geotextiles porosity represents the ratio between the openings surface and the surface of the woven material

$$n_w = \frac{\sum \Omega}{b_w \cdot b_f} 100 \quad (\%) \qquad (32)$$

or

$$n_w = \frac{(N_w - 1)(N_f - 1) w \cdot f}{b_w \cdot b_f} 100 \quad (\%) \qquad (33)$$

3.16. Woven Geotextiles Openings Ratio (e_w)

The woven geotextiles openings ratio represents the ratio between the openings surface and the surface occupied by the fibres that make up the woven fabric

$$e_w = \frac{\sqrt{10^5 \pi \gamma_p}}{2} \frac{(N_w - 1)(N_f - 1) w \cdot f}{b_w N_w \sqrt{\lambda_w} + b_f N_f \sqrt{\lambda_f}} \qquad (34)$$

$$e_w = \frac{\sqrt{10^5 \pi \gamma_p}}{200} \frac{n_w(\%)\, b_w \cdot b_f}{b_w N_w \sqrt{\lambda_w} + b_f N_f \sqrt{\lambda_f}} \qquad ((35)$$

4. PHYSICAL CHARACTERISTICS OF MADRIL(R) GEOTEXTILES

MADRIL(R) geotextiles are non-woven fabrics made of polypropylene fibres of 0.66 Tex (MADRIL(R) M) or of 2.0 Tex (MADRIL(R) V) mechanically bonded by needle-punching.

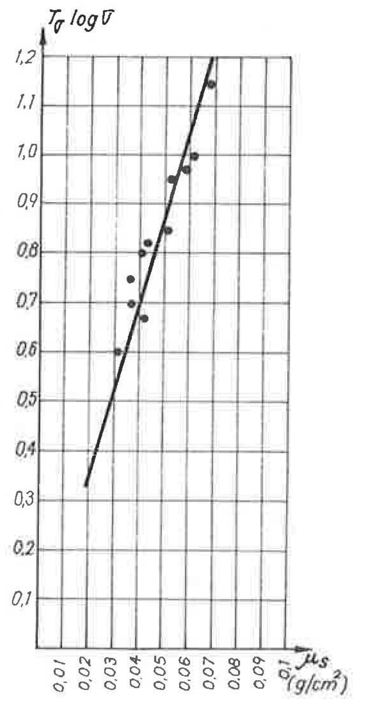

Fig.2. The dependence between the MADRIL(R) M geotextile thickness for different loadings σ and the mass (μ_s) (for σ in the domain $T_\sigma \log \sigma = k^2$).

Figure 2 shows the dependence existing between the MADRIL M geotextile thickness and its nominal mass (μ_s) in the case of the domain B (average loadings). The existence of a proportionality between the nominal mass and the product ($T_\sigma \times \log \sigma$) is to be noticed.

One can notice in figure 2 that

$$T_\sigma = \frac{tg\alpha}{\log \sigma} \mu_s \quad \text{(cm)} \qquad (36)$$

Table 1 presents the MADRIL M geotextile thickness variation (T_σ) as a function of μ_s and σ.

Table 1. The thickness of the MADRIL(R) M geotextile for various loadings σ.

σ (KPa)	μ_s (g/cm²)					
	0.02	0.03	0.04	0.05	0.06	0.07
0.5	0.355	0.458	0.561	0.664	0.767	0.870
5.0	0.206	0.309	0.412	0.515	0.618	0.721
10.0	0.175	0.263	0.350	0.438	0.525	0.613
15.0	0.161	0.241	0.322	0.402	0.483	0.563
20.0	0.152	0.228	0.304	0.380	0.456	0.532
25.0	0.146	0.219	0.292	0.365	0.438	0.511
50.0	0.130	0.195	0.259	0.324	0.389	0.454
100.0	0.117	0.175	0.233	0.292	0.350	0.408

Table 2 presents some of the physical characteristics of the geotextile MADRIL(R) M calculated according to the relations presented in section 3.

Table 2. Physical characteristics of the MADRIL(R) M geotextile for different σ loadings.

$d_f = 31\ \mu m$	$\frac{f}{10^5} = 1.36\ cm^{-2}$		$A_f = 1310\ cm^{-1}$	$A_\mu = 1440\ cm^2/g$	
σ (KPa)	$\mu_s = 0.2 \div 0.7\ g/cm^2$				
	∂_σ (cm^{-2})	n_σ (%)	ℓ	A_σ (cm^{-1})	$V_{f\sigma}$ (cm^3)
0.5	$1.13 \cdot 10^4$	91.72	11.08	$1.08 \cdot 10^2$	$8.30 \cdot 10^{-1}$
5	$1.46 \cdot 10^4$	89.30	8.35	$1.40 \cdot 10^2$	$1.07 \cdot 10^{-1}$
10	$1.71 \cdot 10^4$	87.47	6.98	$1.64 \cdot 10^2$	$1.25 \cdot 10^{-1}$
15	$1.87 \cdot 10^4$	86.30	6.30	$1.79 \cdot 10^2$	$1.37 \cdot 10^{-1}$
20	$1.97 \cdot 10^4$	85.56	5.93	$189 \cdot 10^2$	$1.45 \cdot 10^{-1}$
25	$2.06 \cdot 10^4$	84.91	5.63	$1.97 \cdot 10^2$	$1.50 \cdot 10^{-1}$
50	$2.32 \cdot 10^4$	83.00	4.88	$222 \cdot 10^2$	$1.70 \cdot 10^{-1}$
100	$2.57 \cdot 10^4$	81.17	4.31	$246 \cdot 10^2$	$1.88 \cdot 10^{-1}$

In this table the values written next to the reference loadings σ_i = 0.5 kPa represent the specific characteristics value of the MADRIL M geotextiles (∂, n_i, e_i, A_g and V_f) for μ_s = 0.05 g/cm^2.

5. CONCLUSIONS

The defining of the main physical characteristics of geotextiles, some of them being well known both to the textile specialists and to the geotechnicians,aims at bringing forth the elements specific for the textile materials which determine the value of these characteristics.

The introduction of the non-woven geotextiles thickness variation depending on the normal loading on the textile material plane as a calculation hypothesis offers the possibility of a real evaluation of the stated characteristics variability.

It is useful to underline the fact that the relations of dependence defined in the present paper have a general character, having the possibility to be particularized depending on the laboratory results obtained by means of direct measurements on various types of geotextiles. Moreover for a more precise evaluation of the characteristics values of a certain type of geotextile it is absolutely necessary to perform a detailed laboratory study imposed by the well known anisotropy of these materials.

In this context it is desirable that the various parameters values that contribute to the establishment of the physical characteristics values should be selected as a result of a statistical analysis.

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