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MECHANICAL BEHAVIOUR OF CONTAMINATED GRANITIC RESIDUAL SOILS

Summary. This paper is a contribution for a better knowledge of the mechanical behaviour of contaminated soils, still in an early stage of a broader research on environmental geotechnics. The objective is the research of industrial waste use together with soils, such as soil mixtures with lubricant oil based materials and lime, aiming at the applicability of this product on freeway reinforcement of sub-base. Tests were conducted using a mixture lime and lubricant oil at varied proportions and granitic residual soil. Results and some preliminary discussion on identification, compaction, compressibility and shear strength tests are presented.

WŁASNOŚCI MECHANICZNE ZANIECZYSZCZONYCH GRANITOWYCH GRUNTÓW RODZIMYCH

Streszczenie. Artykuł ten stanowi wkład w lepsze poznanie, własności mechanicznych skażonych gruntów. Celem jest zbadanie wykorzystania odpadów przemysłowych łącznie z gruntami, takich jak mieszanki gruntów z materiałami na bazie olejów smarowych oraz wapna, umożliwiające zastosowania tego produktu do wzmocnienia warstwy nośnej autostrady. Badania przeprowadzono przy użyciu mieszaniny wapna i oleju smarowego w zmiennych proporcjach oraz granitowego gruntu rodzimego. Przedstawiono wyniki oraz część wstępnej dyskusji na temat identyfikacji, badań zagęszczania, ściśliwości i wytrzymałości na ścinanie.

1. Introduction

Substance migration depends on transport condition in soil's multiphase system, on molecular properties of contaminants that limit partition of gaseous and liquid phase, also on

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solid particles retention, that determines a new physical and chemical equilibrium of the system.

Soil is a chemical system that can be described by the interactions that take place in it and by the effects that contaminants have on its chemical composition and phases by dispersion, diffusion and advection, which produces changes in its mechanical behaviour.

Interactions of contaminants and water-soil system are heterogeneous of liquid-solid type. Water chemically reacts with soil components or water solved contaminants can react with soil components trough adsorption. Adsorption capacity depends on soil and contaminant type, whereas in dry granitic soil the maximum adsorption capacity for different contaminants shows a similar behaviour as in respect to the way and the concentration of adsorption. Water layers around soil speckles also have an important role [1].

Laboratory research on contaminated soil shows a need for adjustments of generally accepted soils mechanics theories: whether Proctor theory, water viscosity, physical-chemical interaction and Olson's effective tension theory that include viscosity parameters, surface tension, dielectric constant, liquid density that affects dry weight, permeability, strength and compressibility. These should be analysed for accessing possible tuning to a new model.

2. Research undertaken

To test a granitic saprolitic soil, geologically a variety of the "Covilhã" granite, calcium-alkaline series was chosen; mineralogically a two mica granite mainly biotitic, porfiric texture with megacristals of K-Na feldspar, intensely weathered with visible kaolinization of the feldspar [2].

According to the ASTM D2487-85[3], the classified granitic soil belongs to group SW-SM with gravel, and clay activity is normal to low, revealing the presence of Kaolinite, low expansion clay. Liquid limit and low plasticity index, reflecting the presence of mica minerals, retaining water in internal cleavage, Table 1.

The waste material to be mixed with soil is composed of lime (*L*) and lubricating oil (*O*) using a concentration of [10*kg* (*L*)+6 *l* (*O*)]. The concentration of components is chosen so that an exothermic reaction occurs in order to correct pH and neutralize heavy metals contained in the lubricating oil [4].

Two artificial soils were produced using a 5% and a 15% mixture of waste material and natural soil. Three groups of samples were obtained: i) granitic natural residual soil - NS; ii) granitic residual soil with 5% admixture, contaminated soil - CS5; iii) granitic residual soil with 15% admixture, contaminated soil - CS15. Grain size characteristics are presented at Table 1.

Table 1

Grain size characteristics of tested soils

Sample	Coefficient of uniformity C_U	Coefficient of concavity C_C	Effective size D_{10} (mm)	Liquid limit - w_L (%)	Plasticity index - I_P (%)	Clay activity - A_t
NS	33-200	0.3-5.9	0.006-0.13	40.4-42.5	1.7-5.6	very low
CS5	8.5	1.1	0.2	43.0	4.6	-
CS15	7.5	0.8	0.2	44.1	10.8	-

Preliminary results of compressibility and direct shear tests as well as the usability of the waste material were obtained on samples with physical parameters ($\gamma_{d\ max.}$, $w_{opt.}$), obtained from comparative curves of normal Proctor test. Natural soil, artificial soils CS5 and CS15 were used, Figure 1.

The addition of waste material has generated a reduction in the compaction value when compared to the natural soil. The reduction in a dry unit weight (γ_d), with increasing waste percentage results from the effect of dispersion and lime expansion overlapping, the increased viscosity due to the lubricating oil. With a dispersed soil structure it is difficult to produce a dense matrix with compacting action.

On the contrary, the viscosity of the pore liquid plays a major role in improving the compaction characteristics. With lower dielectric constant of the pore liquid there is a possible weaker physico-chemical interaction of soil-liquid-system that causes soils exhibit dispersed soil structure [5].

From the compressibility testing it is noticeable that an increase in virtual preconsolidation stress (σ'_p*) as the percentage of mixture is increased (Fig. 2). The comparative compression index (C_c) as well as the coefficient of permeability (k), exhibits increased difficulty in stabilization for artificial soils, as it happens in natural soil during normal behaviour, that is for tension levels higher than virtual preconsolidation stress, Fig. 2 and Table 2.

The difficulty in stabilization of permeability parameter (k) for soil CS15 may be a consequence of the higher concentration of lime in the mixture. Lime's higher expansibility generates an increased matrix elements separation.

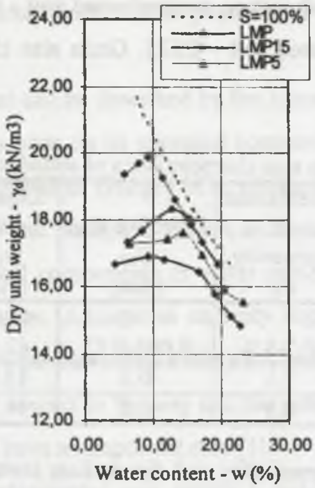

Fig. 1. Compaction test results of soil *NS* and soil contaminated with oil and lime; [E_m=593 kJ/m^3; E_M=2694 kJ/m^3]

Rys. 1. Wyniki prób zagęszczania gruntu NS oraz gruntu zanieczyszczonego olejem i wapnem [E_m=593 kJ/m^3; E_M=2694 kJ/m^3]

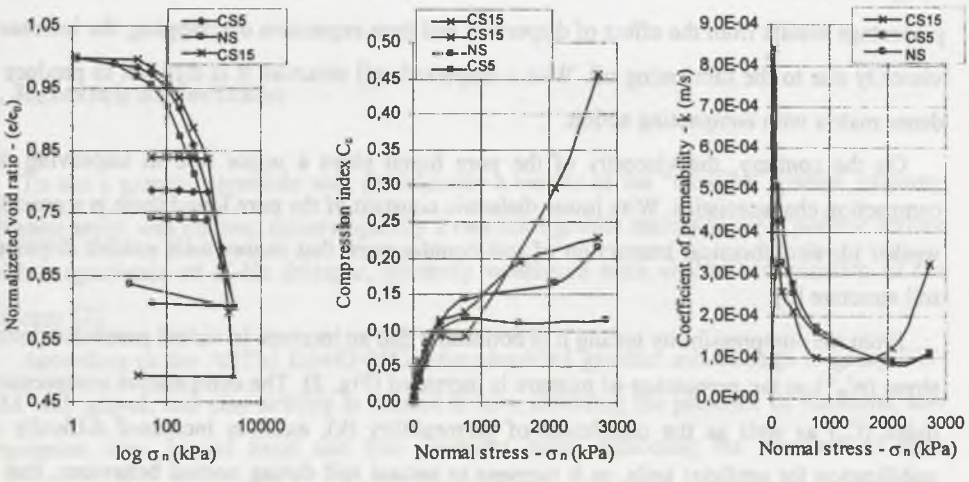

Fig. 2. a) One-dimensional consolidation test results of soil NS and soil contaminated with oil and lime; b) evolution of compression index; c) evolution of coefficient of permeability

Rys. 2. a) Wyniki jednowymiarowego badania konsolidacyjnego gruntu NS oraz gruntu zanieczyszczonego olejem i wapnem; b) zmiany modułu ściśliwości; c) zmiany współczynnika filtracji

Table 2

One-dimensional consolidation test results of soil

Sample	Initial void ratio e_0	Dry unit weight γ_d (kN/m^3)	Virtual preconsolidation stress-σ'_p* (kPa)
NS	0.471	17.86	110
CS5	0.521	16.24	190
CS15	0.567	16.26	220

Such induces to a simulation of increased cemented connections between particles that provides increased stiffness, also observed on the behaviour of shear strength curves strength (τ) versus horizontal displacement (δ_h) (Fig. 3a) and increase in the angle of internal friction in terms of effective stress (ϕ'),Fig. 3 b). (?)

The evolution of the vertical displacement (δ_v) versus horizontal displacement (δ_h), for artificial soils exhibits an initial homogeneous compressive behaviour. With increased δ_h it becomes expansive for all vertical load levels applied. It is probably caused by opposite dispersion effects, the expansion of lime and lubrication due to type of waste material used, Fig. 3c).

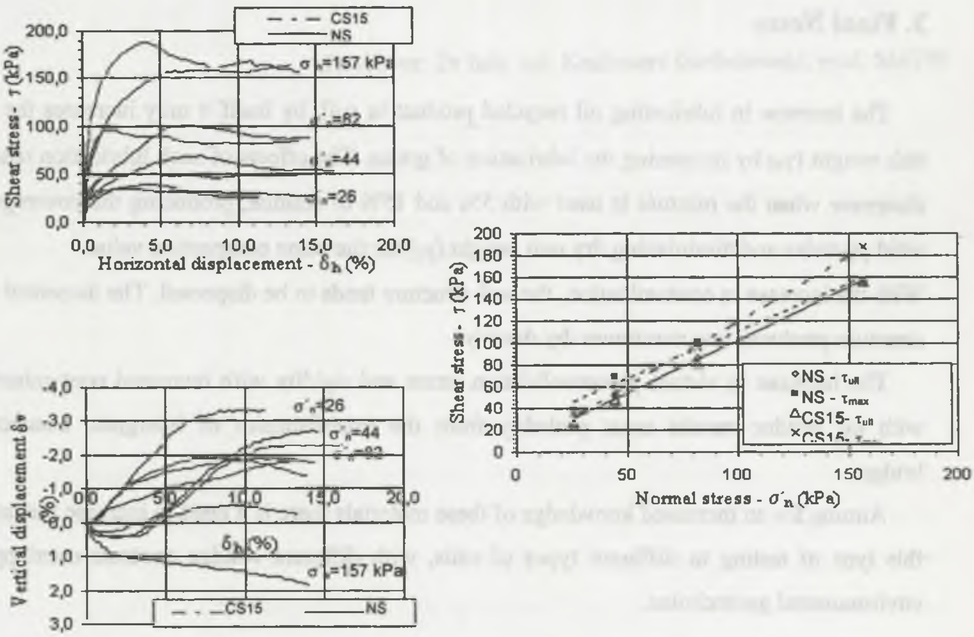

Fig. 3. Results of direct shear tests of soil *NS* and soil contaminated with oil and lime

Rys. 3. Wyniki bezpośrednich prób ścinania gruntu NS oraz gruntu zanieczyszczonego olejem i wapnem

The high values of the angle of internal friction in terms of effective stress for natural soil are caused by high dilatance and closely connected to the shape factor of grains, angular and sub-angular, and irregular surface of grains. Cohesion is apparent due to the curving that the Mohr envelope generates at low vertical tensions while for simplification it was considered a linear function.

On the artificial soil the increase in the angle of internal friction and diminishing of cohesion intercept in terms of effective stress is due to opposite effects of oil and lime. Please note that for final deformations the angle of internal friction is the same, Table 3.

Table 3

Direct shear test parameters for tested soils

Sample	Initial void ratio	Failure criterion - τ_{max}		Failure criterion - $\tau_{ult.}$	
		c´ (kPa)	ϕ´ (°)	c´ (kPa)	ϕ´ (°)
NS	0.460-0.474	23.9	41	5.2	44
CS15	0.660-0.684	0.6	49	2.4	44

3. Final Notes

The increase in lubricating oil recycled product in soil, by itself it only increases the dry unit weight (γ_d) by increasing the lubrication of grains. The effects of such lubrication tend to disappear when the mixture is used with 5% and 15% of residue, producing the coverage of solid particles and diminishing dry unit weight (γ_d) for the same compaction value.

With the increase in contamination, the soil structure tends to be dispersed. The dispersed soil structure produces low maximum dry density.

The increase in virtual preconsolidation stress and rigidity with increased contamination with oil residue results most probably from the establishment of intergrain connecting bridges.

Aiming for an increased knowledge of these materials there is a need to increase the use of this type of testing to different types of soils, with different residue contents overlapping environmental geotechnics.

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