GEOLOGIJA. 2008. Vol. 50. Supplement. P. S40–S48
DOI: 10.2478/V10056-008-0023-4

Engineering-geological properties of normally consolidated tills from Płock area

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Barański M. Engineering-geological properties of normally consolidated tills from Płock area. *Geologija*. Vilnius. 2008. Vol. 50. Supplement. P. S40–S48. ISSN 1392-110X

Glacial deposits are among those most widespread in the world. Tills are extremely variable soils. The article deals with the research of normally consolidated, non-weathered tills. In Poland, they are stratigraphically classified into the last Scandinavian Glaciation – Vistula Glaciation. Their mechanical behaviour has been described with reference to their structure, and to microstructure in particular. The influence of structure on compressibility, strength and stiffness has been examined for tills by comparing the behaviour of intact samples with that of reconstituted unstructured samples.

Key words: till, engineering-geological properties, laboratory studies, compressibility, strength, stiffness

Received 07 April 2008, accepted 12 May 2008

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INTRODUCTION

Tills are among the most widespread Pleistocene sediments of continental Quaternary glaciations. These soils occur in many areas of Europe and North America. They are often present directly on the surface or underlie other Quaternary sediments. They were formed as a result of consecutive continental glacier thrusts in the Pleistocene (Lindner, 1988).

Understanding the mechanical behaviour of natural soils is the main part of engineering geology and soil mechanics (Chandler, 2000). Tills are heterogeneous soils of specific properties, which considerably differ from typical clays. They differ from soft, sedimentary clays in that they contain a wider range of grain size, with some particles extending into the gravel to boulder ranges, and they are much denser. Many tills have been subjected to high vertical and tangential stresses as a result of re-advancing ice sheets (Mitchell, 1993).

Tills are often subsoils for many buildings. Their engineering-geological and geotechnical properties are of great interest to civil engineers and other earth scientists. Tills are extremely variable soils, gravitationally compacted and possibly sheared when deposited. Tills are non-textbook soils that should be treated as difficult ground (Clarke et al., 1997).

The application of empirical correlations and theoretical models in order to select certain mechanical parameters determined for clays may not be proper and justified in case of tills because of their different sedimentation conditions and post-sedimentational processes (Clarke et al., 1998).

The effects of structure are as important in determining engineering behaviour as are the effects of initial porosity and stress-history, which are the basic concepts of soil mechanics (Leroueil, Vaughan, 1990). The influence of the structure of naturally deposited tills was explained by determining the compressibility and shear strength characteristics for reconstituted tills.

A wide variation in the composition, structure and stress history of till is reflected by large variations in engineering parameters (Boulton, Paul, 1976; Marsland, 1977; McGown, Derbyshire, 1977; Barański, Czajka, 1994; Dobak, Barański, 1994).

THE GENESIS AND KINDS OF TILLS

The Scottish term "till" is the most popular for glacial sediments in the English language, but the term "boulder clay" is used as well (Dreimanis, 1990). Till is a non-sorted sediment with changeable proportions of gravel, sand, silt and clay fraction. Tills are often accompanied by plain fluvioglacial sediments sedimented in the environment of lotic and lentic water. Boundaries between certain types of glacial sediments and between them and fluvioglacial sediments may be dim.

Many researchers took up problems of the genetic classification of tills. Crucial for determining the origin and classification of Pleistocene glacial sediments were studies of glacial sedimentation processes and their effects in the areas covered by glaciers nowadays. They resulted in the distinction of there main genetic types of tills: lodgement till, melt-out till and sublimation till, flow till.

The till's division takes into consideration the accumulation zone in the glacial environment. The mechanical properties of tills are connected to the phase of transport of debris by the glacier, deposition and post-deposition. Grain size distribution, state of consolidation, presence of joints affects a wide range of geotechnical parameters (Boulton, Paul, 1976). It should be emphasized that post-depositional processes connected with the activity of wind, water, gravitational force, temperature and organisms may lead to dramatic changes in the structure of tills (Boulton, Paul, 1976; McGown, Derbyshire, 1977).

The definition of the type of soil and the model of its sedimentation may be used for an appropriate programming of site investigation. The properties of different till types within one sequence may also be quite distinct. For example, lodgement tills show more predictable patterns of jointing and may contain very hard and strong zones defined by a boulder cluster (Boulton, Paul, 1976). Melt-out tills exhibit a relatively low bulk density but show some variation depending on particle size distribution (McGown, Derbyshire, 1977). Flow tills tend not to be so dense as lodgement tills, they drain much better and show a much greater variation in grain size and the properties (LL, PI, ϕ', c') that are dependent upon grain size (Boulton, Paul, 1976).

STRUCTURE AND ENGINEERING CLASSIFICATIONS OF TILLS

In the article, the structure is treated as the arrangement of the soil component particles and bonding (the interparticle forces that are not of a purely frictional nature) (Lambe, Whitman, 1969; Cotecchia, Chandler, 2000; Chandler, 2000).

The structure is inherent in natural materials such as soils. The understanding of mechanical behaviour of soils in laboratory and field tests requires taking into consideration the effect of structure. Structure affects a wide range of properties. Although structure is modified by many factors, its influence on the behaviour of soils is similar (Leroueil, Vaughan, 1990). The importance of the research of structure in engineering geology was stressed by Barden (1972). Many processes play a role in the shaping and evolution of structure in cohesive soils. Clay structure is a result of sedimentation, consolidation, compaction and uplift, erosion and weathering – the 'geotechnical cycle' (Chandler, 2000).

However, tills are a distinctive geological and engineering group of soils (McGown, Derbyshire, 1977). The properties of tills differ substantially from the properties of typical clays.

The earth's surface is part of a dynamic system evolving both progressively and episodically through the actions of geological, geomorphologic and meteorological processes (Hutchinson, 1995). D'Elia et al. (1998) defined several types of structure that characterise this 'earth surface' and influence the behaviour of geomaterials at different scales: megastructure, macrostructure, mesostructure and microstructure (Fig. 1).

As one can see, soil structure can be discussed at different levels. Microstructure is one of the most important factors defining soil properties. The first attempts of characterizing the cohesive soil structure were made by researchers such as Terzaghi (1925), Casagrande (1932), Skempton (1964). A real breakthrough in microstructure research was application of scanning electron microscope (SEM). Such type of microscope was used for the first time in microstructure research by Roscoe from Cambridge University. The further progress of microstructural research enabled also a quantitative microstructural analysis of soils.

The quantitative analysis includes a qualitative and quantitative morphometric and geometric evaluation of structural elements and the use of the SEM system – a computer with special software which registers and analyses images. One of these systems is the STIMAN program (Structural Image Analysis) which was developed and implemented at Moscow University by Sokolov's team (Sergeyev et al., 1980; Sokolov, 1990).

The engineering classification of tills is based on their genetic classification supplemented with the dominant soil fraction concept and total fabric description (McGown, Derbyshire, 1977; Tretner, 1999). This classification is broadly used in engineering geology and geotechnics.

CONSISTENT FRAMEWORK

Terzaghi (1941) drew a comparison between compression of clays in nature and compression of clays in the laboratory. He found that the relation between the void ratio and increasing pressure for clay in nature and in the laboratory is not identical but similar. Terzaghi defined the compressibility curve for clays in nature as the sedimentation compression curve (SCC).

Skempton (1944) compared SCC curves with laboratory compression curves for undisturbed and slurried samples. The comparison concerned also tills from Whitehaven. According to Skempton, 'laboratory curves for undisturbed samples lie closer to the sedimentation curves (SCC) than do those for slurries'.

Skempton (1970) examined 21 SCCs for normally consolidated argillaceous deposits and showed that the position of different SCCs depends on the liquid limit of the soil and that the relation between e_0 and log p'_0 is essentially linear for any particular clay.

Burland (1990) showed that the compressibility and strength of a reconstituted clay could provide a 'sensitivity framework' for interpreting the properties of natural, undisturbed clay. Burland proposed a new deformability parameter for cohesive soils – the

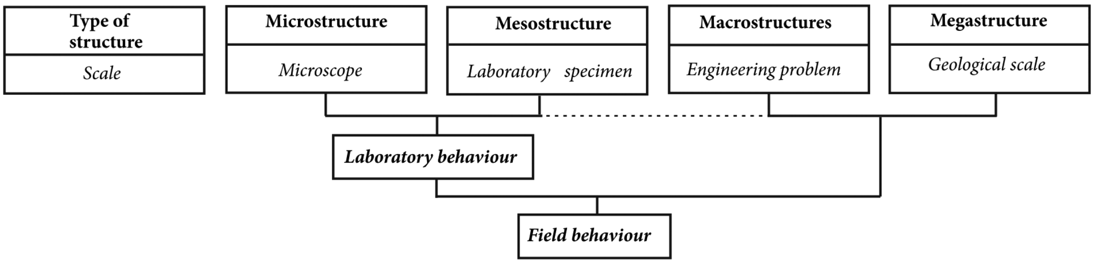

Fig. 1. Relation between structure and material behaviour (after D'Elia et al., 1998)

void index I_v. The void index is defined in terms of two measured mechanical properties (equation 1):

$$I_v = \frac{e - e^*_{100}}{e^*_{100} - e^*_{1000}} = \frac{e - e^*_{100}}{C^*_c}. \quad (1)$$

Burland (1990) proved that there is a ICL, the only one of its kind, for reconstituted samples, called the intrinsic compression line. This line can be described by the equation (2) given below:

$$I_v = 2.45 – 1.285 \log\sigma'_v + 0.015 (\log\sigma'_v)^3. \quad (2)$$

Chandler (2000) gave a slightly different equation (3) for the ICL line:

$$I_v = 2.6 – 1.475 \log\sigma'_v + 0.075 (\log\sigma'_v)^2 + 0.0055 (\log\sigma'_v)^3. \quad (3)$$

Liu and Carter (1999), on the basis of examination of 35 various cohesive soils, have stated that there is a correlation between deformability of cohesive soils of intact structure and deformability of reconstituted soil. Such correlation takes place from the moment in which the yield stress, designated as σ'_y, has been exceeded. Those researchers introduced two new parameters: A_v – the structural compression factor and S_v – the structure index-equation (4):

$$e = e^* + S_v \frac{\sigma'_y}{\sigma'_v} \ln \sigma'_y - C^*_c \ln \sigma'_v. \quad (4)$$

Clarke et al. (1997, 1998) applied Burland's conceptions to examine lodgement and deformation tills coming from the area of North East England and Scotland. One-dimensional and isotropic tests on reconstituted tills show that the compression characteristics confirm the ICL, therefore developments in the application of the ICL can be applied to tills.

ENGINEERING-GEOLOGICAL PROPERTIES OF THE VISTULA GLACIATION TILLS

On the basis of analysis of geological data and the history of loads, 39 samples of till which normally should be consolidated were used for testing (Trzciński, 1998; Trzciński, Barański, 2001) (Fig. 2).

Samples subjected to examination were taken from natural or artificial outcrops in the form of block samples. The tills discussed are believed to belong to Vistula Glaciation, the latest glaciation which occurred over the Polish territory. These tills are commonly examined as they are the subsoil for many engineering structures. Many researchers examined the engineering-geological properties of those tills (Kaczyński, Trzciński, 1992; Barański, Czajka, 1994; Dobak, Barański, 1994); Pinińska, Wysokiński 1997; Trzciński, 1998; Trzciński, Barański, 2001). Recently Barański (2000, 2003) has presented oil-derived benzene contamination influence on the change of geological-engineering properties of tills from the subsoil of a petroleum rafinery in Płock. Also in other countries geological-engineering properties of tills are presented in synthetic studies, e. g., Trenter (1999), Larson (2001).

A programme of tests was carried out to establish whether the tills of Vistula. Glaciation also conform to the unique ICL and the formula proposed by Liu and Carter (1999).

TYPES OF EXAMINED TILLS AND THEIR BASIC PARAMETERS

According to the classification of McGown and Derbyshire (1977), the tills examined are numbered among: granular matrix – 48%, well graded W – 38% and cohesive matrix Mc – 18%. The mechanical features of tills are influenced, among other factors, by the content of clay fraction and the content and type of

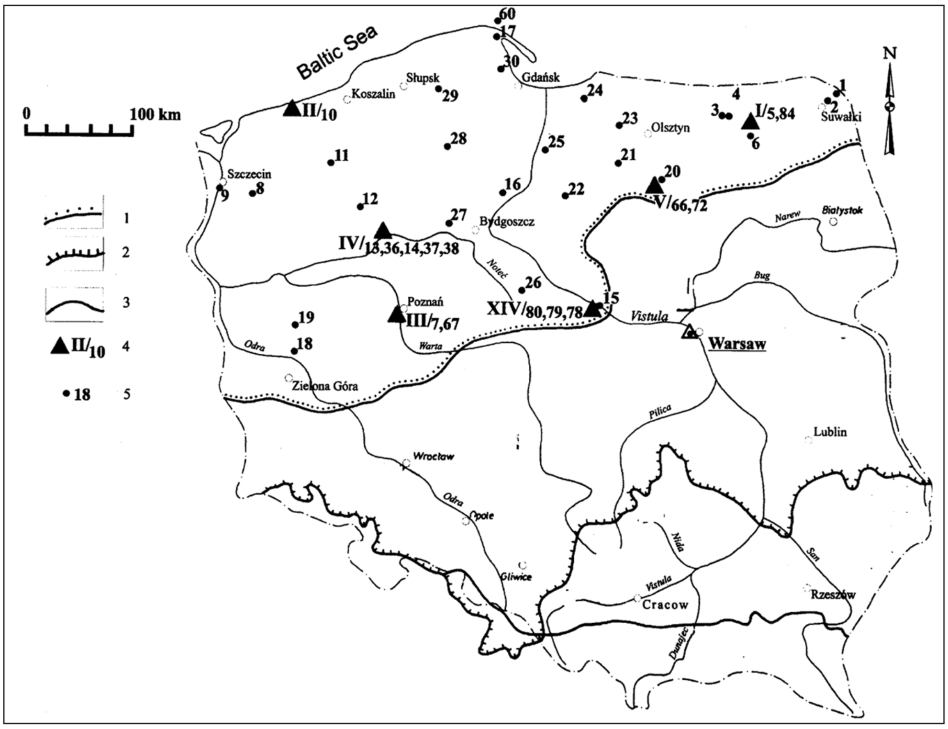

Fig. 2. Location of sampling points and extent of glaciation in Poland: *1* – Vistula Glaciation; *2* – Warta Glaciation; *3* – Odra Glaciation; *4, 5* – sampling points (after Trzciński, 1998)

Table 1. **Properties of natural tills**

Parameter	G_s	w, %	LL, %	PL, %	PI, %	I_L	CF, %	e	A	S_t, m²/g
Min	2.63	10.5	15.5	9.6	4.3	–0.16	8.0	0.427	0.23	20.5
Max	2.76	25.9	47.1	20.7	26.4	0.54	65.0	0.845	0.78	70.0
μ	**2.70**	**15.1**	**25.5**	**13.2**	**12.2**	**0.16**	**23.0**	**0.606**	**0.56**	**45.0**
σ	0.03	3.5	7.1	2.9	5.0	0.17	11.0	0.117	0.14	13.4
COV %	1	23	28	22	41	106	48	19	25	30

Table 2. **Clay fraction mineralogical composition of tills**

Parameter	Clay minerals				Organic matter, %	Goethite, %	Calcite, %	Quartz, %
	Content, %	Beidellite, %	Illite, %	Kaolinite, %				
Min	8	0	0	0	0	0.5	0	14.5
Max	73	100	100	80	0.5	8.0	15.6	88.6
μ	**25**	**55**	**33**	**12**	**0.3**	**2.7**	**2.6**	**69.4**
σ	13	32	32	22	0.1	1.6	3.9	15.5
COV %	53	57	101	172	76	60	152	22

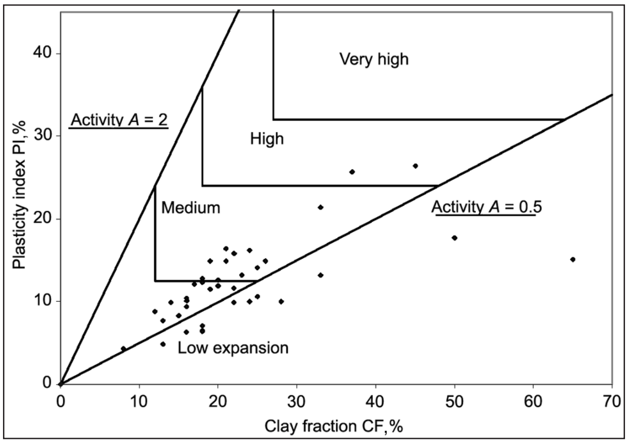

Fig. 3. Relationship between clay fraction and plasticity index

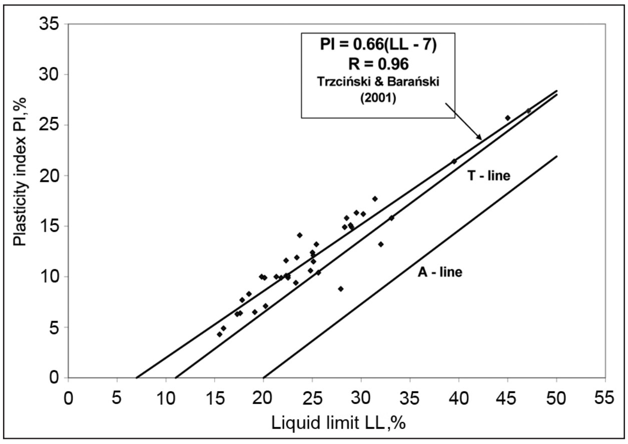

Fig. 4. Plasticity chart for test tills

clay minerals. The test clays are characterized by a high variability of the liquidity index, clay fraction content, and mineral content. The basic properties of the natural till are presented in Table 1 and Figs. 3, 4, while the clay fraction mineralogical composition is shown in Table 2. The predominant clay minerals are beidellite (55%) and illite (33%). Certain samples of till demonstrate a high content of calcium carbonate $CaCO_3$ (up to 15.6%), which influences the mechanical features of tills. The majority of test tills are featured by low and medium colloidal activity A (Fig. 3).

The Vistula Glaciation tills showed a relationship between the plasticity index PI and the liquid limit LL: PI = 0.66 (LL-7). This line is shifted to the left in relation to line T and line A (Fig. 4).

STRUCTURE OF THE TILLS

The tills examined were classified as lodgement till 10%, melt-out till 80%, and flow till 10%. Studies by Trzciński (1998) and Trzciński, Barański (2001) include their geological conditions of occurrence and lithologic description.

Microstructural examinations were carried out with a scanning electron microscope according to the methodology by Trzciński (1995, 1998). The qualitative analysis showed that the tills, according to classification of Sergeyev et al. (1980), Grabowska et al. (1984), have the following microstructure: skeleton 18%, matrix 79% and matrix-turbulent 3%. Four morphometric parameters were subjected to quantitative analysis: diameter D, area S, circumference *P*, pore form index $K_{f\alpha}$ and two microstructure geometric parameters α, microstructure anisotropy index K_α. Also, the contents of pores were analysed, special consideration having been given to morphology. Data on the mentioned microstructural parameters are presented in Table 3. In the tills, prevailing are anisometric pores (41%), fissures pores (54%), micropores and mezopores (97%). The microstructure orientation rate, determined on the basis of K_α, is as follows: poor 28%, average 67%, high 5%. The values of microstructured geometric parameters are characteristic of normally consolidated cohesive soils (Kaczyński, Trzciński, 1992; Trzciński, 1998).

Table 3. **Basic morphometric and geometric parameters of tills microstructures**

Parameter	D, μm	S, μm²	P, μm	$K_{f\alpha}$	α °	K_α, %
Min	0.12	0.07	1.08	0.380	12.20	0.40
Max	6.99	109.3	49.02	0.600	155	31.30
μ	**1.39**	**10.03**	**10.10**	**0.500**	**79.10**	**10.62**
σ	1.99	25.29	14.31	0.050	37.79	6.54
COV %	144	252	142	10	48	61

LABORATORY EXAMINATION OF THE MECHANICAL BEHAVIOUR OF NORMALLY CONSOLIDATED TILL

The mechanical behaviour of normally consolidated till was examined on the basis of a sample coming from Płock, point No. 15 (Fig. 2). Tests were carried out on undisturbed samples (U, well graded) and on reconstituted samples (R). Reconstituted samples one-dimensionally compressed from slurry were prepared at about 1.25 × LL (Burland, 1990). Detailed data on the till and conditions were given in Barański's (2000, 2003) studies. It should be stressed that undistributed samples had a matrix microstructure, whereas the reconstituted samples had a skeleton microstructure.

COMPRESSIBILITY

A one-dimensional compression test was carried out in the oedometer of stress range 0–1000 kPa. The test was carried out in accordance with the ASTM D 2435 standard. Till samples were normally consolidated soils. The average preconsolidation stress amounted to 80 kPa, whereas the yield stress was 175 kPa, and OCR = 1.07 and YSR = 2.27 (Table 4).

Table 5 shows the intrinsic parameters of all tills from 39 places. For the test tills, an interrelation was obtained between the intrinsic compression index C^*_c and the liquid limit: $C^*_c = 0.007(LL-7)$ (Fig. 5). This line is shifted to the left in respect to the relation provided by Skempton (1944). The figure illustrates a comparison of the ICL curve for reconstituted samples from a Płock site with the ICL line proposed by Burland (1990). The figure shows that data from one-dimensional tests conform with the equation, but only over a stress range of 50 through 1000 kPa.

Table 4. **Stress history from oedometric tests**

Parameter	σ'_p kPa	OCR	σ'_y kPa	YSR
Min	70	0.93	120	1.60
Max	90	1.28	200	2.80
μ	**80**	**1.07**	**155**	**2.27**
σ	10	0.25	30	0.44
COV %	12	23	19	19

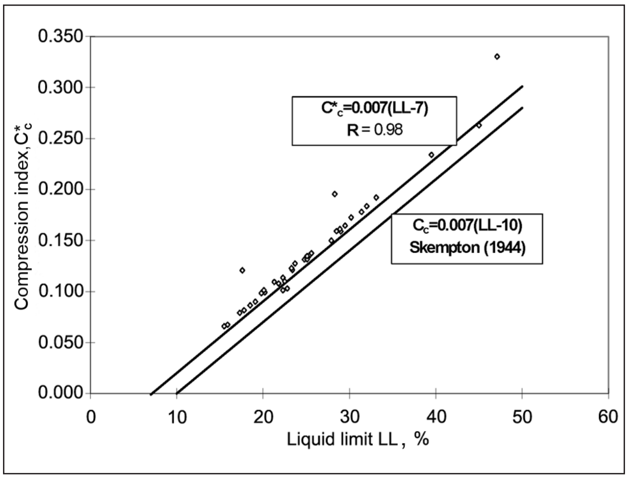

Fig. 5. Relationship between LL and C^*_c

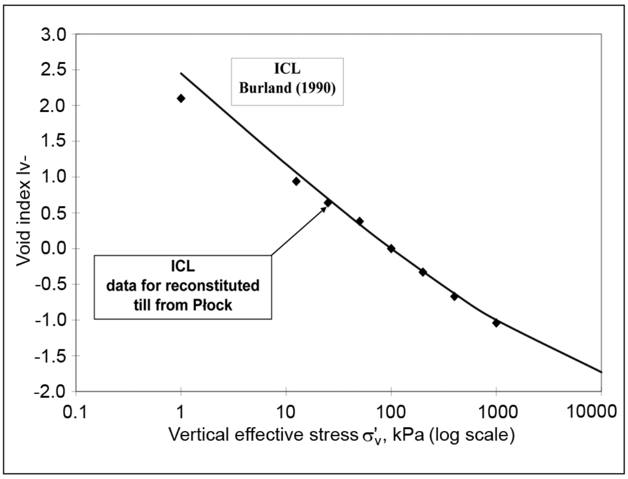

Fig. 6. The ICL for till from Płock

Figure 6 shows data obtained from oedometer tests for the Vistula Glaciation till from Płock (No. 15). Figure 7 also shows the calculated void index I_v values for 38 other tills. e_L was calculated on the basis of the relation parameters G_s and LL. The e_{100}, e_{1000} and C^*_c values were calculated with the use of e_L, from relations given by Burland (1990), and then I_v was calculated. I_v was determined on the basis of edometric tests for tills No. 15 from the Płock region.

Table 5. **Intrinsic parameters of compressibility for reconstituted tills**

Parameter	e_L		e^*_{100}		C^*_c		I_v	
	All samples	Płock No. 15	All samples	Płock No. 15	All samples	Płock No. 15	All samples	Płock No. 15
Min	0.414	0.567	0.342	0.318	0.066	0.068	–0.29	1.20
Max	1.291	0.646	0.871	0.413	0.330	0.136	2.52	1.79
μ	**0.686**	**0.609**	**0.519**	**0.360**	**0.138**	**0.103**	**0.76**	**1.38**
σ	0.198	0.041	0.120	0.034	0.054	0.026	0.65	0.18
COV %	29	7	23	9	40	25	85	13

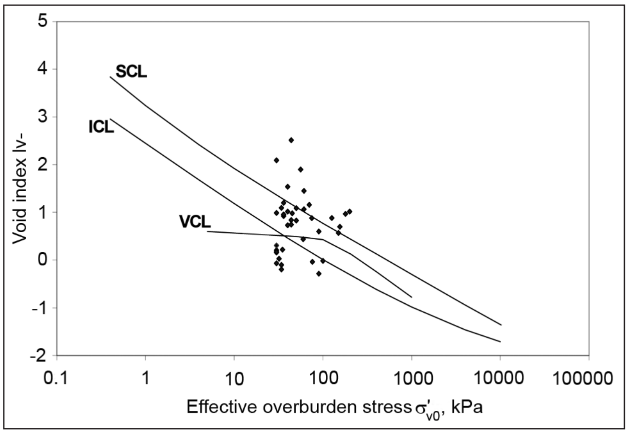

Fig. 7. Relationship between σ'_{v0} and I_v

Figure 7 gives a chart of dependence I_{v0}–σ'_{v0} for all the 39 till samples from the Vistula Glaciation area. According to the geological data, the discussed tills should be in a state of normal consolidation. However, approximately 30% of points are located below the ICL curve. A considerable part of these tills has more than 10% of calcium carbonate. Only a spare number of these tills can be found in an overconsolidated state. Approximately 20% of till samples are located considerably above the SCL curve. The analysis of the content and type of clay fraction revealed these samples to contain more than 40% of beidellite.

For tests of till from Płock (No. 15), a new approach proposed by Liu & Carter (1999) was applied. The structural compression factor is A_v = 5.70 kPa, whereas the structure index S_v = 0.009 and the yield stress amounts to 130 kPa. Results of oedometric tests were also presented in Fig. 8. The hyperbolic relationship successfully describes the virgin compression behaviour of structured tills.

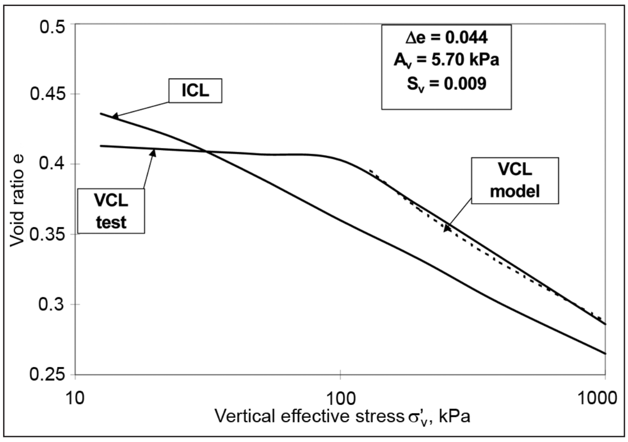

Fig. 8. Virgin compression model

SHEAR STRENGTH

Similar to the compressibility tests, the strength tests were carried out on undisturbed samples (*U*) and on reconstituted samples (*R*). Laboratory tests were carried out by the Trx CIU methodology proposed by Head (1986). The tests were continued till the moment when the soil reached the critical state. The results are presented in Table 6.

Normalized undrained strength was calculated from equation (6) given by Wroth (1984), worked out on the basis of the modified Cam-clay model:

$$\left(\frac{s_u}{\sigma'_{vo}}\right)_{CIU} = \frac{1}{2} M \left(\frac{R}{2}\right)^{\Lambda}, \tag{6}$$

$$\Lambda = (1 - \kappa/\lambda),$$

$$R = \alpha_R \, OCR.$$

The normalized Young's initial modulus was calculated from the relation given by Mayne (1995). Calculations were based on oedometric tests, i. e. the compressibility index C_c and the swelling index C_s. This relation was introduced on the basis of the modified Cam-clay model, equation (7):

$$\frac{E_{ui}}{p'_0} = \frac{36 \ln(10)(1 + e_0)}{C_s(1 - C_s / C_c)[3/\sin \varphi') - 1]^2}. \tag{7}$$

The normalized Young's initial tangent undrained modulus was calculated on the basis of tests carried out in a triaxial chamber equipped with piezoelements generating shear S and compression P waves (Barański, 2000; 2003).

The results are very similar, irrespective of whether tests were carried out on undisturbed or on reconstituted samples. The sensitivity of the strength is close to unity. Skempton & Bishop (1954) obtained similar results for well-graded low plasticity glacial tills. The only discrepancies concern normalized Young's modulus. Atkinson & Little (1998), Gens & Higth (1979) and Coop, Atkinson & Taylor (1995) obtained similar results for tills from the area of the UK. It is thus evident that the influence of structure on strength parameters is marginal. At the same time, owing to the difficulty with taking samples of tills for laboratory tests, design parameters for reconstituted samples can be determined.

Table 6. **Results of Płock till strength tests**

Parameter	**s_u / σ_{v0} undrained triaxial test**		**s_u / σ_{v0} modified Cam Clay**		**critical state parameter M'**		**E_u / p' undrained triaxial test**		**E_u / p' modified Cam clay**	
	U	**R**	**U**	**R**	**U**	**R**	**U**	**R**	**U**	**R**
Min	0.605	0.598	0.601	0.622	1,20	1.22	253	223	220	208
Max	0.665	0.671	0.679	0.683	1.39	1.39	286	260	251	236
μ	**0.637**	**0.639**	**0.656**	**0.658**	**1.31**	**1.30**	**270**	**240**	**235**	**219**
σ	0.042	0.060	0.066	0.046	0.06	0.06	24	29	26	22
COV %	7	9	10	7	5	5	9	12	11	10

CONCLUSIONS

The properties of tills differ substantially from the properties of typical clays. Sampling in tills is difficult, and laboratory tests are frequently carried out on reconstituted material. Data presented in this study are results of one-dimensional consolidation tests and undrained strength test on reconstituted and undisturbed tills of Vistula Glaciation. An attempt was made to analyse till examination results with reference to their structure, microstructure in particular.

One-dimensional test on reconstituted tills shows that the compression characteristics conform to the ICL. Till structure substantially influences the behaviour during the one-dimensional consolidation test. It is possible to forecast the course of compressibility of intact tills on the strength of tests carried out on reconstituted till samples. The influence of structure on the characteristics obtained from strength tests is very small. Vital differences concern only Young's modulus. In contrast to the strength parameters, prefailure behaviour depends on the soil structure.

The properties of till including its structure and intrinsic parameters of compression and strength are to be used as an engineering-geological and geotechnical model to provide a consistent framework for the interpretation of site investigation data from tests on these extremely variable soils. The obtained results are convergent with those reported for various tills from Europe (Atkinson, Little, 1988; Clarke et al., 1997, 1998; Gens, Higth, 1979), which proves that the accepted research methods and interpretation procedures were correct.

Only complex geological, geological engineering and geotechnical tests allow a better, more reliable evaluation of the state of consolidation of cohesive soils, tills in particular. Such approach reduces the uncertainty connected with restoration of the geological history of soils.

ACKNOWLEDGEMENTS

The author would like to thank financial support for this work from the Ministry of Science and Higher Education and Faculty of Geology, University of Warsaw. The author also thanks Prof. R. Kaczyński and Dr. J. Trzciński, Warsaw University, for useful discussions and comments.

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Notation

A – colloidal activity
A_v – structural compression factor
C_c – compression index
C^*_c – intrinsic compression index (= $e^*_{100} - e^*_{1000}$)
C_s – swelling index
CF – clay fraction
COV – coefficient of variation (= σ/μ)
D – pore diameter; morphometric parameter
e_0, e_L – void ratio *in situ*; void ratio at liquid limit
e^* – void ratio, during one-dimensional intrinsic compression
e^*_{100}, e^*_{1000} – void ratio at σ'_v = 100 kPa; 1000 kPa during one-dimensional intrinsic compression
E_u – undrained Young modulus
G_s – specific gravity of soil grains
ICL – intrinsic compression line (Burland 1990)
I_L – liquidity index (= (w-PL) / PI)
I_v – void index (= $(e-e_{100}) / C^*_c$)
$K_{f\alpha}$ – pore form index, morphometric parameter
K_α – microstructure anisotropy index, geometric parameter
LL – liquid limit
M – stress ratio at critical state
Min – minimum value
Max – maximum value
OCR – (geological) overconsolidated ratio (= σ'_p / σ'_{v0})
P – pore perimeter, morphometric parameter
p'_0 – effective overburden pressure or mean effective stress
PI – plasticity index (= LL–PL)
PL – plastic limit
R – isotropic overconsolidation ratio (= α_R OCR)
R – reconstituted sample
SCC – sedimentation compression curve (Terzaghi, 1941)
SCL – sedimentation compression line (Burland, 1990)
S – pore area, morphometric parameter
S_t – specific surface
s_u – undrained shear of strength
S_v – structure index
Trx CIU – triaxial test, consolidated isotropic undrained test
U – undisturbed sample
VCL – virgin compression line (Liu & Carter, 1999)
w – water content
YSR – yield stress ratio in oedometer compression (= $\sigma'_{vy} / \sigma'_{v0}$)
Δe – change of void ratio
α – dominant orientation direction of microstrural elements, geometric parameter
α_R – R to OCR ratio (= R / OCR)
κ – isotropic swelling index
λ – isotropic compression index
Λ – plastic volumetric strain ratio (= $(1-\kappa/\lambda)$)
μ – mean
σ – standard deviation
σ'_p – preconsolidation stress
σ'_{v0} – *in situ* vertical effective stress
σ'_y – vertical effective yielding stress
ϕ' – effective angle of shearing resistance

Marek Barański

PLOCKO RAJONO NORMALIAI KONSOLIDUOTO MORENINIO PRIEMOLIO INŽINERINĖS GEOLOGINĖS SAVYBĖS

Santrauka

Moreninis priemolis pasižymi ypač didele inžinerinių geologinių savybių kaita. Nevienalyčio grunto mechaninių savybių pažinimas yra svarbus inžineriniams geologiniams tyrimams, nes šis gruntas dažnai yra statinių pagrindas. Tirtas moreninis priemolis yra priskiriamas paskutiniam ledynmečiui Lenkijos teritorijoje – Vyslos glacialui. Tyrimams buvo paimti nesuardytos sandaros moreninio priemolio ėminiai 39-iose atodangų arba karjerų vietose ir nustatytos pagrindinės grunto fizinės savybės, struktūros tipas ir rūšis. Išanalizuotas struktūros ir geologinės apkrovos poveikis mechaniniams rodikliams, tirtas natūralios ir suardytos grunto struktūros stiprumas, standumas. Gauti rezultatai rodo, jog struktūros įtaka stiprumo parametrams nėra didelė. Kadangi sudėtinga paimti natūralios struktūros ėminius iš moreninio grunto, stiprumo bandymus galima atlikti su grunto pasta. Struktūros reikšmė yra svarbi tiriant deformacijas. Pateikti tyrimų rezultatai gerai koreliuojasi su kituose Europos kraštuose gautais rezultatais, ir tai patvirtina interpretacinių procedūrų tinkamumą.

Marek Barański

GEOLOGICZNO-INŻYNIERSKIE WŁAŚCIWOŚCI NORMALNIE SKONSOLIDOWANYCH GLIN LODOWCOWYCH Z TERENU PŁOCKA

Streszczenie

Osady pochodzenia lodowcowego występują w wielu miejscach na świecie. Gliny lodowcowe są gruntami spoistymi o wyjątkowo zmiennych właściwościach. Zrozumienie mechanicznego zachowania się tak niejednorodnego gruntu jest ważnym geologiczno-inżynierskim zadaniem badawczym.

W artykule przedstawiono wyniki badań geologiczno-inżynierskich normalnie skonsolidowanych glin lodowcowych. Gliny te stratygraficznie zaliczane są do ostatniego zlodowacenia skandynawskiego w Polsce – zlodowacenia Wisły. Grunty te bardzo często są podłożem dla obiektów budowlanych.

Do badań laboratoryjnych pobrano próbki glin lodowcowych z 39 miejsc, z naturalnych bądź sztucznych odsłonięć w postaci monolitów. Dla każdej próbki oznaczono podstawowe właściwości fizyczne, określono typy i rodzaj struktury gruntu. Mechaniczne zachowanie się glin przedstawiono na przykładzie próbek glin pobranych z terenu Płocka. Celem badań była ocena wpływu struktury i geologicznej historii obciążania na parametry mechaniczne gliny lodowcowej. Wpływ struktury gruntu na ściśliwość, wytrzymałość, sztywność oceniono przez porównanie zachowania się próbek o nienaruszonej i naruszonej strukturze. Stwierdzono, że wpływ struktury na parametry wytrzymałościowe jest niewielki. Gliny lodowcowe są gruntami trudnymi do pobierania i przygotowania próbek o nienaruszonej strukturze do badań laboratoryjnych. Wykazano, że badania wytrzymałościowe można wykonać na próbkach w postaci past gruntowych. Wpływ struktury glin lodowcowych jest istotny w przypadku badań odkształcalności. Istnieje możliwość prognozowania przebiegu ściśliwości w oparciu o badania na pastach.

Opisane wyniki badań są zbieżne z wynikami uzyskanymi przez badaczy dla różnych glin z terenu Europy. Potwierdza to słuszność przyjętych metod badawczych i procedur interpretacyjnych.

Марек Бараньски

ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИЕ СВОЙСТВА НОРМАЛЬНО КОНСОЛИДИРОВАННЫХ МОРЕННЫХ СУГЛИНКОВ РАЙОНА ПЛОЦКА

Резюме

Для моренных суглинков характерна значительная изменчивость инженерно-геологических свойств. Познание механических свойств таких неоднородных грунтов является весьма важной задачей при инженерно-геологических изысканиях. Исследованные моренные суглинки относятся к последнему оледенению на территории Польши – висленскому гляциалу. Данные грунты часто используются в качестве основания для сооружений. Образцы моренных суглинков отбирались в 39 местах. Образцы ненарушенного сложения отбирались в обнажениях и в карьерах. По каждому образцу исследовались основные физические свойства грунта, типы и виды структуры. Оценивалось влияние структуры и природного давления на значения механических свойств. Изучалось влияние структуры грунта на прочность и сжимаемость на образцах естественного и нарушенного сложения. Полученные результаты показывают, что влияние структуры на прочность незначительно. Отбор монолитов суглинков связан с определенными трудностями. Доказано, что испытания на прочность возможно проводить на пастах. Значение структуры важно для деформационных испытаний. Однако представляется возможным прогнозировать сжимаемость грунта по результатам исследования на пастах грунта. В данном случае полученные результаты хорошо коррелируют с данными, полученными в других странах Европы. Это подтверждает правильность интерпретационных процедур.