ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2003
Volume 6
Issue 2
Series CIVIL ENGINEERING

SOBOLEWSKI M. EFFECT OF NON-HOMOGENEITY OF PLIOCENE CLAYS IN THE VICINITY OF WARSAW AND THEIR PHYSICAL PROPERTIES 2003. EXPANDER COOKING OF RAPESEED-FABA BEAN MIXTURES **Electronic Journal of Polish Agricultural Universities**, Civil Engineering, Volume 6, Issue 2.
Available Online http://www.ejpau.media.pl

EFFECT OF NON-HOMOGENEITY OF PLIOCENE CLAYS IN THE VICINITY OF WARSAW AND THEIR PHYSICAL PROPERTIES

Mariusz Sobolewski
Department of Civil Engineering and Geodesy, Warsaw Agricultural University, Warsaw, Poland

ABSTRACT

Non-homogeneity of soils is the reason for considerable variability of their properties and the problems related with interpretation of geotechnical parameters at the same time. The paper presents and discusses results of examination of physical properties of Pliocene clays as well as their variability in the profile of an experimental plot in Stegny district, Warsaw. Alogn the thickness, there appear changes in the amount of clay fraction, water content, liqudity index and density of soil within layers of soils. These properties can constitute leading features for the analysis of strength, deformation, filtration, consolidation and other parameters. The determination of the character of changes in these properties gives an opportunity for separating soils behaving in a similar way in the section of the subsoil.

Key words: Pliocene clays, cohesive soil, non-homogeneity soil, physical properties.

INTRODUCTION

In the engineering practice, one can come across problems of designing and manufacturing of building structures as well as problems dealing with the co-operation of such structures with the subsoil. In civil engineering, the problems related to soil mechanics play an essential role. Geotechnical parameters, characterising particular layers of soils in the subsoil, are hard to be estimated with good accuracy by carrying out only few experimental studies. The situation looks different when the experiments are numerous. The cost, however, profoundly reduces their realisation down to the necessary limit. Under such circumstances, so-called soil indicators (leading features) are being used, which enable determination of geotechnical parameters on the base of a relationship between a given feature and parameter. The making use of soil indicators is an easy, economic and efficient method of obtaining these geotechnical parameters. The attractiveness and advantage of the incorporation of the soil indicators ensues from the possibility of transferring, by analogy, the observed relationships to other locations of the investigation. Nonetheless, control studies aiming at the verification of the finally assumed parameters, are necessary. The accuracy of estimation of the parameters depends then on the precision of identification of the soil properties and their variability in the geological profile. The geotechnical parameters are usually taken into considerations in functions describing courses of processes and phenomena that take place in nature. It is the most frequently used method of making forecasts related to the character of structure-subsoil co-operation. Therefore, the precise identification of water-ground conditions in the foundation and interaction zone of a given building structure on environment becomes particularly precious.

NON-HOMOGENEITY OF A SOIL MEDIUM

Engineering works are being carried out on soils having different degrees of composition. The composition of a building foundation subsoil results not only from the arrangement of strata, ground water levels or kinds of occurring soils, but also from spatial diversification of the soil within one stratum.

Soils, by nature, are non-homogeneous media, and anisotropic in general. This means that their properties vary within relatively short distances in the vertical and horizontal directions. Even in the case of subsoil consisting of a single kind of soil, the parameter being determined can yet differ for two samples taken out from shortly distanced locations of the soil.

The non-homogeneity of a soil is one of the main difficulties in mathematical description of the soil medium itself and all phenomena appearing there. In science related to soil mechanics as well as in the engineering practice, some simplifying assumptions are very often introduced. The soil is treated as a homogeneous and isotropic medium. Solutions obtained from models based on such assumptions yield approximate results, and the accuracy of the given model depends on the accuracy of determination of parameters introduced to governing relations and the degree of non-homogeneity and anisotropy of the assumed medium. Precise assessment of physical properties of subsoil requires a large amount of experimental studies to be carried out. The traditional way of interpretation of the results assumed in engineering calculations consists in their approximation by finding a single value (most often arithmetic average) meant to characterise the selected layer of the soil. The treating of the average value as constant and representative for a given layer escapes far from real conditions however. In cases, where good accuracy of the solution is not necessary, such an approach is satisfactory. Nevertheless, one should keep in mind the discrepancies ensuing from the above mentioned reasons. A better way of interpreting the results can be the making use of relationships between parameter defining position in the profile at the same time. It has been noticed for long that in natural conditions different soil parameters vary with depth [1,3,5,6,12]. And this can be described with a function of position and direction.

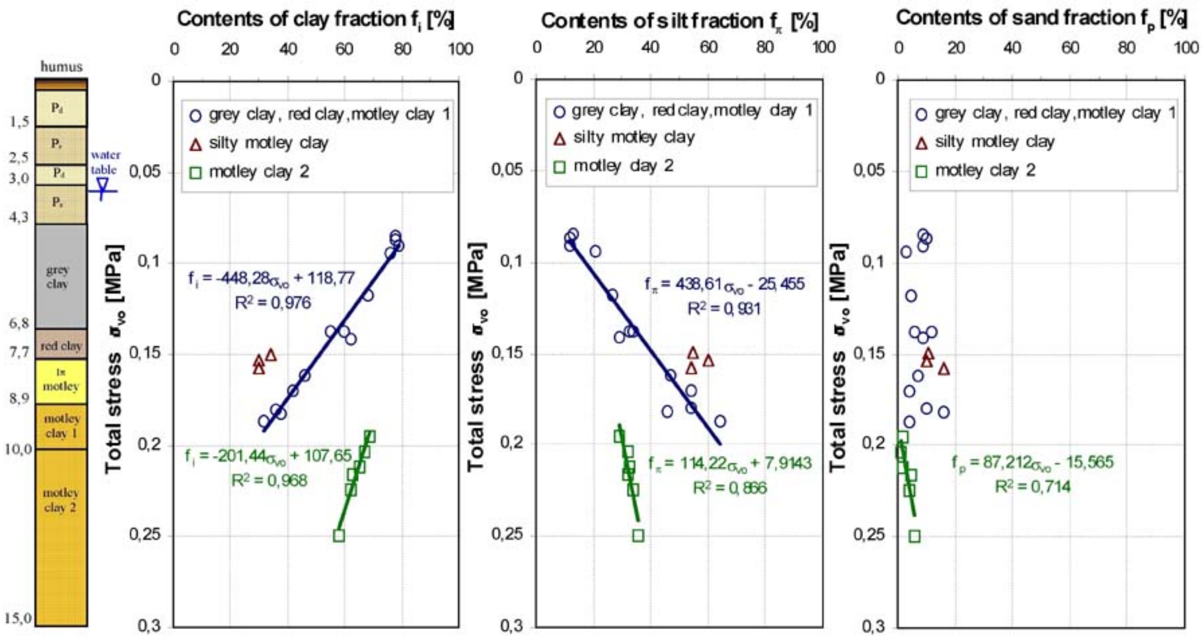
The non-homogeneity affects behaviour of soils, and can be manifested by, among others, variability of physical properties and mechanical parameters [9,10,11]. Such a non-homogeneity can result from different reasons amidst which one may distinguish primary processes connected with the soil genesis as well as secondary processes responsible for structure-textural disturbances. Hence, the following factors have an effect on the properties of soils: lithology of formations, sedimentation conditions, history of loading and current state of stress, features of internal constitution of microstructures and constituent minerals. Geotechnical properties of a soil largely depend on its structure. Therefore, in soil investigations, it is very important to preserve its natural constitution. For the characterisation of the internal constitution of a soil two notions are usually introduced: the structure and texture. They bespeak the course of transport, sedimentation and genesis of the soil. The size of particles, their shape, mutual configuration, type of cementation of mineral constituents, types of configuration, links connecting particular elements of the soil skeleton say whether the sedimentation of the given material was of water or land character. The mineral composition tells about the sources the analysed deposit originated from. The factor deciding on the structure and texture of a soil is, apart from the history of soil creation, the history of loading understood in terms of type, magnitude and duration of that loading.

The notion of the soil structure is related to the mutual configuration of particles and grains creating the soil skeleton and to the forces acting between neighbouring particles and grains of the soil. The texture, on the other hand, is characterised by spatial layout of particular mineral constituents in the soil and non-homogeneity of its structure. This non-homogeneity can consist in a layerwise settlement of soil components. That is why the texture of sedimentary soils is defined in the layerwise context. It is known that the texture can undergo transformations during hardening of the deposit (diagenesis) and its petrification (lithiphycation). It should be emphasised, however, that in many cases in cohesive soils, one cannot clearly distinguish the structure from the texture, in which case the notion of structure is only mentioned. Results of investigations presented in further parts of this paper confirm observations known in literature, and enable determination of the texture of Pliocene clays found as layerwise. The non-homogeneity of the ground environment of these clays reveals a continuous pattern as far as the physical properties are concerned. This has also been proved with the help of a mathematical equation.

GEOLOGICAL-ENGINEERING CONDITIONS OF THE SUBSOIL

The investigations were carried out in 1999-2000 on an experimental plot in Stegny, Warsaw. The place of research was located on a Quaternary overflood terrace of Wisła river distanced by 0.5 km from the Wisła slope. From the surface down to 4.3 m in depth, there appear dark-yellow homogeneous medium and fine sands that exhibit alternate deposition in the vertical direction. Within these sands, the ground water level is at 3.2 m in depth. Beneath the sands, a complex of Tertiary clays is found. The bed of clays reveals a clear layerwise structure characterised by different colouring of particular layers at the same time. The horizontal character of layered clays indicates a natural arrangement of formations and lack of glacitectonical dislocations in the form of xenoliths. Tertiary clays consist mostly of clays and silty clays. Admittedly, the clays overdominate the silty clays. This bespeaks mechanical variability of the clay complex yet on a small section of the profile, see Fig. 1. Pliocene clays, being in a hard-plastic state, transit into a half-compact form along with the thickness. Four different layers of clays are distinguished there. The shallowest are deposits of the dark-grey clay laid down on the flaming clay of a rusty-red colour. The characteristic element of the geological structure is an inserted pad of silty motley clay of yellow colour and thickness of 1.2 m. Deeper are motley clays with numerous bright yellowish stains, from which two layers were selected with respect to the differences in geotechnical parameters. The boundary separating these layers runs at the depth of 10.0-10.5 m.

Figure 1. Type of soils and variations capacity of clay, silt and sand fraction in the profile

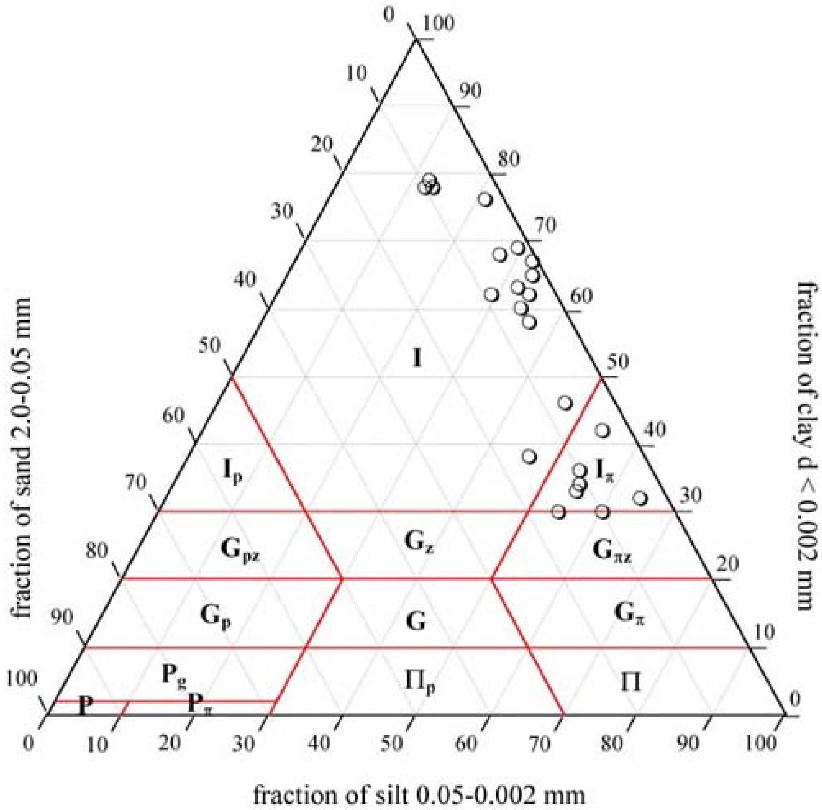


SCOPE AND METODOLOGY OF CARRIED OUT TESTS

In most countries, including Poland, the base for the classification of soils are suitably selected and realised identification researches. For this purpose, the mechanical composition of soils is determined by sedimentation methods. Very useful in the identification and classification of soils are water content, Atterberg's limits and related dependencies. Additionally, as an auxiliary test, the determination of the density of soil and density of dry soil is realised.

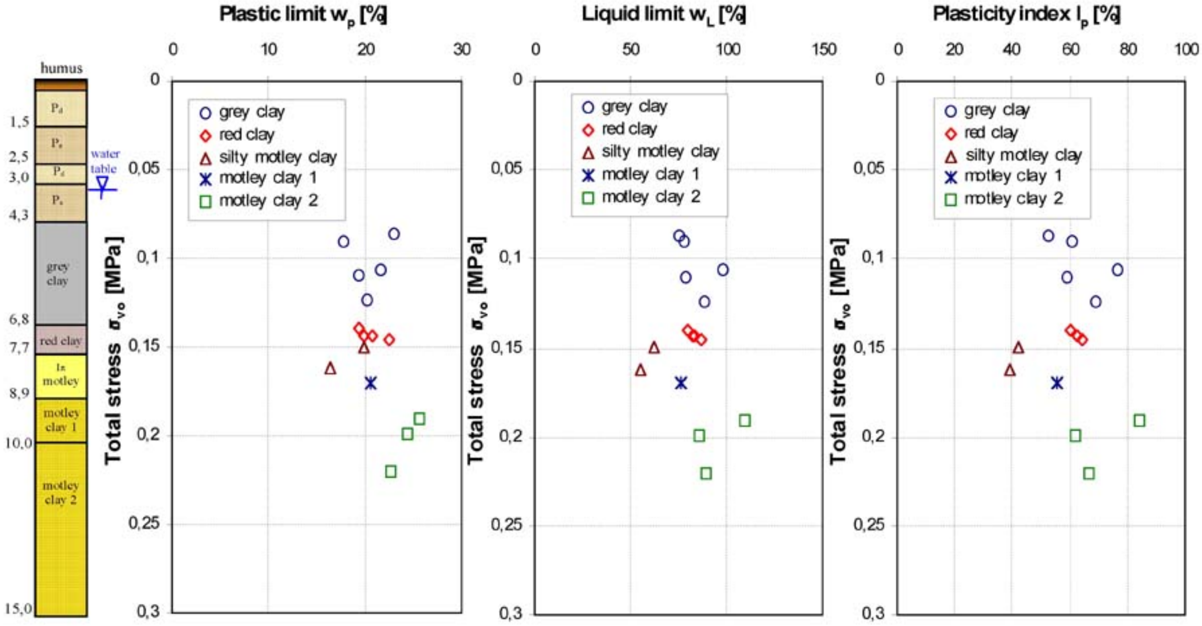
Such tests were carried out on NS and NNS samples at the Geoengineering Department of Warsaw Agricultural University (SGGW) for the determination of the following physical properties of Pliocene clays: particular soil fraction contents, water content w_n, density of soil ρ, density of dry soil ρ_d. The consistence limits, i.e. the liquid w_L and plastic w_p limits, which enabling determination of the plasticity index I_p and the liqudity index I_L, were studied as well. Soil samples were taken from two holes with 7 different depths from 5 to 11.5 m, distanced by 1 m.
The mechanical composition of clays and silty clays was determined via areometric Casegrand's method with Prószyński's modification. In the tests, a peptising agent in the form of a 10 ml 10% solution of hexametaphosphate chloride ($Na_6P_6O_{18}$) was used. The peptising agent enabled full dispersion of colloidal suspension in the cylinder. Totally, there were 33 areometric analyses realised. Average values of the content of particular fractions representing particular layers in the vertical profile are shown on Feret's terynary diagram in Fig. 2.

Figure 2. Feret's terynary diagram with results of laboratory measurements



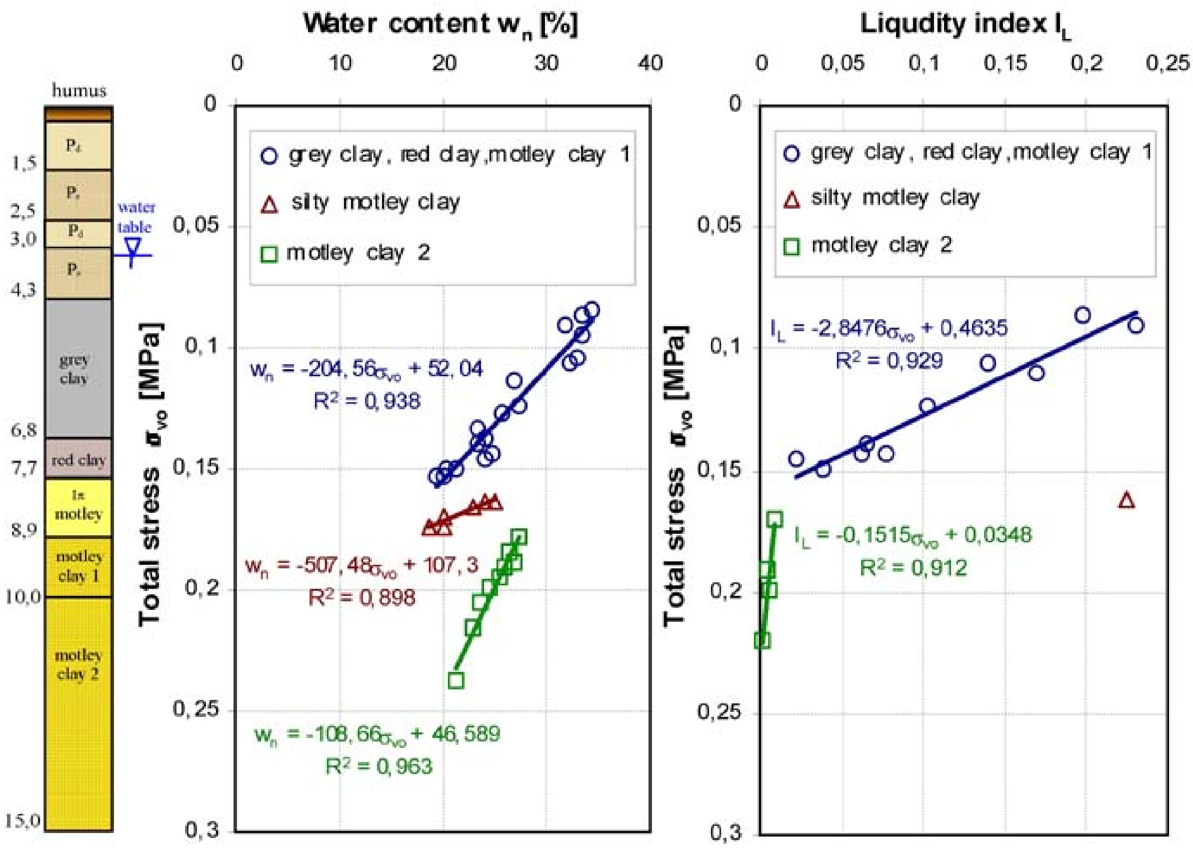
The plastic w_p and liquid w_L limits were examined on the same material taken from 15 depths of the geological profile. The results of the investigations are arithmetic averages of two tests for the limit w_p, and in the case of the limit w_L, being determined via Casegrand's method, there were 6-9 test repetitions. The results, together with the plasticity index I_p, found from the difference between w_L and w_p are presented in Fig. 3.

Figure 3. Values of plastic limit, liquid limit and plasticity index in the profile



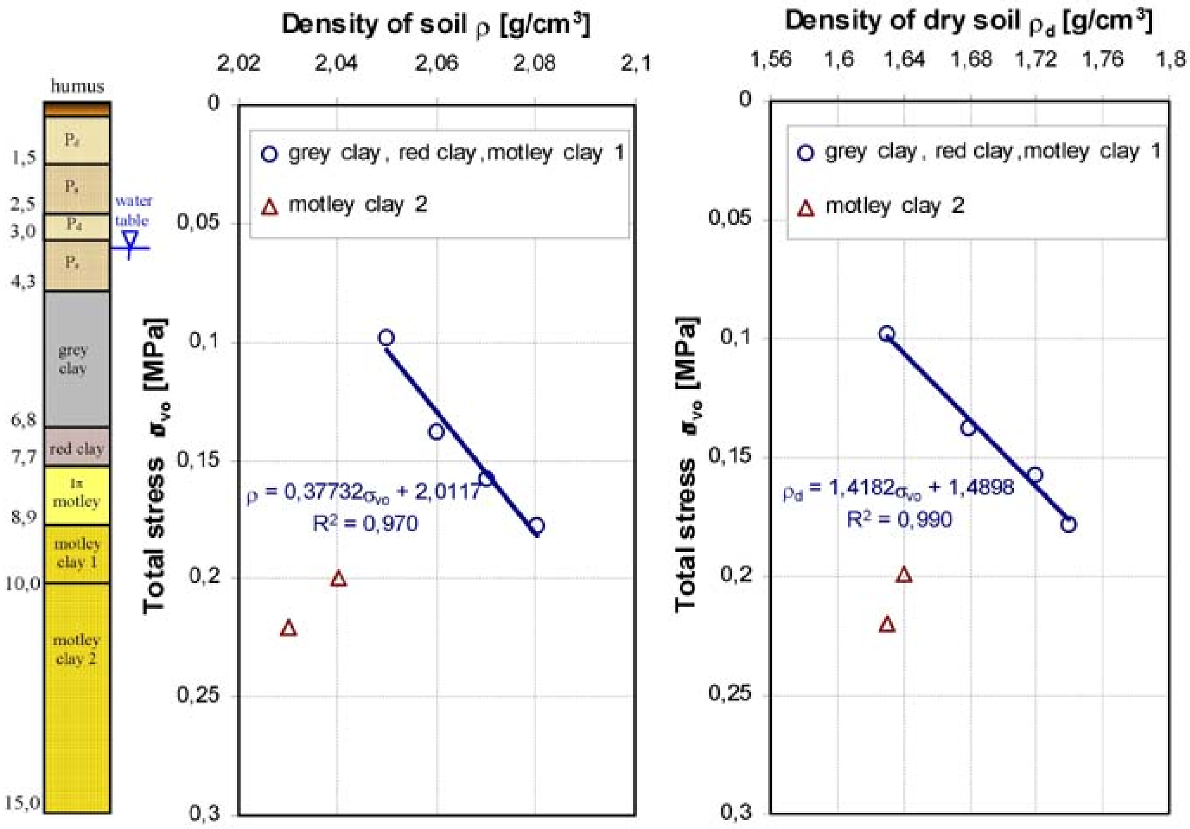
The water content w_n of cohesive soils was estimated by making use of the classical oven-balance method. In sum, there were 150 measurements that gave 34 results in the form of mean values from 5 tests on the average. Taking into account the water content as well as limits w_L and w_p, the liqudity index I_L was calculated. The results are shown in Fig. 4.

Figure 4. Variations of water content and liqudity index in the profile



The density of soil ρ and density of dry soil ρ_d was determined from the mass and volume of the NNS samples prepared for tests on compressibility and water permeability. The global number of measurements was 44. A graphical illustration of the average values in the profile is shown in Fig. 5.

Figure 5. Variations of density of soil and density of dry soil in the profile



INTERPRETATION OF OBTAINED RESULTS

Pliocene clays originated from a long-term process of sedimentation. During that time, changes in the depositing material changes in conditions of its transport as well as effect on the environment took place. The changes in these factors, which affected the properties of the deposits, made the Pliocene clays have different properties in the vertical direction mainly. From sections of soils shown in Figs 1-5, it ensues that some physical properties of the soils vary considerably along the thickness. In an 8 m long part of the soil section, there were 4 layers of Pliocene clays separated. It can be seen then that within a moderate thickness of the clay layer, say 1.0 m, there appear considerable variations in the mechanical composition, water content, liqudity index and density of soil (including density of solid particles). These variations were found in a small space not only between the separated layers but also within particular layers and sedimentation cycles.

From the analysis on mechanical composition, one concludes that clays and silty clays are the typical Tertiary deposits (Fig. 2). Generally, a considerable decrease in the clay fraction is marked in the deposits while observing along the thickness. The silt fraction however, appears in an ascending manner (Fig. 1). This conclusion is also supported with the found equation, which has a very high determination coefficient (R^2>0.87), and describes that phenomenon. Within at the depth of 5-15 m, two sedimentation cycles can be outlined. The first one is located at 4.3-10 m. It includes grey, rusty-red, and the upper zone of motley clays. This bespeaks the variability of conditions in which particles deposit. In this cycle, the clay fraction content vary between 79-32%. The exception is a silty interbedding with 30-34% content of the clay fraction. In the second sedimentation cycle, reaching 12.5 m, the clay fraction is found between 69-58%. The character of the observed cycles indicates that the sedimentation took place in a water environment (bigger particles deposit first, then the finer ones). In all cases, the mechanical composition is completed with the silt up to the clay fraction.

Some peculiarity is observed in the case of the water content of the investigated soil. It exhibits, like the clay fraction content, decreasing trend with the depth. In Fig. 4, one can see 3 different zones of various characteristics of this parameter. The first upper zone from 4.5 down to 8 m shows changes in w_n within 34.4-19.5%. In the middle zone, at the depth 8.5-9.0 m the clay changes its water content from 25 to 18.6%. The third layer zone at 12 m exhibits w_n on the level of 27.3-21.2%. Within the entire examined volume the water content varied between 18.6-34.4%.

There are two visible trends of the liqudity index I_L. This parameter decreases from 0.23 down to 0.02 in the upper zone of clays. The liqudity index confirms the presence of a silty soil pad assuming at the depth 8.4 m the value of 0.22. Deeper are observed very steep slope of the function describing this parameter near values close to zero (Fig. 4).

The density of soil ρ as well as the density of dry soil ρ_d grow down to the depth 9.5 m, after which a sudden drop of their values is observed in deeper zones of clays (Fig. 5). Changes of the densities correspond with changes of the mechanical parameters, which was the reason for emerging of 2 zones in the motley clays. The density of soil in the upper part of clays varies between 2.05-2.08 g/cm^3, while in the lower part between 2.03-2.04 g/cm^3. The density of dry soil changes from 1.63 up to 1.74 g/cm^3, and below 9.5 m drops down to 1.63 g/cm^3.

The range within which the plastic limit is kept oscillates from 16.4 to 25.6%. Majority of the point are placed around 20%, see Fig. 3. The liquid limit changes between 55.7-109.6%. The most of the points lie around 80%. The calculated plasticity index I_p of all clays falls between 40-85%, 60% on the average.

The plastic limit w_p, liquid limit w_L and plasticity index I_p do not exhibit visible distributions along the thickness. The reason for such a situation may be the distributed soil the samples were taken from, instead of an undisturbed soil. Hence, the parameters do not reflect the structure of the soil and primary connections between the particles that appear in the natural soil, and were destroyed during preparation of samples. Suchnicka [8] explains close values of the limits w_p and w_L by poor colloidal activity of Tertiary formations. It is in contrast to the case of the liqudity index I_L that describes the state of a cohesive soil. An essential effect on the behaviour of this parameter has the water content, taken into account in calculations, as it decides about the state of the soil. This is why the changes in the liqudity index I_L are possible to be captured.

Variability intervals and mean values of physical properties are listed in Tab. 1.

Table 1. Ranges of variation and mean values of physical properties for tested soils*

Parameter	Type of soil		
	grey clay, red clay, motley clay 1	silty motley clay	motley clay 2
f_i [%]	32.0-79.0 / 57.7	30.0-34.0 / 31.3	58.0-69.0 / 64.0
f_π [%]	12.0-64.0 / 34.3	54.0-60.0 / 56.3	29.0-36.0 / 32.7
f_p [%]	3.0-16.0 / 8.0	10.0-16.0 / 12.3	1.0-6.0 / 3.3
w_n [%]	19.5-34.4 / 26.6	18.6-25.0 / 21.8	21.2-27.3 / 25.1
w_p [%]	17.8-23.0 / 20.5	16.4-19.8 / 18.1	22.6-25.6 / 24.2
w_L [%]	75.6-98.0 / 82.9	55.7-62.0 / 58.8	86.4-109.6 / 95.1
I_p [%]	52.6-76.4 / 62.4	39.3-42.2 / 40.8	61.9-84.0 / 70.9
I_L	0.023-0.231 / 0.111	0.223-0.225 / 0.224	0.001-0.006 / 0.004
ρ [g/cm^3]	2.05-2.08 / 2.06	2.06-2.08 / 2.07	2.03-2.04 / 2.03
ρ_d [g/cm^3]	1.63-1.74 / 1.69	1.71-1.73 / 1.72	1.63-1.64 / 1.63

*Numerator showed ranges of variation, denominator showed mean values of physical properties

PROPOSED RELATIONSHIPS

The captured from results of investigations and described variability of physical properties of clays, bespeaking their non-homogeneity, characterises the surface zone of the Pliocene clay deposits. The variability of physical properties within the clay layers is uniform, consistent with sedimentation cycles, with the arrangement of the layers, and the stress state (historical and present). Uniformly growing changes enabled finding mathematical relations describing these parameters. The above remarks suggest that the course of variability of the physical properties of the examined soils can be dependent mainly on lithologic features, thus on the mechanical composition, content of particular constituent minerals, or internal structure (types of microstructure) of such deposits.

The Pliocene clays of Stegny are heavily overconsolidated soils (σ'_p = 0.9-1.2 MPa). The preconsolidation pressure assumes a uniform distribution according to the current state of stress *in situ* [7]. It can be said then that the maximum vertical effective past pressure do not disturb the general trends of changes in the geostatic stresses.

According to Kaczyński's [4] studies, in the whole profile of the clays there appear transition types of microstructures: matrix-turbulent and turbulent-laminar microstructures (according to Grabowska-Olszewska et al. [2] classification). The deeper zone of motley clays is marked by a higher degree of the orientation of a microstructure with smaller porosity. Along the thickness, the clays exhibit a drop in the porosity from 52% down to 37%. The mineral composition is some monotonous as well. The essential components are mineral clays and quartz. The main constituents are: beidelite, illite, and kaolinite in various proportions. Generally, the mineral composition of the examined clays can be presented in the form $B^{50-80}>>I^{10-45}>K^{5-10}$.
Since the type of a microstructure and particular components do not exhibit bigger differences in the profile, then they cannot greatly affect the properties of the deposits. According to the carried out analysis of the investigation results, it ensues that the greatest effect on the physical properties is due to the content of particular fractions of clays. According to the carried out analysis of the investigation results, it ensues that the greatest effect on the physical properties is due to the content of particular fractions of clays. Increase in the clay fraction content and simultaneous decrease of the silt fraction content entails growth of the water content w_n, liqudity index I_L and drop of the density of soil ρ and density of dry soil ρ_d (which directly lowers the density of solid particles ρ_s).
Relatively big non-homogeneity of clays, characterised by diversity of their features, enabled one to prove important relationships between the mechanical composition and physical properties in the selected layers. For statistical analysis of these relationships, the standard packages MS Excel 7.0 and Statgraphics 4.1 was applied. The relationships that could be approximated with an equation having the determination coefficient R^2>0.8 were recognised as particularly significant. The found quantitative relations between the physical properties and mechanical composition proved the strong effect of the clay and silt fraction content as well as their ratio. The results of investigations are presented in terms of the percentage share of the clay fraction as it revealed the greatest value of the determination coefficient R^2. Because of the small number of the examination results, the obtaining of functions describing physical properties of silty motley clays and motley clays is not possible. Proposed relations that can serve for finding chosen physical properties of Pliocene clays are listed in Tab. 2. Correlations between the selected parameters illustrate the enclosed below figures.

Table 2. Empirical formulae of physical properties of Pliocene Stegny clay*

Parameter	Type of soil		
	grey clay, red clay, motley clay 1	silty motley clay	motley clay 2
w_n [%]	$w_n = 28.261\ f_i + 9.987$	$w_n = 115.18\ f_i – 27.989$	$w_n = 53.72\ f_i – 11.326$
I_L [-]	$I_L = 0.636$ fi $– 0.291$	-	$I_L = 0.075\ f_i – 0.046$
ρ [g/cm^3]	$\rho = -0.063\ f_i + 2.097$	-	-
ρ_d [g/cm^3]	$\rho_d = -0.251\ f_i + 1.821$	-	-

* In empirical formulaes should by apply f_i nonnamed

Figure 6. Dependence of water content and liquidity index on clay fraction

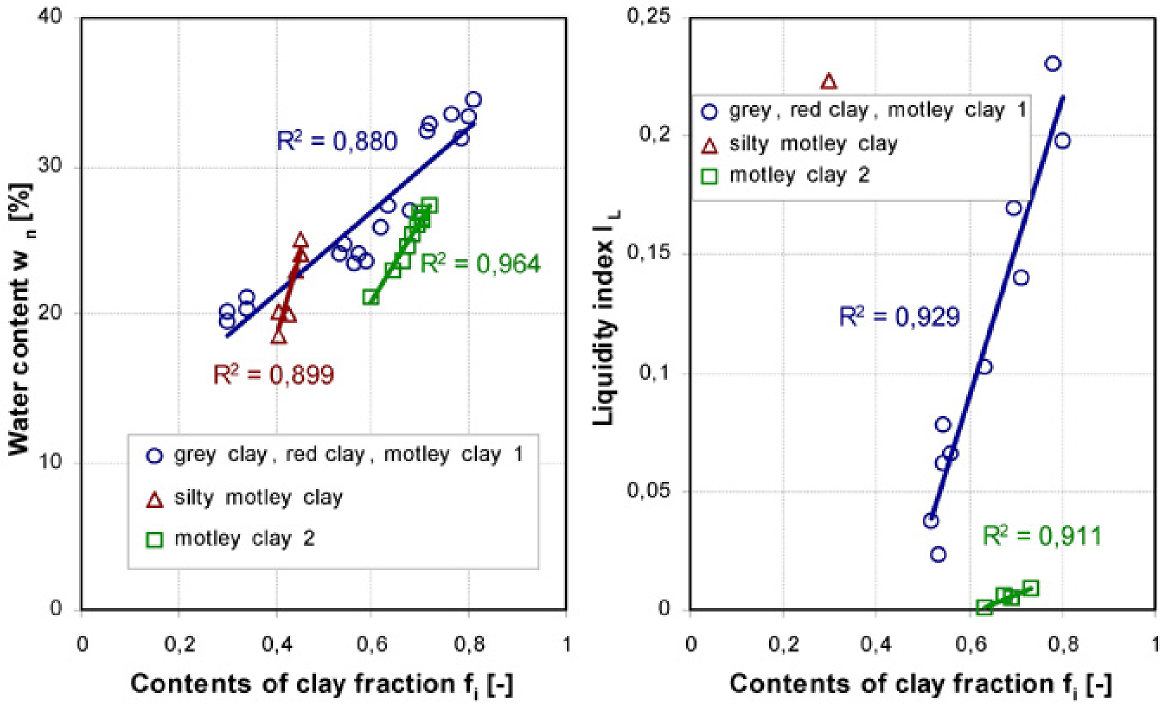
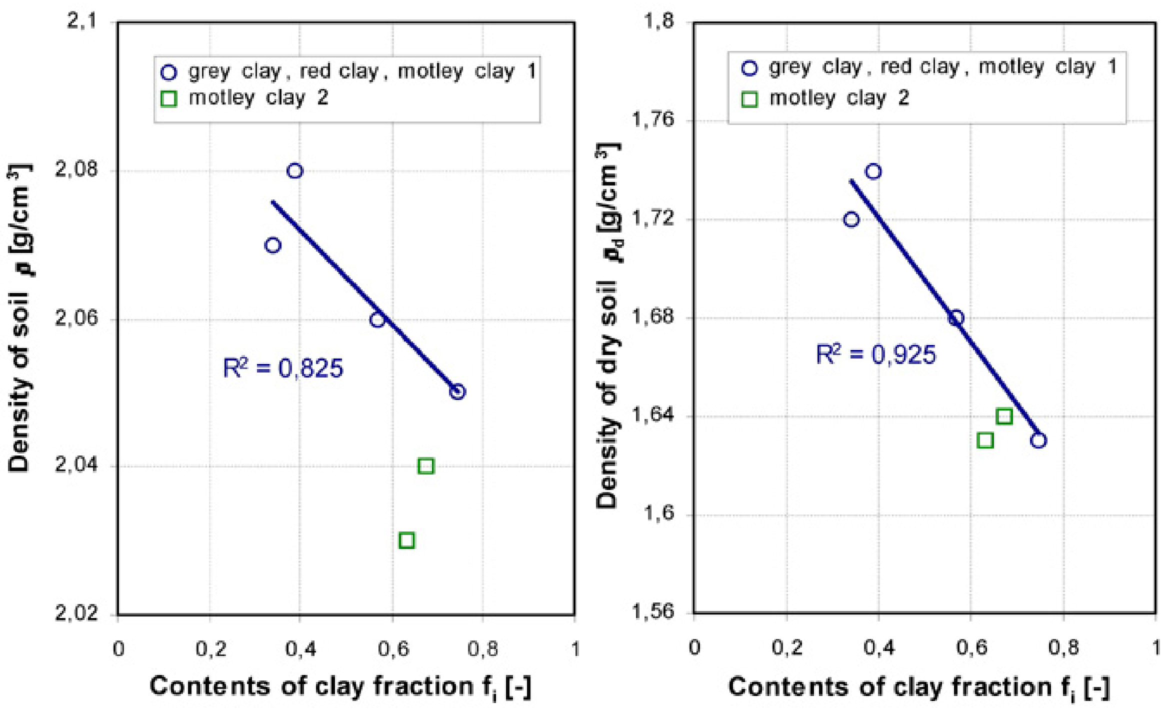


Figure 7. Dependence of density of soil and density of dry soil on clay fraction



Taking directly the advantage of the above relations, one can calculate w_n, I_L, ρ, ρ_d of Pliocene clays. The thus found values of the fundamental properties were compared with the corresponding parameters obtained from experiments in the natural state of the soil.

The comparison results are presented in subsequent figures. They reflect high correlation of the analysed physical properties.

Figure 8. Comparision of water content and plasticity index between the laboratory and calculated values

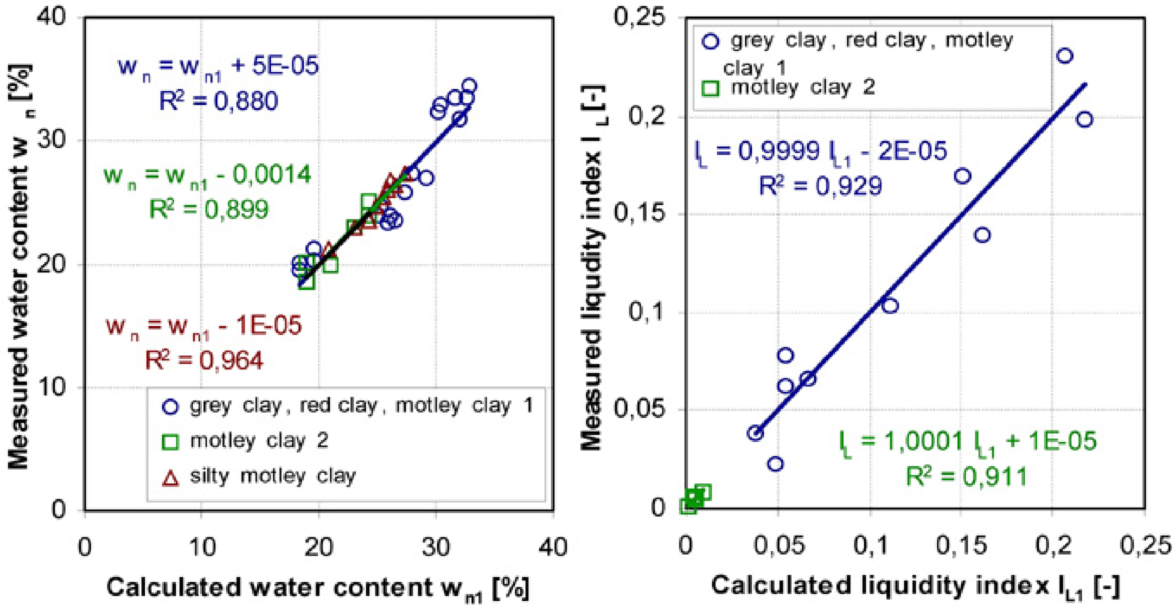
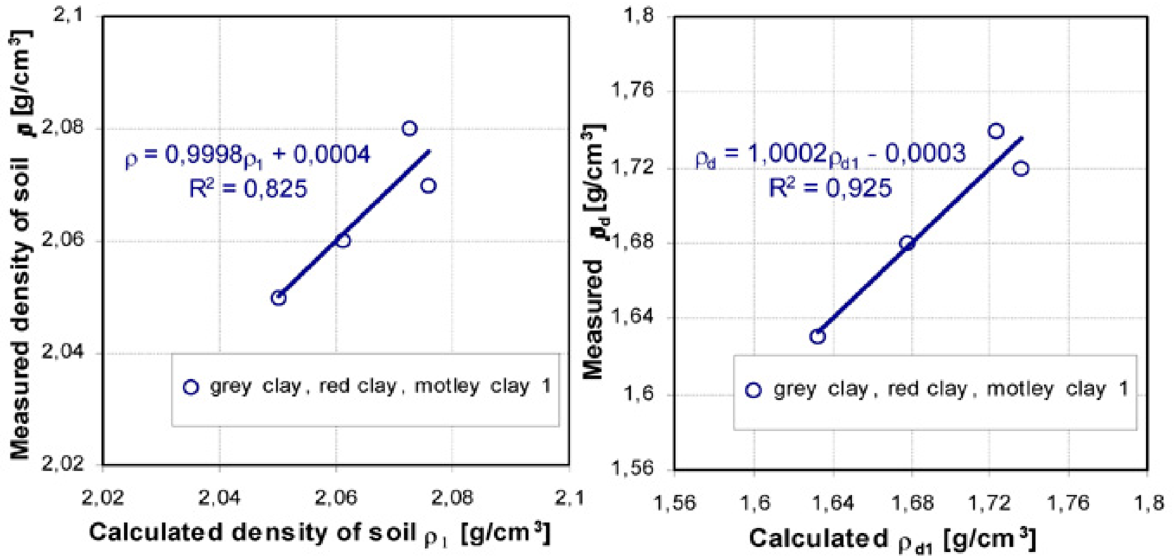


Figure 9. Comparision of density soil and density of dry soil between the laboratory and calculated values



CONCLUDING REMARKS

Clays are recognised as the most homogeneous soils among cohesive ones. They are the most anisotropic with respect to the structure at the same time. The structure of these deposits enables selection of zones of the same genesis. Within particular layers, however, variability of physical properties and mechanical parameters is marked despite classification of the material to the same given genetic layer. In practice, within a small distance in the vertical direction, the changes in soils are not sufficiently pronounced to be described by a mathematical formula. The horizontal non-homogeneity of soils can be observed near boundaries of sedimentation basin [6]. Therefore, purposeful seems to be the exploration of the dependencies in the vertical profile.

A more detailed exploration of soils is recommended. Collection of large information sets can occur fruitful for a further classification of soils. Moreover, there also exists a need of seeking correlation relationships and empirical formulas describing material indicators and their sensibility to the strength, deformation, filtration and

consolidation parameters. An effect of such investigations can be new characteristics of geotechnical parameters expressed in the form of relations containing functions that are assumed in engineering calculations.
The analysis of the investigation results confirmed once again that the properties of soils depend on the genesis and changes, which had taken place since the time of origin of the soil up to the present. The behaviour of soils depends on stress, lithological features and environment. The obtained image of these changes is a qualitative interpretation of the examined material, whereas the range of the changes extends this interpretation quantitatively.

Despite the fact that the carried out analysis was based on a small number of tests on the physical properties of Pliocene clays and, admittedly, tests realised on samples coming from one experimental plot only, the obtained results posses logical explanation, and the observed trends can be treated as unambiguously confirmed. The carried out identification of clays taken out from the depth 5-12 m and the analysis of the physical properties together with relationships between them, enables one to draw the following conclusions:

1. Pliocene clays exhibit a layerwise texture, which allows for treating them as non-homogeneous media.
2. Non-homogeneity of the clays appears within single layers and sedimentation cycles.
3. The content of the clay fraction has the greatest influence on the physical properties of the examined clays, however the silt fraction content affects them greatly as well.
4. Variable mechanical composition is reflected by considerable differences in the water content, liqudity index and by small changes in the density of soil.
5. In order to obtain correlation relationships dealing with the determination of physical properties and geotechnical parameters of the examined soils, one can find it helpful to make use of the trends of the changes in these parameters that appear under application of stress.
6. The stress induced changes indicate only such physical properties and geotechnical parameters, which describe the structure of a soil only. In the case of other physical properties that have not been tested, such as porosity and void ratio or shrinkage limit and density of solid particles, one can expect analogous trends.
7. The physical parameters which have been found from the proposed correlation relationships via calculation are convergent with the parameters determined from the laboratory tests.

REFERENCES

1. Choma-Moryl K.: Variability of physical properties of the Poznan Clays (Neogene) from the area of Wrocław, with reference to their genesis and litostratigraphy. Geologia Sudetica. 1988, Vol. XXIII, nr 1, 1-63.
2. Grabowska-Olszewska B., Osipow V., Sokołow V.: Atlas of the microstructure of clays soils. PWN, Warsaw, 1984.
3. Fortunat W.: Characteristic phisical properties of pliocene clays from the area of Warsaw, Bydgoszcz and Tarnobrzeg. Z badań Geol.-Inż. w Polsce. Wyd. Geol.1960, t. 1, 125-155.
4. Kaczyński R., Grabowska-Olszewska B., Borowczyk M., Ruczyńska-Szenajch H., Krauzlis K., Trzciński J., Barański M., Gawriuczenko J., Wójcik E.: Litogenesis, microstructures and geological-ingineering properties of pliocene clays from Warsaw region. 2000, Project KBN nr 9T12B00516.
5. Kłębek A., Łoszewski B.: The pliocene clays as the subsoil in Warsaw region. VI Polish Conf. Soil Mech. and Found. Warsaw 1981, t. 1, 298-307.
6. Lambe T.W., Whitman R.V.: Soil mechanics. Arkady, Warsaw, t. 1-2, 1978.
7. Sobolewski M.: Determination of flow water characteristic in cohesive soils on the basis in situ tests. PhD, Dep. Geoingineering SGGW, Warsaw, 2002.
8. Suchnicka H.: More about soil properties in the area of sedimentary discontinuity. Inż. Morska i Geot., 2003, nr 3-4, 152-156.
9. Szymański A., Sobolewski M.: Determination of permeability parameters in cohesive soils. Inż. Morska i Geot., 2003, nr 3-4, 159-163.
10. Szymański A., Sobolewski M.: The use of dilatometer test for determination of permeability coefficient in cohesive soils. VI Conf. Aktual problems science-research archtecture. Olsztyn-Kortowo, 2003, 381-387.
11. Szymański A., Sobolewski M.: The use of BAT probe for determination of permeability coefficient in heavily overconsolidated clays. Acta Scientiarum Polonorum, Archtectura, 2003, 2 (1), 51-62.
12. Zadroga B., Damicz J.: The lithology influence on gyttja's physical properties., IV Conf. Aktual problems science-research archtecture. Olsztyn-Łańsk, 2000, 623-631.

Mariusz Sobolewski
Department of Civil Engineering and Geodesy
Warsaw Agricultural University
Nowoursynowska 159, 02-787 Warsaw, Poland

TEL. (+48 22) 8472782
e-mail: sobolewskim@alpha.sggw.waw.pl