The effect of natural factors on bearing capacity of sands

Incidences de facteurs naturels sur la capacite de charge des sables

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ABSTRACT

The is a ruling principle in geotechnics that the bearing capacity of sands depends on its density and structure is incorrect.

The formation of sand's bearing capacity is affected by the processes influencing its settlement and diagenesis and they byproducts. In the currect paper there are analysed 800 plate load tests and CTP tests that have been performed on various sands. The analysis is based on the methodology of characteristic points that enables the evaluation of the pressures under which there occur changes in the physical processes of the soils situated under the sands. This methodology also enables the evaluation of shear parameters while taking in account the above-mentioned changes.

The bearing capacity of sands is largely influenced by the presence of additional compounds - cement, organic matter, bacteria etc. These may either increase or decrease the bearing capacity of sands.

RÉSUMÉ

Le principe souverain en géotechnique selon lequel la capacité de charge du sable dépendrait de sa densitsé et sa structure est erroné.

La capacité de charge du sable est modifiée par les processus ayant une incidence sur ses tassements, sa diagenèse ainsi que leurs conséquences. La communication actuelle présente 800 essais sur table et tests CTP menés sur des sables différents. L'analyse s'appuie sur la méthode des points caractéristiques permettant d'évaluer les pressions qui engendrent des changements dans les processus physiques des sols sous les sables. Cette méthode permet également d'évaluer les paramètres de cisaillement tout en tenant compte des changements précités.

La capacité de charge des sables est fortement influencée par la présence d'autres éléments tels : le ciment, la matière organique , les bactéries etc. Ces derniers peuvent accroître ou diminuer la capacité de charge des sables.

Houses have been built on sand for thousands of years even in spite of the specific advice given in the Gospels not to do so. And to be honest, geotechnics view sand as a fairly good base for building something.

In most of the textbooks and norms, the approach to sands has been simplified – everything „hangs" from the size of the sand grain and the density of sand. We are supposed to determine the angle of internal friction and, based on the result, calculate the bearing capacity of the sand or the stability of the slopes or retaining walls. In the more recent years however, also the geological history and the phenomena accompanying the creation of sands gets investigated.

The effect of the geological history has been described as a mechanical factor that enhances the mechanical strength of the sand at retaining density levels. This is explained by overconsolidation pressure. This phenomenon has also been explained by chemical processes during which cement occurs between the sand particles and the strength of sand increases.

The strenth of sand is influenced by the development of intraparticle shear movement in the course of the sedimenation process and it is clear that a larger shear deformation accords to a larger strength.

Laboratory testsing has proved course sand as the strongest and silty sand as the weakest of sandy soils. But an investigation of the granular <condition and density of sand has proved that course sand in nature is loose and medium dense, while fine and medium sand are medium dense and silty sand dense (see Figure 1).

This, a somewhat surprising fact, is explained by the investigation based on the Proctor methods (see Figure 2) of the optimal water content and maximum density.

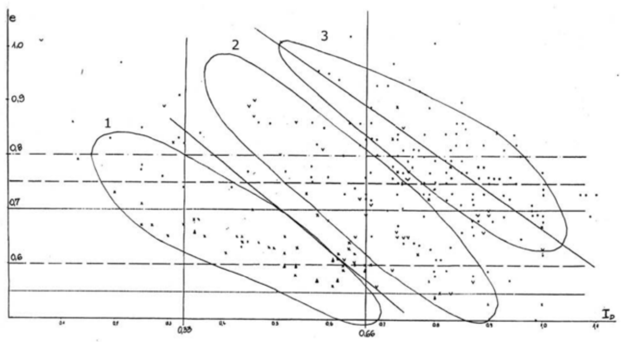

Figure 1. Dependence between void ratio (e) and density index I_d.
1 – course sand
2 – medium and fine sand
3 – silty sand

The maximum strength on all sands is reached with near-zero or optimal water content. The optimal water content is much smaller for coarse sand and much higher for silty sand (close to the saturation ratio 0,8). As the investigated sands are mostly settled in water (the sea, river, lake) at a saturation level close to 1,0 it is obvious that the coarse sand could not become denser when the silty sands had much better conditions for that.

Plate load tests have been used for determining the bearing capacity of sand; in the course of the tests, the dependency between the settelement S and the pressure q is estimated, as are the characteristic points that change the physical picture of the development of the soil deformations.

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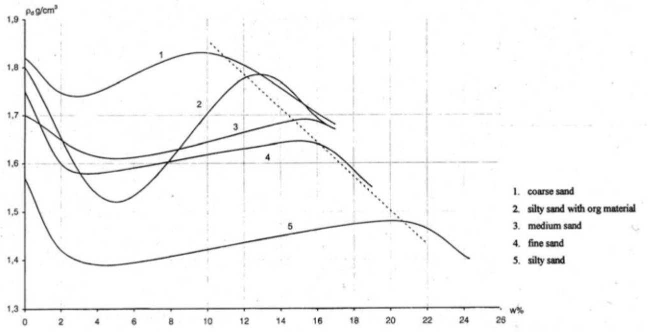

Figure 2. Results of Proctor test (different sands).

CPT tests were made in parallel to the plate load tests and samples were taken for determining the density, make-up, shear strength and compressibility of sand.

When processing the data of plate load tests, characteristic points were discerned on the curve $s = f(q)$ between the settlement S and the pressure q at which change occurs in the behaviour of the soil under the plate. The method of temporality was used for that end and the dependency $s = a\ (t/t_1)^b$ was determined at every load level in which a- initial settlement at t_1, t – time and b –reological factor characterising the slowing down of the settlement velocity.

The characteristic points are the following (Figure 3):

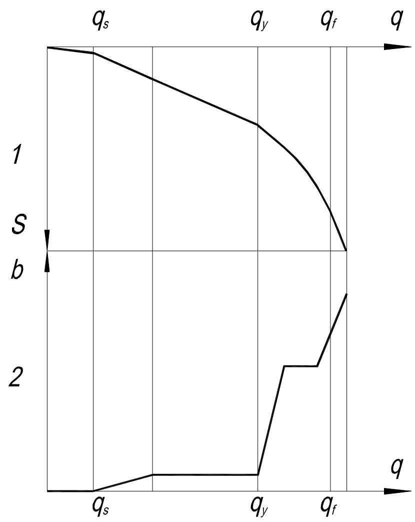

Figure 3. Characeristic point on curve S = f(q).

1. S = f(q) dependence between load and settlement
2. b = f(q)

q_s – structural strength of sand, the pressure the plate does not settle to , b= 0

q_y – creep point, the pressure until which the dependency s = f(q) is linear. Up till the creep point the factor b is a constant and the exceeding of the creep point is accompanied by its sudden increase and the pressing of the soil from under the plate;

q_f – ultimate load. Relatively unclear limit. For determining that, either the 10 % parametre has been (s = 10% of the diametre of the plate) or there has been an observable breaking of the plate at a pressure level over q_f .

In the course of shear strength investigations the maximum shear strength τ_f and the shear strength at creep level were determined. The Coloumb law can be used for determining both these shear strength. For the unpolluted sand φ_y = 18...22° and c_y = 10...20 kPa (shear parametres at the creep level) and φ_f = 31...33° and c_f = 10...18 kPa (shear parametres at maximum shear strength) it was possible to estimate fairly accurately q_y and q_f with the help pf the ultimate bearing capacity theory.

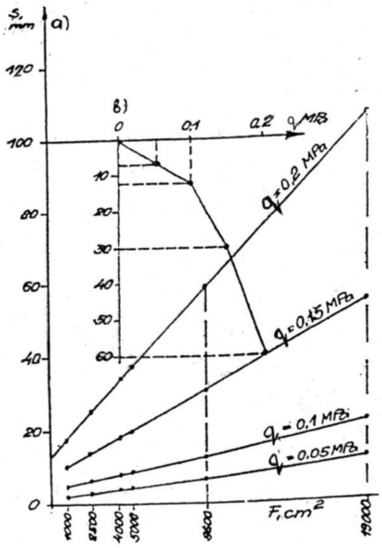

Figure 4. a) - Dependence between the plate settlement (F) and load (q). b) – The 9600 cm^2 plate's settlement from load (q).

s – settlement

q – load

F – surface area.

The differences between the empiricaally determined and calculated results was ± 10..15%.

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Shear tests on polluted sand gave an unexpected result. The maximum shear strength parametres were olid φ_f = 42° and c_f = 20..25 kPa. The accordingly calculated bearing capacities were remarkably higher than those determined by the tests. The parametres of the creep level at vertical pressure up to 150 kPa were φ_y = 0 °, c_y = 30 kPa and at higher pressures φ_y = 26 °, c_y = 20 kPa.

In a laboratory with the temperature + 18 ° C (higher than in the soil + 6...8 °), the pollution increased the shear strength and gave results that overestimated the actual bearing capacity of the polluted soil.

These investigations have proved the influence geological history has on sand properties. The following table shows three sands with a similar make-up, but very different bearing capacities.

The high bearing capacity of fluvioglacial sands can be explained by the mild FE cement that has formed in time.

The investigations showed that it is very important to consider the geological history of the sand. Three medium sands with a similar granular condition, I_D and e_0 were investigated. Also the shear parametres determined in the laboratory were quite similar. The investigated sands were fluvioglacial, marine and eolean sand. The test results are shown below in Table 1.

Sand is very much also influenced by additional components, especially organic matter. When estimating its influence, its percentage in weight is considered, which differs from the volume percentage 2..3 times. In many countries, the 3 % impact that the influence of organic matter is taken into considreration with actually indicates a 10 % content of organic matter and a very big influence on the properties of sand. Colloidial organic matter has an especially strong impact on the

Table 1.

	I_D MPa	e_0	q_s Mpa	q_y Mpa	q_f Mpa	φ_f °	c_f kPa	q_c Mpa
Eolian Sand	0,67	0,61	0	0,4	0,95	33	10	6,5
Maritim e Sand	0,63	0,66	0,05	0,8	1,6	35	10	13,5
Fluvio-Glacial sand	0,65	0,64	0,1	1,8	2,1	35	5	28

bearing capacity of sands. The following table shows the impact of organic matter on the creep level and the ultimate load in the case of silty sands.

The differences in the behaviour of different sands can be explained by overconsolidation, but this is not the most accurate approach to the subject. Actually, the better bearing capacity of fluvioglacial sand is in correlation to the weak cement between the particles. The marine sand, on the other hand, is characterized by a larger shear deformation in the course of its formation process than the eolean sand.

The determined shear parametres fitted in a satisfactory manner only to marine sand. The bearing capacity of eolean sand was overestimated by them and the bearing capacity of fluvioglacial sand remained much lower from its actual value which can be explained with the quality differences in testing.

Tabel 2.

Organic matter	q_y MPa	q_u MPa
Pure sand	0,7...0,8	1,5
0,5 % organic matter	0,35	1,2
3 % organic matter	0,2	0,7
5 % organic matter	0,15	0,5
0,5 % colloidial organic matter	0,15	0,8
1,0 % colloidial organic matter	0,1	0,5
2,0 % colloidial matter	0,05	0,15

Investigations have proved that the relation q_f /q_y is not permanent and this relationship decreases with the increase of the sand's strength, whichfore no certain safety coeficient can be spoken. Still, the world has been created right and a greater safety is characteristic of weaker sands (Figure 5).

The shear parametres determined in the laboratory always overestimated the shear strength and the q_y and q_f values based on them exceeded the results required through tests 2...6 times.

In the case of 600 tests, the plate test results were compared to the CPT tests and the following correlative interdependencies were reached:

$q_y = q_c / 16...20$

$E_y = 3..4\ q_c$

CONCLUSION

The bearing capacity of sands is not depending on its density and granular condition.

The formation of sand's bearing capacity is affected by the processes influencing its diagenesis and their byproducts.

The bearing capacity of sands is largely influenced by the presence of additional comppunds – cement, organic mater, bacteria etc. These may either increase or decrease the bearing capacity of sands.

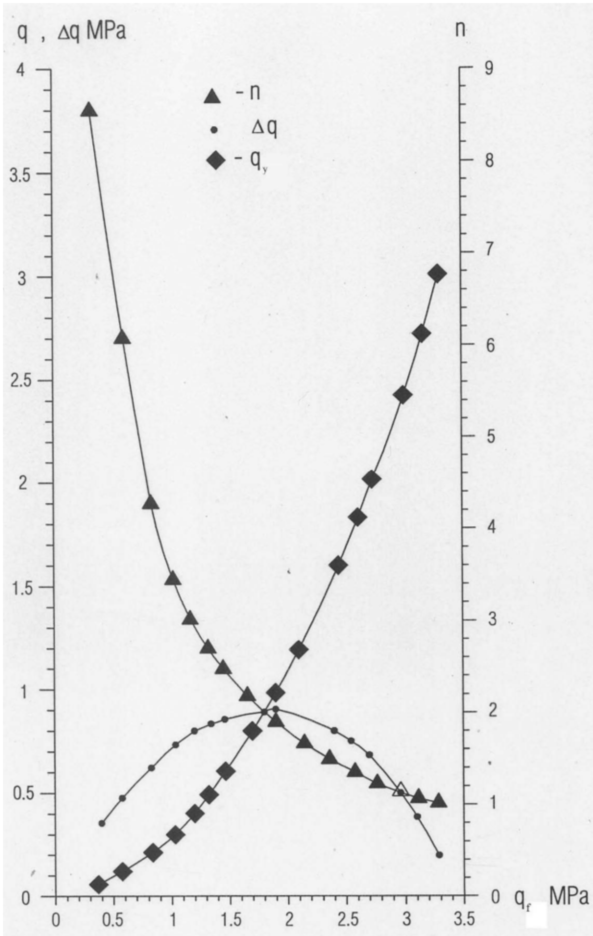

Figure 5. The dependence $q_y = f(q_f)$.
$\Delta q = q_f - q_y$
$n = q_f/q_y$

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