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Force Transfer at the Contact of Geotextiles and Soil Under Permanent and Cyclic Loads

Transfert des forces sur le contact des géotextiles et des sols auprès des charges constant et cyclique

Tests of sand - geotextile friction were made with the shear force either continuously variable, or cyclically transient. The paper analyzes the principal factors influencing the results of tests in a shear box apparatus, explains the differences in character of dilatancy changes in the shear of sand alone and the friction of sand with geotextile. The angle of friction between the soil and the fabric with static function is approximately the same as the residual angle of internal friction of the soil. The tests with cyclic changes of shear stresses were made with sand friction with duraluminium, wood, concrete and geotextile. The energy supplied to the soil during one cycle is markedly higher in the case of the geotextile base than in other cases. Since it has been already previously proved that the fatigue phenomena of the soil depend on the energy supplied to the soil, a high sensitivity of soil structures with geotextiles.

On a procédé aux expériences portant sur le frottement du sol pulvérulent et géotextiles. La force de cisaillement a été, d´une part, progressivement variable, et, de l´autre, cycliquement. L´étude analyse les facteurs principaux influençant les résultats des essais dans un appareil de cisaillement direct. On élucide les différences dans le caractère des changements de dilatation lors du glissement du sable meme et lors du glissement du sable sur les géotextiles. Les essais dans les cas cyclique ont été réalisées avec le sable sur la surface de duralumin, de bois, de béton et de géotextiles. L´énergie, inculquée au so durant un cycle est relativement plus grande dans les cas des géotextiles. Etant donnée le fait que déjà par le passé il a été prouvé que les manifestation de la fatigue du sol dépendent de l´énergie inculquée au sol, on suppose une sensibilité élevée des constructions du génie civil et géotextiles.

Laboratory tests of friction of Zbraslav sand were carried out with the purpose of specifying with greater accuracy the informative values of coefficients of friction of soils and type PAD TT4-181/77 geotextiles. The mechanical properties of the fabric were ascertained in detail as a separate problem /1/, /6/, /3/. The results of uniaxial tensile tests are shown in Fig.1 and Fig.2. The test of shear transfer from the soil to the fabric were carried out in shear box apparatus /Fig.3/. The tests were carried out under constant temperature for 15 minutes so that it can be assumed that the strain changes with temperature are negligible /2/, /3/. Since during the tests of the shear of soil along the fabric the latter slid along a duraluminium base, tests of friction of the fabric along a duraluminium plate with various surface treatment were carried out /Fig.4/. The angle of friction at rest δ_f was greater than the angle of friction in motion δ_r; however, the differences in the case of a dry,clean duraluminium plate were very small. In further tests, therefore, the angle of friction was considered as $\delta \doteq \delta_f \doteq \delta_r \doteq 13^o$. A comparison of standard shear tests with the tests of the shear of a soil along the fabric is shown in Fig.4. Up to the stress level of $\tau = \sigma_n \, tg \, \delta$ the effect of the fabric on the course of the test was non-existing. After the shear stress τ has been attained, the fabric began sliding along the base and elongate. In the soil a failure zone at about 0,6 cm above the fabric arose /the overall test sample height above the fabric being 1,2 cm/. The described phenomenon was monitored by photographing the movement of the grains through the transparent side of the shear box by a camera connected with it. The sliding of the soil along the fabric is not identical along the whole box length. By the soil friction the fabric elongated and its movement was braked by its friction along the duraluminium base. The analysis of these displacements for one point of the working diagram of sand/fabric friction is shown in Fig.6. The differences of the sand displacement along the fabric in the individual points of the shear box length are considerable, even under the assumption that the vertical normal stresses are regularly distributed. Actually the local normal stresses σ_n vary, due to irregular porosity, so that the dashed curve in Fig.6. must be considered approximate only. The effect of the fabric influences substantially the effect of structure of adjacent soil under shear stress. The peak shear strength of soil is overcome only locally. In the majority of the shear surface there is $\tau < \tau_f$, if the peak shear strength τ_f has just been mobilized in some place. Let us introduce the notation δ_f for the peak and δ_r for the residual value of the angle of soil/fabric friction; in loose soils δ_f nears δ_r the more, the higher the porosity of the soil. /Analogy is known from the angle of internal friction of soil ϕ_f and ϕ_r /4/ /. We obtain $\delta_f \doteq 0.5 \, /\phi_f + \phi_r/$

and $\delta_r \doteq \phi_r$ for $\bar{\delta} \approx 0.4\delta$ and $\bar{l} = 2\ d_{50}$, when $1/\bar{l}$ = 7 threads/cm is the density of the fabric and d_{50} is the diameter of the grains /in cm/ representing 50% of the weight of the sample on the granulometric curve.

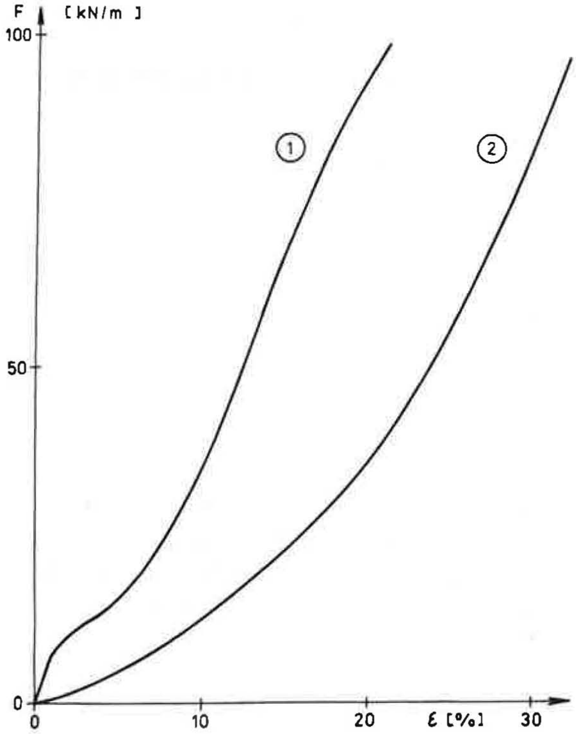

Fig.1 Working diagram of type PAD 12823 geotextile fabric in uniaxial tension. /After Minster 1974/
1 - tension in warp direction
2 - tension in weft direction.

The tests of the fabrics on a carborundum plate, with fine and coarse sand have ascertained that when $\bar{\delta} > \delta$ and $l \geqslant 2\ d_{50}$, the shear surface originates in the sand adjacent to the relatively coarse fabric. Then it is necessary to count with $\delta_f \rightarrow \phi_f$ and $\delta_r \rightarrow \phi_r$. If $\bar{l} \doteq d_{50}$, any movements of the fabric cause approximately identical movements of adjacent grains. If simultaneously $\bar{\delta} < \delta$, the elongation of the fabric causes major changes of porosity of adjacent soil; the porosity gest stabilized, when the critical value has been attained. Since the grains are well wedged in the fabric with approximately identical depth, the shear in the soil adjacent to the fabric occurs under approximately critical porosity in the whole failure zone.

It was also tested how the change /reduction/ of the angle $\bar{\delta}$ of friction of the fabric along its base will influence the measured value of the angle δ of friction of the fabric and the sand. The residual angle δ_r did not depend on $\bar{\delta}$, but it did influence the course of the test. Due to the reduction of $\bar{\delta}$ the displacements of the fabric increased and the places, where probably the peak value of friction was mobilized, were even more locally limited. The low value of $\bar{\delta}$ resulted in the test result recalling the tress-strain diagram of loose sand. In either case the angle of soil/fabric friction got stabilized at $\delta_r \doteq \phi_r$.

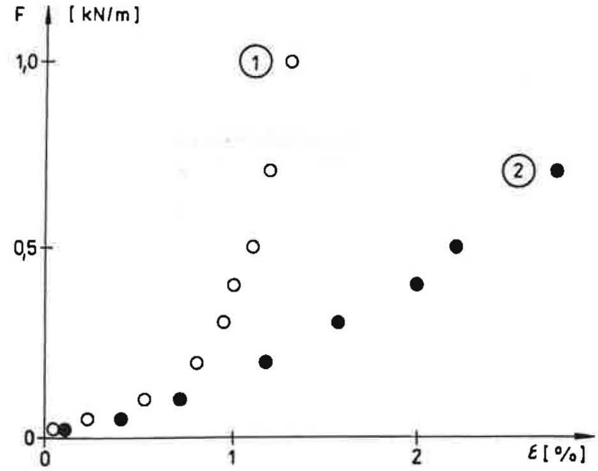

Fig.2 Detail of Fig.1 for small tensile forces F and small relative strain /After Minster 1974/.

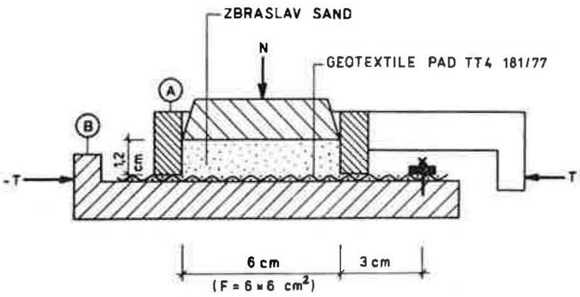

Fig.3 Diagram of friction tests of sand with fabric
A - shear box mobile in the direction of force T under vertical load N,
B - base

In the tests dry, clean fabrics were considered. In actual practice, however, the openings of the fabric may become clogged, after a short displacement, with a material with a low angle of internal friction. In further friction the expansive behaviour of adjacent soil will not manifest itself in its full extent; in an extreme case the friction of soil with the moist, clogged fabric must be characterized by the angle of $\delta \ll \phi_r$. Similar case may occur also, when dense or unwoven, precompressed fabrics are used.

It should be noted that the described tests do not characterize the spatial behaviour of fabrics in the conditions of actual construction. The fabrics are, as a rule, orthogonally anisotropic. In time their degradation and degeneration takes place, while the soils under variable load may become subject to fatigue /5/, /6/, but also to improvement by consolidation.

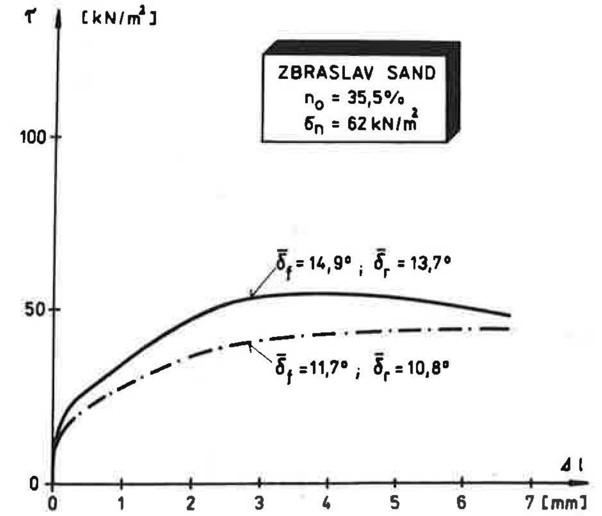

Fig.4 Shear tests of friction of sand with fabric under a vertical stress $σ_n$ = 62 kN/m² for different peak / $\bar{δ}_f$/ and residual / $\bar{δ}_r$/ friction of fabric with its base.

So far we have considered only the case of a static shear test. The simple equipment available to authors made it possible to carry out a comparative study of the friction of soil with various materials under repeated transient shear loading. The test of this type differed from the standard test in that the attained shear stress was reduced to zero as soon as the displacement of the shear box attained one whole mm, and slowly increased again immediately afterwards. A typical course of the test is shown in Fig.7. During the tests no signs of soil fatigue were observed /5/, /6/, probably due to the small number of repeated cycles. The peak and residual stresses / $τ_f$, $τ_r$/ in a repeated shear loading of a sand sample correspond approximately with analogous values of the angles of friction $δ_f$, $δ_r$ with different materials ascertained by standard test.

However, the transient repeated shear load tests have opened a new vista of structural soil changes occuring during soil friction with other materials. The diagram showing the friction of Zbraslav sand with concrete in Fig.7 comprizes a loop "C", shown in a thick line, which has the property of being the first loop after the value of $τ_f$ has been attained. This loop is shown again in Fig.8 together with other loops obtained analogously during the friction tests with other materials/A - duraluminium, B - wood, C - concrete, D - type PAD TT4-181/77 fabric/ for $σ_n$ = 212 kN/m² and $σ_n$ = 62 kN/m². Apart from the initial sand porosity n_o every loop

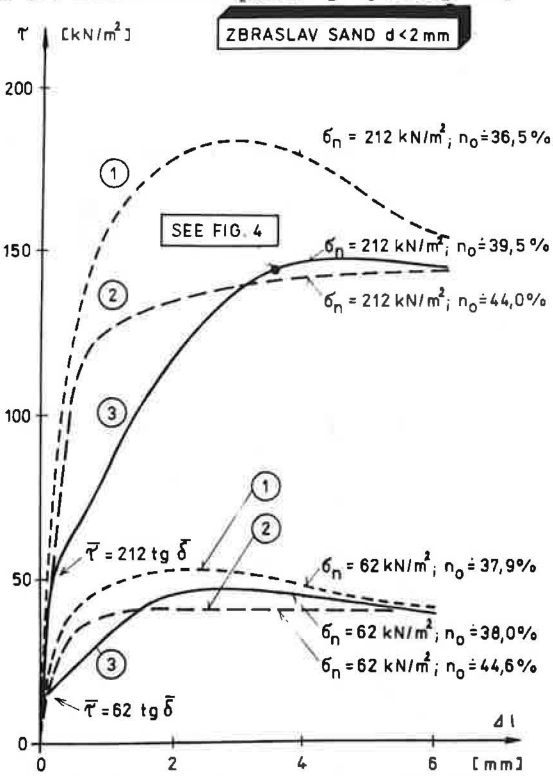

Fig.5 Comparison of standard shear tests of Zbraslav sand /dashed line/ with the friction tests of the same sand with geotextile /solid lines/.

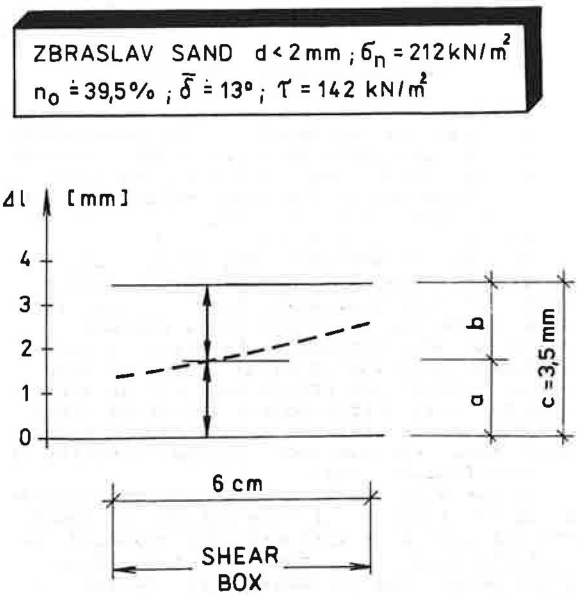

Fig.6 Analysis of displacements of a selected point /according to Fig.5/ during the

friction test of sand with fabric.
a - displacement of the shear box along the fabric,
b - displacement of the fabric along the base,
c - displacement of the shear box with regard to the base.

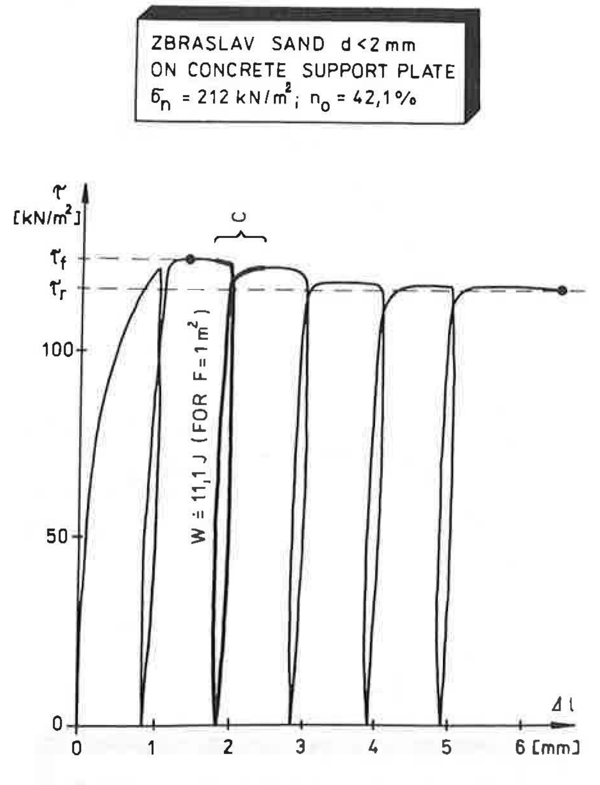

Fig.7 Working diagram of the friction test of soil with concrete under repeated shear loading. The first loop after the peak value of τ_f has been attained is marked in thick lines. W - energy corresponding with the area of the loop referred to 1 m^2 of the shear surface

shows also the energy W supplied to the soil during the cycle represented by the loop. /The energy in J is referred to 1 m^2 of the shear surface/. In /5/, /6/ it was shown that the structural changes in the soil due to the reduction and re-increase of τ were higher with higher W and vice versa. It was also shown that the higher the energy supplied to the soil during one cycle, the sooner the soil might fail. On the basis of these studies it is possible, for example, to assume a higher fatigue resistance to friction on the surface of metal piles than on the surface of timber or concrete. Let us note that the loops "D" are only slightly higher than the loops "C" in the tests of otherwise identical conditions, /for "D" there were $\overline{l} \doteq 2\ d_{50}$ and $\overline{\delta} = 0.4\,\delta$ /, but the energy supplied to the soil-fabric system was about four times as high as the energy supplied to the failure zone in the case of loop "C". We do not know what quota of energy corresponding with the loop "D" will be applied to the changes of soil structure and what quota will be applied to the degeneration of the fabric. However, the energy richness of the loop "D" is so marked that a high sensitivity of soil structures with built-in fabrics of tested type to repeated loading may be expected.

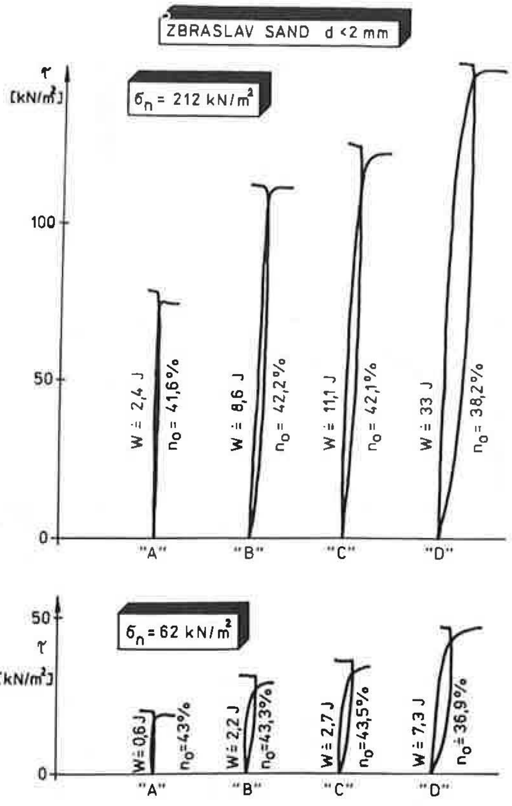

Fig.8 Comparison of first repetitions of shear stresses τ after the value of τ_f has been attained, analogously with the loop "C" in Fig.7. Every loop comorizes the corresponding energy W referred to 1 m^2 of the failure surface and the average porosity n_o at the beginning of the test under vertical loads of 62 kN/m^2 and 212 kN/m^2 respectively. The loops correspond with the following base materials: A - duraluminium, B - wood, C - concrete, D - geotextiles /type PAD TT4-181/77 fabric/.

The reinforcing elements of geotextiles /fabrics/ should be so situated in the soil as to be loaded for a short period and dynamically as little as possible, until the soil has attained the necessary strength by consolidation. As a rule, the speed of consolidation will be very favourably influenced by the fabric.

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Note: UTAM ČSAV - Institute of Theoretical and Applied Mechanics, Czechoslovak Academy of Sciences, Prague.