JOURNAL OF THEORETICAL
AND APPLIED MECHANICS
3, **36**, 1998

NONHOMOGENEITY OF THE PHYSICAL-MECHANICAL PROPERTIES OF SOIL MEDIUM COMPOSED OF TERTIARY CLAYS AND QUATERNARY LOESSES[1]

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The properties of typical soils occurring in Poland and Ukraine are analysed in this paper. The Tertiary maritime clays from Krakowiec and Quaternary eolic loesses of the porosity lying within the range of $25 \div 60\%$ and of the laminar and skeletal microstructures, respectively, have been tested. They often constitute foundations of buildings, and therefore, their physical-mechanical parameters should be determined. The analysis of nonhomogeneity has been limited to the presentation of statistical coefficient of variation for basic parameters used in design of foundations of engineering objects. Nonhomogeneity of soils is caused by geological conditions of their origin. The results presented indicate that the tested loesses and clays from Poland and Ukraine are very similar from the viewpoint of their parameters nonhomogeneity. The parameters of soils change within a wide range. The physical parameters vary within the range below $30 \div 40\%$, whereas the coefficient of variation for mechanical parameters often exceeds 100%. The coefficient of variation becomes smaller when the subsets of samples are extracted from the whole testing set. In view of engineering-geological properties of soils, for the purpose of engineering calculations one may assume that the homogeneous soils are those for which the values of coefficient of variation do not exceed the limit values for particular parameters (Table 5).

Key words: nonhomogeneity, loesses, clays, coefficient of variation

[1]The paper presented at the Second Polish-Ukrainian Conference "Current Problems of Mechanics of Nonhomogeneous Media", Warsaw 1997

1. Introduction

Economic aspect of engineering object design enforces consideration of the physical-mechanical properties of soils or rocks underlying engineering objects. It concerns mainly determination of the bearing capacity and checking whether the assumed load does not exceed the strength of soils as well as whether the calculated settlement of the object does not exceed its admissible deformation. The main parameters used in calculations of building foundations are: strength (or, to be more specific – the angle of internal friction and cohesion), deformability (primary and secondary moduli of compressibility) of the soil. The parameters characterising strength and deformability of soils are not material constants but depend on many factors. Most often they are functions of:

- Effective stress, time and conditions of natural surrounding
- Load history and conditions of origin
- Physical properties: porosity index, ratio of saturation and structure (microstructure).

Additionally, the analysed parameters are significantly influenced by the testing method used, particularly by the velocity of load the soil is subjected to. There are also other important issues, which should be discussed: representativity of the tested soils, nonhomogeneity of the loading states, deformabiliy in the tested samples, as well as nonhomogeneity and anisotropy of the soils. The problems of nonhomogeneity, anisotropy and weakened surfaces (discontinuities) become more important for bigger areas of the contact zone between the soil foundation and engineering object. Nonhomogeneity of soils is caused mainly by geological conditions of its origin.

In the paper the authors do not discuss the problem of scale of nonhomogeneity. Depending on the scale (megascopic, macroscopic, microscopic or ultramicroscopic) employed the soil may either homogeneous or nonhomogeneous.

It is often assumed that physical-mechanical parameters used in engineering geology, geotechnics or geomechanics are random variables. Thus, the level of nonhomogeneity one can describe using the following statistical parameters:

- Measures of central tendency (arithmetic mean $\overline{x}$)
- Measures of variability (coefficient of variation V, standard deviation σ, range of variation $R = x_{max} - x_{min}$, nonhomogenity ratio $\gamma_m = 1 \pm V$.

In the present contribution we consider the nonhomogeneity of parameters only from the viewpoint of coefficient of variation, using a macroscopic scale. The other problem consists in determination of the criteria for measurement of nonhomogeneity, for example on the basis of coefficient of variation. Nonhomogeneity of the properties of soils is considered on the example of the following soils occurring in Poland and Ukraine:

- Tertiary, Krakowiec clays
- Quaternary loesses.

2. Nonhomogeneity of Krakowiec clays

Thick (from several meters in the region of Lvov up to a few dozen meters in the region of Tarnobrzeg) clay and sandy clay sediments of the Upper Miocene (Tertiary), which occur almost only in the outer zone of the Carpathian Foredeep (with the Upper Badenian sediments developed in a similar way) are usually called the Krakowiec clays. Two following regions are considered: I – South Poland area (mainly upper Vistula and lower San valleys), II – region of Lvov, Ukraine (Fig.1).

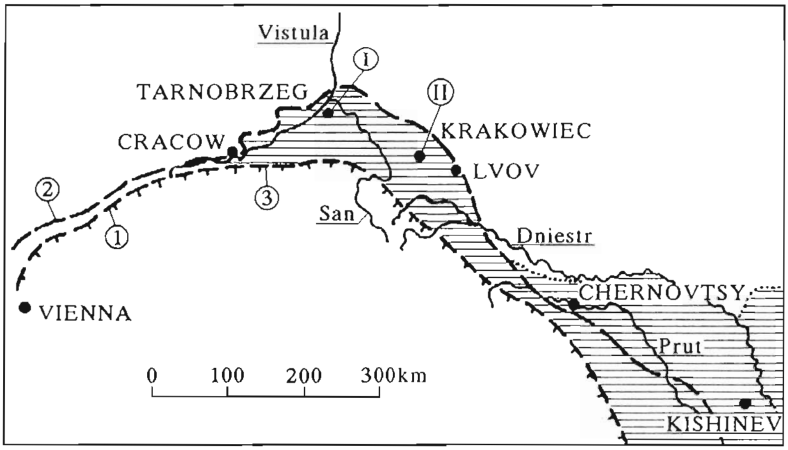

Fig. 1. Location of the analysed areas of Krakowiec (Tertiary) clays; 1 – the Carpatian boundary, 2 – outer boundary of the Carpathian Foredeep, 3 – area of occurance of Tertiary clay sediments, I, II – analysed areas

The Krakowiec clays consist of fine laminated grey and dark grey clays, mudstones and clay shales with numerous inclusions of fine sand, silt and bentonite. The coarse-grained clastic material fraction increases in clays towards peripheral zones of the Sarmatian basin.

From the engineering-geological point of view, the massif of the Krakowiec clays should be treated as a heterogeneous, anisotropic and discontinuous medium. The soil massif is cut by weakened surfaces, the two types of which can be distinguished: sedimentary surfaces and discontinuities. Weakened surfaces of the sedimentary type are represented by various laminae intercalation of silty-sand deposits. The surfaces of discontinuity-type represent structural surfaces of the joint or slickenside nature.

The Krakowiec clay sediments are represented by marine, montmorillonitic and illitic, marly, consolidated, and laminated clays. Thickness of a laminae can vary from less than a millimetre to several centimetres (Fig.2).

The clays reveal, depending on the observation scale, various textures and structures:

- Macrolevel: usually stratified, fractured
- Mezolevel: laminated, random
- Microlevel: laminated, random, liquid
- Ultramicrolevel: matrix-turbulent, laminar.

Physical and mechanical properties of the Krakowiec clays result from long and complicated geological processes, during which they were subject to several loading and unloading cycles. As a results the overconsolidated state of the clays appeared. In the natural state the Krakowiec clays reveal high strength. Due to the clay overconsolidation they are very sensitive to changes in strength with time. When the critical state is reached, a rapid decrease in bearing capacity follows. The weakened surfaces in clays affect a decrease in strength down to a value close to the residual strength. The Krakowiec clays in Poland are similar from both lithologic and physical-mechanical properties viewpoint, respectively, to south Ukrainian clays.

The Krakowiec clays are very sensitive to exogenic factors. Due to cyclic drying and getting wet they were transported from a soil with very favourable properties into a weathering waste with low strength parameters. When compared to non-weathered clays, the weathered soils are characterised by higher values of porosity and lower values of volume density and overconsolidation ratio. These soils may be treated as unconsolidated or normal consolidated.

Basing on the research carried out at more than 50 observation points the following two general two zones in the weathering profile can be distinguished:

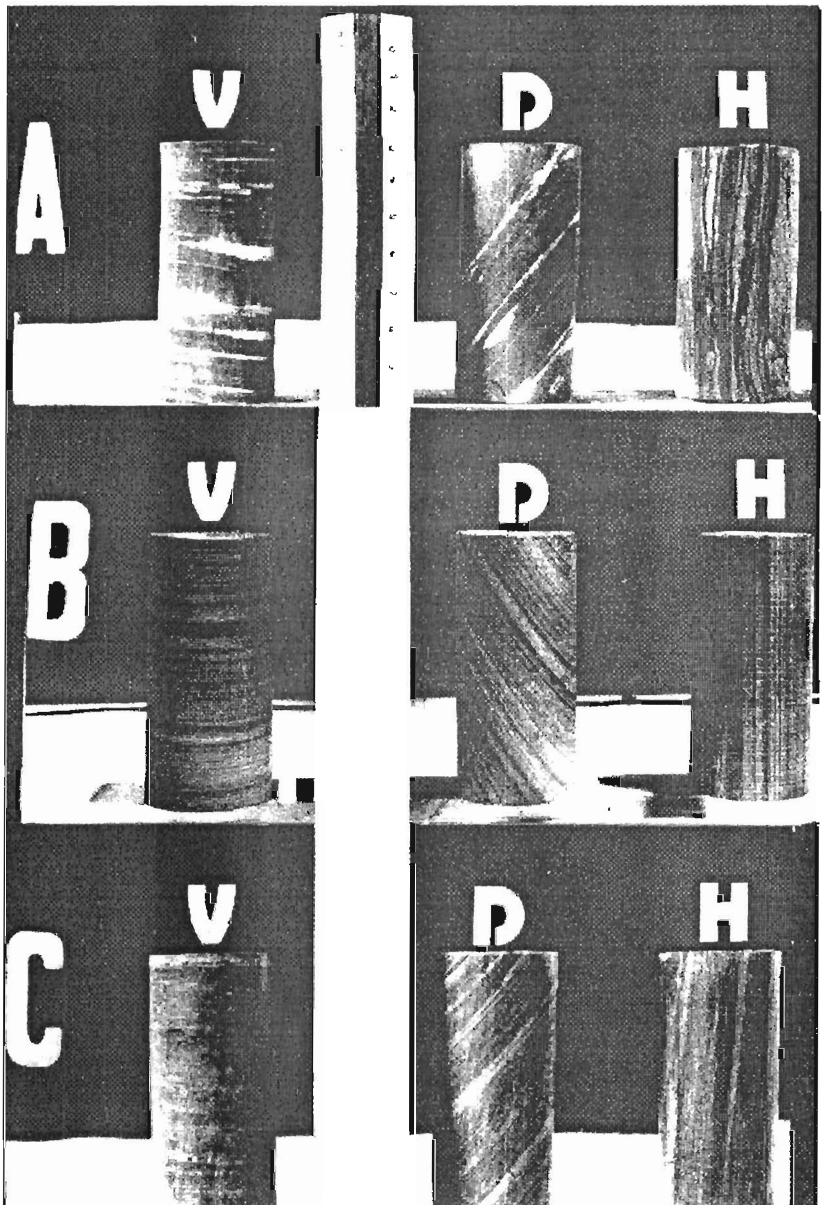

Fig. 2. Samples of Krakowiec clays with horizontal (H), diagonal (D) and vertical (V)

Zone I – strongly weathered clays. It is characterised by the complete loss of original form of the bedrock clays (change above 70%). Neither lamination nor layers, which are typical for some Krakowiec clays are observed. The anisotropic properties are destroyed. Decalcification proceeds mostly in the uppermost part of the profile.

Zone II – moderately (or slightly) weathered clays. They are strongly (or weakly) fissured. The weathering processes develop only on the weakened surfaces of discontinuity or sedimentary type. Changes $30 \div 70\%$ (sometimes up to 30%).

In the weathering profile of preconsolidated Krakowiec clays one can observe the following features when compared to unweathered clays:
– decrease in content of calcium carbonate,
– distinct process of increase in the montmorillonite content,
– decrease in the shear strength (to $80 \div 90\%$),
– decrease in the volume density (to 20-30 %).

For details of the Krakowiec clays the reader is referred to 1, 2, 3.

The results for the Krakowiec clays, together with the statistical parameters, are presented in Table 1 and Table 2. Table 1 covers the results of tests on clays from the territory of Poland (Carpathian Foredeep), while Table 2 shows the results for the Ukraine clays (region of Lvov).

Table 1. Physical-mechanical properties of the Tertiary Krakowiec clays from the Carpathian Foredeep (Poland)

	1	2	3	4	5
R	60÷15	2.76÷2.57	2.30÷1.58	2.04÷1.18	54.2÷25.2
X	33	2.70	1.93	1.51	43.9
σ	94	0.04	0.18	0.23	8.04
V	28.5	1.5	9.3	15.2	18.5

	6	7	8	9	10
R	46.2÷17.2	94.2÷34.3	41.0÷14.0	53.2÷11.1	0.96÷0.51
X	24.5	60.3	33.5	33.5	0.015
σ	9.30	13.52	8.67	8.67	0.23
V	38.0	22.4	25.9	25.9	1534

	11	12	13
R	27.5÷3.0	425÷10	148000÷900
X	14.5	86	23000
σ	27.5	590	30000
V	1901	686	130

Table 2. Physical-mechanical properties of the Tertiary Krakowiec clays from the region of Lvov (Ukraine)

	1	2	3	4	5
R	–	2.67÷2.56	2.10÷1.86	1.79÷1.21	52.7÷35.1
X	–	2.70	1.96	1.55	42.6
σ	–	0.04	0.15	0.12	8.5
V	–	1.5	8	8	20
γ_m	–	0.985÷1.015	0.92÷1.08	0.92÷1.08	0.80÷1.20

	6	7	8	9	10
R	66÷12	75÷20	39÷12	43÷8	0.63÷0
X	26	44	23	21	0.15
σ	11	11	5	7	–
V	42	25	22	33	–
γ_m	0.58÷1.42	0.75÷1.25	0.78÷1.22	0.67÷1.33	–

	11	12	13
R	34÷6	90.0÷16.6	16000÷30000
X	17	42	8000
σ	6.3	15	2590
V	37	36	32
γ_m	0.63÷1.37	0.64÷1.36	0.68÷1.32

where: $R = X_{max} - X_{min}$ – area of variation, X – arithmetic mean, σ – standard deviation, V – coefficient of variation, γ_m – coefficient of nonhomogeneity, 1 – clay fraction content [%], 2 – specific density [Mg/m^3], 3 – volume density of the natural soil [Mg/m^3], 4 – volume density of the soil skeleton [Mg/m^3], 5 – porosity [%], 6 – natural water content [%], 7 – liquidity limit [%], 8 – plastic limit [%], 9 – plasticity index [%], 10 – liquidity index [–], 11 – angle of internal friction [°], 12 – cohesion [kPa], 13 – modulus of compressibility [kPa].

There is a general resemblance between the parameters, although one can observe some differences in specific values. The nonhomogeneity of parameters is variable – variation coefficient of physical parameters, generally, does not exceed $30 \div 40\%$, whereas the same coefficient for strength and deformability parameters exceeds 30%, and in the case of Polish clays even 100%. This is caused by the two facts, i.e. a very large area of the research – the tested samples were taken from the whole territory of the Carpathian Foredeep and by a relatively big depth of sampling. Such a situation takes place when one analyses the results as one set. When this set is divided into subsets; e.g., weathered clays from zone I, weathered clays from zone II, unweathered clays, the coefficient of variation is much smaller in each of the given subsets.

3. Nonhomogeneity of loesses

Fig. 3. Location of the analysed areas of Quaternary loesses; 1 – the Lublin Upland region, 2 – the Carpathian region, 3 – the Volhynia region

The investigations into physical and mechanical properties of loesses occurring on the uplands of south-eastern Poland as well as on the Upland of Wołyń in Ukraine (Fig.3) have been carried out. These loesses create a part of the sediments originated in the Pleistocene. The uppermost layers building loess sediments were accumulated in the period of Vistula glaciaton. On the territory of Poland these are upper younger loesses, described as the so called typical loesses. They contain a $70 \div 90\%$ silt fraction $(0.05 \div 0.002\,\mathrm{mm})$, a sand fraction up to 20% and a clay fraction between 10 and 20%. The loesses are characterised by a disordered texture and a content of carbonates reaching up to 10% $CaCO_3$. Typical loesses are of the silt structure. These are the loesses of eolic facies, unweathered and, as it has been proved in various investigations, most homogeneous. Table 3 and Table 4 present the results of investigations into the loesses typical for the Lublin Upland and Wołyń. The region of Lublin Upland is the largest loess area in Poland and typical loesses of great thickness occur there. The results of investigations have been obtained in the regions of Kazimierz Dolny, Kraśnik and Zamość. The investigations in the area of Carpathian region were carried out mainly in the region of Jarosław. A characteristic feature of the typical loesses is their high porosity. The porosity exceeding 42% is considered as that indicating the possibility of occurring an unstable structure. The results of investigations have shown, that in the area of Lublin Upland the loesses of unstable structure occur down to the depth of 5 m, while in the Carpathian region to the depth of 4 m. The investigations into the natural water content in the upland loesses were made mostly at depths up to 10 m. The results have proved that most of the typical loesses could be characterised by a water content below 15%. The presented parameters of strength determined by a pressiometer and a dynamic probe are representative for the typical loesses characterised by a porosity index $0.60 \div 0.75$ (porosity $38 \div 45\%$) and a water content lying within the range $0.3 \div 0.7$. The lowest values of mechanical parameters refer to loesses from the subsurface zone of $2 \div 3$ m in thickness, which is most influenced by atmospheric conditions.

Table 3. Geotechnical parameters of loesses (Poland)

	1	2	3	4	5	6
Lublin Upland region						
R	2.0÷47.0	49.0÷93.0	2.0÷11.0	1.35÷2.05	32.9÷57.6	7.2÷21.9
X	14.2	79.5	6.3	1.77	41.0	12.51
σ	7.6	6.8	2.1	0.12	3.8	3.01
V	53.7	8.7	34.1	7.0	9.3	24.1
Carpathian region						
R	2.5÷58.0	33.0÷89.0	3.0÷12.0	1.42÷2.18	29.2÷55.0	7.1÷34.0
X	13.5	79.1	7.4	1.81	40.1	13.67
σ	8.6	8.4	2.1	0.12	3.8	3.51
V	63.6	10.7	27.7	6.7	9.4	25.8

	7	8	9	10	11	12
Lublin Upland region						
R	23.8 ÷ 27.3	18.6 ÷ 24.7	1.0 ÷ 6.5	0.015 ÷ 0.236	1.6 ÷ 27.0	0.115 ÷ 1.170
X	25.5	20.6	4.9	0.102	11.09	0.715
σ	0.8	1.3	1.3	0.039	5.25	0.262
V	3.3	6.7	27.0	38.2	47.6	36.8
Carpathian region						
R	18.3 ÷ 30.8	12.8 ÷ 22.3	3.1 ÷ 10.3	0.026 ÷ 0.272	4.0 ÷ 26.5	0.20 ÷ 1.78
X	26.2	20.0	6.1	0.113	12.78	0.734
σ	2.1	1.6	1.6	0.034	3.94	0.212
V	8.2	8.3	25.7	30.2	30.9	28.9

where: $R = X_{max} - X_{min}$ – area of variation, X – arithmetic mean, σ – standard deviation, V – coefficient of variation, 1 – sand fraction content [%], 2 – silt fraction content [%], 3 – clay fraction content [%], 4 – bulk density [Mg/m^3), 5 – porosity [%], 6 – natural water content [%], 7 – liquidity limit [%], 8 – plastic limit [%], 9 – plasticity index [%], 10 – undrained shear strength [MPa], 11 – Menard pressiometer modulus [MPa], 12 – limit pressure [MPa].

Table 4. Geotechnical parameters of theVolhynia region loesses (Ukraine)

	1	2	3	4	5	6
R	2.65÷2.71	1.39÷2.03	1.21÷1.71	36.9÷53.2	8÷26	21÷32
X	2.68	1.79	1.51	43.7	15	26
σ	0.01	0.09	0.07	9	3	2
V	0.4	5	5	12	20	8

	7	8	9	10	11
R	16÷28	4÷11	18÷33	10.4÷68.3	430÷4370
X	19	7	26	33.8	1790
σ	2	1	3.5	10.6	876
V	11	14	13	32	49

where: $R = X_{max} - X_{min}$ – area of variation, X – arithmetic mean, σ – standard deviation, V – coefficient of variation, 1 – specific density [Mg/m^3], 2 – bulk density [Mg/m^3], 3 – volume density of the soil skeleton [Mg/m^3], 4 – porosity [%], 5 – natural water content [%], 6 – liquidity limit [%], 7 – plastic limit [%], 8 – plasticity index [%], 9 – angle of internal friction [°], 10 – cohesion [kPa], 11 – modulus of compressibility [kPa].

The loesses on the territory of Wołyń Upland occur mostly at a depth $0 \div 10\,\mathrm{m}$. They constitute building foundations for a majority of engineering objects. They reveal features and properties similar to those of the loesses occurring in Poland. Their parameters change within the following ranges: macroporosity $(36.9 \div 53.2\%)$, angle of internal friction $(10 \div 18)$ degrees, cohesion $(10.4 \div 68.3\,\mathrm{kPa})$, and compressibility modulus $(430 \div 4370\,\mathrm{kPa})$.

The analysis of data presented in Table 3 and Table 4 reveals distinct similarity between the obtained values, which concerns both the properties and statistical parameters. The loesses from the analysed area, from the viewpoint of their engineering-geological assessment, are very similar. The coefficient of variation have not exceeded 40%, often being below 10%.

4. Assessment of the analysed soils nonhomogeneity

The assessment of nonhomogeneity may be made using various criteria, often basing on the limit values of the coefficient of variation V. The limit values which can be found in the literature are given in Table 5. Different authors assume different values of V for particular parameters. The new criteria of nonhomogeneity of the properties of soils have been proposed taking into account the literature data, authors' experience, accuracy of the testing methods and natural variability of soils (Table 5).

Table 5. Criteria for determining nonhomogeneity of soils in terms of the coefficient of variation V [%] for different parameters

Author	1	2	3	4	5	6	7
Ingles, 1979	–	–	3	–	25	–	10
Biernatowski, 1984	–	–	2.5	–	30	–	15
Kagan, 1985	–	–	–	3	–	–	20
Proposal	20	1.5÷2.0	3	4÷5	25	20	20

Author	8	9	10	11	12	13
Ingles, 1979	10	30	–	10	30	30
Biernatowski, 1984	10	20(30)	–	5(15)	12.5÷30	5÷20
Kagan, 1985	20	–	–	–	–	–
Proposal	20	25	50	15	20	30

where: 1 – clay fraction content [%], 2 – specific density [$\mathrm{Mg/m^3}$], 3 – volume density of the natural soil [$\mathrm{Mg/m^3}$], 4 – volume density of the soil skeleton

[Mg/m^3], 5 – porosity [%], 6 – natural water content [%], 7 – liquidity limit [%], 8 – plastic limit [%], 9 – plasticity index [%], 10 – liquidity index [–], 11 – angle of internal friction [–], 12 – cohesion [kPa], 13 – modulus of compressibility [kPa].

According to the presented criteria, in view of most physical parameters, the analysed loesses may be treated as homogeneous; unless the strength-deformability parameters are considered, in that case they are slightly nonhomogeneous.

The Krakowiec clays treated as a massif are generally nonhomogeneous. Only when divided in to subsets, for physical properties they reveal the coefficient of variation V not exceeding the limit values, whereas for the strength-deformability parameters the coefficient V exceeds limit values.

5. Characteristics of the porous space

Quantitative microstructural tests provide information about morphogenetic and geometrical parameters of the porous space. The natural soils are porous media. Total porosity of the tested soils varies within the ranges of $30 \div 60\%$ for loesses, and $25 \div 55\%$ for clays. The coefficient of variation for loesses is $10 \div 12\%$ whereas for clays $18 \div 20\%$.

The Tertiary clays reveal mostly laminar microstructures with elements of a turbulent structure. They are characterised by the presence of pores in the modal class within the range $0.06 \div 0.17$ mm, anisotropic pores dominate and there is no evidence of any macropores. The average value of form index is $0.41 \div 0.52$, the number of pores is $2 \div 270 \cdot 10^3$.

In loesses, pores reveal a shape similar to the isometric one, the average value of form index is $0.50 \div 0.65$, whereas the number of pores is $7 \div 100 \cdot 10^3$. The microstructure is of slightly oriented skeleton type.

6. Conclusions

It should be emphasised that, generally, the soils are nonhomogeneous media. Their nonhomogeneity is affected by the origin, and later changes, including the anthropogenic ones.

- The nonhomogeneity of the investigated soils is mainly influenced by the changes in: percentage contents of various granulometric fractions, mineral composition, and various impurities, inclusions, concretions. Variable consolidation and occurrence of weakened surfaces (fissure) are also of great importance.
- The physical-mechanical parameters of the tested soils reveal different values of the coefficient of variation V. High values of V (sometimes above 100%) occur for: the angle of internal friction, cohesion and compressibility modulus, whereas for the physical parameters most often the values of V range between $30 \div 40\%$.
- The tested Quaternary loesses and Krakowiec clays, occurring on the territories of Poland and Ukraine, generally, reveal strong similarity, in view of their properties and nonhomogeneity. This concerns mainly loesses, whereas in clays one can observe much stronger dispersion of the values of V, due to the area of the analysed regions. On the territory of Poland the clays from the whole area of Carpathian Foredeep were considered, while on the Ukrainian side only the Krakowiec clays occurring in the region of Lvov were take into account.
- The coefficient of variation V decreases when the whole set is divided into subsets, for example in the Krakowiec clays one can distinguish the weathered (zone I and zone II) and unweathered clays (undisturbed structure), respectively.
- Considering engineering-geological properties, for the purposes of engineering calculations, the tested soils may be classified as the homogeneous ones (homogeneous layer for calculations), characterised by a value of the coefficient of variation the limit value. The proposed limit values of V are presented in the Table 5.

References

1. BIERNATOWSKI K., 1984, Statistical Characteristics of Geological-Engineering Environment, *Mat. Konfer. "Metody statystyczne w geotechnice", Prace Nauk. Inst. Geotechn. Pol. Wrocławskiej*, **44**, 5-12, in Polish

2. INGLES O.G., 1979, Soil Variability Construction quality Control and Performance Reliability, *Proc. University of New South Wales*, Sydney, 1-49

3. KACZYŃSKI R., 1981, Strength and Deformability of Upper Miocene Clays of the Carpathian Foredeep, *Bull. of Geology*, Warsaw University, **29**, (in Polish), 105-193

4. KACZYŃSKI R., 1993, Table of Engineering-Geological Properties of Miocene Clays of the Carpathian Foredeep, *Proc. Int. Symp. "On Hard Soils – Soft Rocks"*, Athens, Balkema, 189-194

5. KACZYŃSKI R., 1996, Geological Nonhomogeneity of the Subgrade, *Matematicheskie Metody i Fizikomekhanicheskie Polya, Sbornik Naucznykh Rabot*, **36**, A.N. Ukraina, 1-8

6. KACZYŃSKI R., 1997, Properties and Microstructural Features in the Weathering Profile in Miocene Carpathian Foredeep Clays, *Proc. Int. Symp. "Engineering Geology and Enviroment"*, Athems, Balkema, 173-179

7. KACZYŃSKI R., GRABOWSKA-OLSZEWSKA B., 1997, Soil Mechanics of the Potentially Expansive Clays in Poland, *Applied Clay Science*, **11**, Elsevier, 337-355

8. KAGAN A.A., 1985, *Computational Characteristics of Soils*, Stroizgat., Moscow, in Russian

9. KOSTYANOĬ M.G., 1974, *Vliyanie Uslovii Formirovaniya i Sostava Neogenovych Glin Juga Ukrainy na ikh Inzhynerno-Geologicheskie Svoistva*, (in Russian), Naukova Dumka, Kiev, 102-130

Niejednorodność właściwości fizyczno-mechanicznych ośrodka gruntowego zbudowanego z trzeciorzędowych iłów i czwartorzędowych lessów

Streszczenie

W pracy przeanalizowano niejednorodność właściwości typowych gruntów występujących na terenie Polski i Ukrainy. Testowymi gruntami były trzeciorzędowe morskie iły krakowieckie i czwartorzędowe eoliczne lessy o porowatości w granicach $25 \div 60\%$ oraz mikrostrukturach laminarnej w iłach i szkieletowej w lessach. Badane grunty stanowią podłoże budowlane, wymagające określenia parametrów fizyczno-mechanicznych. Analiza niejednorodności została ograniczona do przedstawienia wyników współczynnika statystycznego zmienności (niejednorodności) wyznaczonego dla podstawowych parametrów, wykorzystywanych podczas projektowania posadowienia

obiektów inżynierskich na podłożu gruntowym. Niejednorodność gruntów jest uzasadniona genetycznie, spowodowana geologicznymi warunkami powstawania. Przedstawione wyniki wskazują, że badane lessy i iły Polski i Ukrainy pod względem niejednorodności parametrów wykazują dużą zbieżność. Zmienność parametrów gruntów jest silnie zróżnicowana. Parametry fizyczne zmieniają się poniżej $30 \div 40\%$, natomiast współczynnik zmienności dla parametrów mechanicznych często przekracza 100%. Współczynnik zmienności zmniejsza się przy wydzieleniu podzbiorów z całości uzyskanych wyników. Pod względem geologiczno-inżynierskim, dla celów obliczeń projektowych, można przyjąć za jednorodne (jednorodną warstwę obliczeniową) grunty charakteryzujące się wartością współczynnika zmienności nie przekraczającą wartości granicznych dla poszczególnych parametrów gruntów, Tabela 5.

Manuscript received December 9, 1997; accepted for print February 19, 1998