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Variability of engineering geological parameters in flood facies sediments

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Flood-deposited, muds are characterised by considerable variability of their lithological characters. This variability reflects the development of the river forming the terrace, the geological setting of the drainage basin and the morphology of the flood plain. The lithological variability of the muds causes great vertical and lateral variability in the engineering geological parameters. Therefore all calculations based on mean values obtained from laboratory analyses are prove to error. The most reliable values of parameters are obtained from fieldwork "*in situ*".

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Key words: mud types, lithological succession, geological-engineering parameters.

INTRODUCTION

The commonly applied lithological classification of flood facies sediments in river valleys into silty-sandy and loamy muds, followed by a genetic classification into muds of braided (wild) and meandering rivers (Leopold *et al*., 1964; Falkowski, 1980; Myślińska, 1984; Bozzano *et al*., 2000) is insufficiently for engineering geological purposes, as shown below precise. These subdivisions may suggest that, within the two main groups, the soils are not variable, have a similar lithology and possess similar physical and chemical parameters.

Data for muds from the Vistula River valley in the vicinity of Warsaw, given below, indicate that flood facies sediments are much more diverse, and that further subdivision is justified by their engineering geological parameters.

ENGINEERING GEOLOGICAL PARAMETERS IN FLOOD FACIES SEDIMENTS

There is ever increasing data on the lithology and physical-mechanical parameters of muds. In general, the data justify the classification of flood facies sediments into two basic groups (silty-sandy muds series I, loamy muds series II). This basic subdivision can be observed during analyses of soil profiles, from both macroscopic analyses of deposits and quantitative data, i.e. from statistical (CPT), dilatometric (DMT), and BAT soundings (Groundwater Monitoring System) (Figs. 1–3). BAT field investigations of the hydraulic conductivity (k_w) indicated a high variability of this parameter (Fig. 1): for muds series II $k_w = 1.3 \times 10^{-8}$ (Kaczyński, 1997, unpubl.) 2.92×10^{-9} m/s, at the saturation index (Sr) below 100% (unsaturated soil). For saturated soils the filtration coefficient determined in the compressional permeameter GEONOR was 1.4×10^{-8} m/s.

However, compilation of data from a larger area shows subdivision to be less clear. Table 1. showing the physical properties of soils, indicates that the ranges obtained overlap in particular groups of sediments. It is also difficult to pinpoint a parameter linked with their identification. Similar conclusions can be drawn from the analysis of the engineering geological parameters (Tables 2 and 3). although the sub-division is more distinct in this case.

The large scatter of results of laboratory and field analyses points to the fact that soils of the flood facies include a large spectrum of soils characterised by different parameters, necessitating a more detailed engineering geological evaluation of the valley.

In general, the lithological succession of flood facies sediments of the Vistula River valley from the vicinity of Warsaw is as follows: 0.5–2.0 m of silty-sandy mud (silty sands and silts); followed by 1.0–2.5 m of thick loamy mud (loam to clay). The topmost part of the succession in urban areas is represented by anthropogenic soils (embankments). The thickness

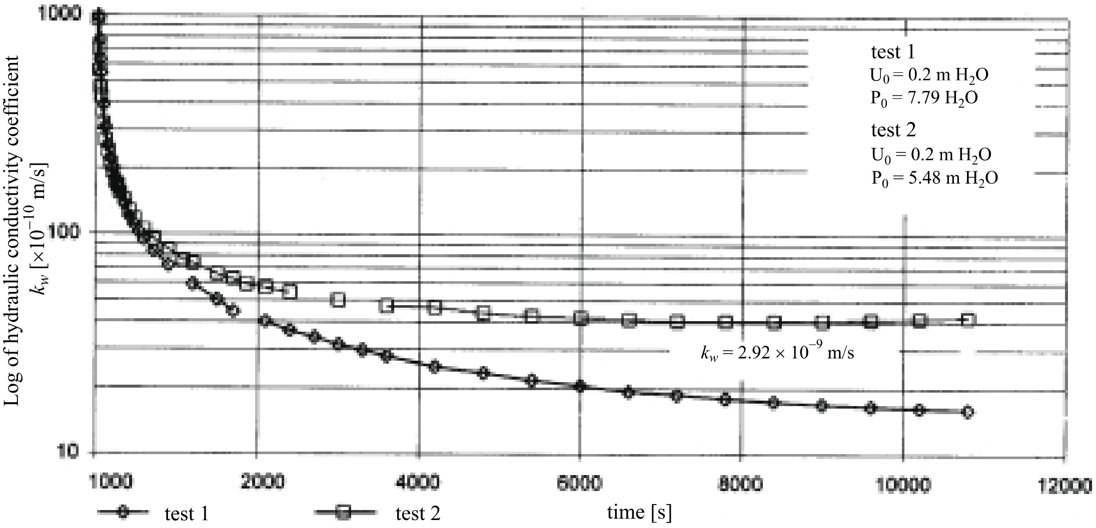


Fig. 1. The hydraulic conductivity coefficient (k_w) for muds series II

U_0 — pore pressure (mH_2O); P_0 — gas pressure in permeameter (mH_2O) at time t = 0

of loamy muds increases from the riverbed towards the margin of the Pleistocene terrace, concordantly with the stratigraphic sequence of the Holocene river meanders.

THE LITHOLOGICAL-MECHANICAL PROPERTIES OF MUDS

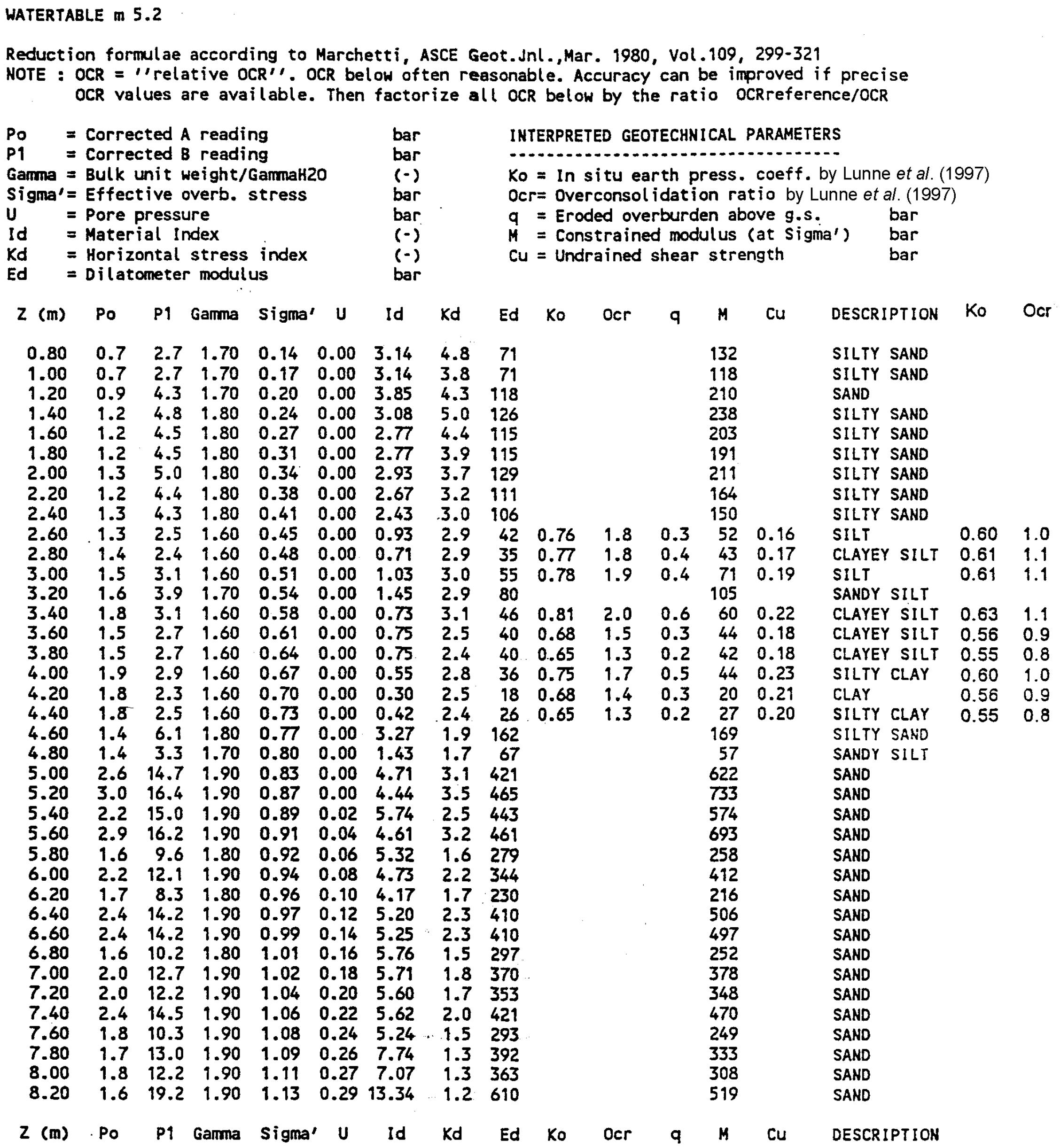
The variability of muds formed in the same interval may be explained by the specific conditions, in which they were formed. The factors influencing the formation of mud (Fig. 4) show local variability. This variability results from the interaction of three main factors: type of water level rise, quantity and type of the transported debris and the geomorphology of the flood area.

The type of water level rise and its characteristics. The rapid outflow of water from the river channel, flow rate, high water level, duration of water rise may differ in particular river sections. The retreat of floodwater into the river channel may also vary.

Table 1

Physical parameters of the Vistula River muds from the vicinity of Warsaw

Type of mud	Parameter	Myślińska (1984, unpubl.) Profile W-wa Świdry Małe	Szmidt (unpubl.) Profile W-wa Wilanów	Filipek (unpubl.) Profile W-wa Zawady
I Sandy silty muds	Granulometry [%] Fraction sand silty clay	 3.0–41.0 41.0–80.0 15.0–24.0	 3.0–11.0 71.0–84.0 13.0–18.0	 4.0–12.0 70.0–82.0 14.0–18.0
	Natural moisture content W_n [%]	8.8–37.0	22.8–28.6	23.2–25.2
	Plasticity limit w_p [%]	16.0–26.0	20.0–23.0	19.0–21.0
	Liquid limit w_L [%] (Casagrande′s method)	31.0–46.0	34.2–38.7	32.0–36.0
	Plasticity index I_p [%]	12.0–20.0	11.5–18.4	12.3–15.6
	Liquidity index I_L	–0.6–0.70	0.13–0.50	0.16–0.48
	Ignition loss [%]	1.9–9.0	–	–
II Laomy muds	Granulometry [%] Fraction sand silty clay	 10.0–68.0 26.0–72.0 6.0–18.0	 45.0–57.0 35.0–46.0 7.0–9.0	 43.0–59.0 33.0–48.0 8.0–9.0
	Natural moisture content W_n [%]	6.5–25.4	12.1–15.3	12.8–15.2
	Plasticity limit w_p [%]	21.0–24.0	15.0–18.0	17.0–18.0
	Liquid limit w_L [%] (Casagrande′s method)	24.0–41.0	22.0–26.0	25.0–26.0
	Plasticidy index I_p [%]	4.0–17.0	7.3–8.1	7.9–9.3
	Liquidity index I_L	–2.2–1.22	–0.5– –0.27	–0.45– –0.29
	Ignition loss [%]	1.6–9.3	–	–



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WATERTABLE m 5.2

Reduction formulae according to Marchetti, ASCE Geot.Jnl.,Mar. 1980, Vol.109, 299-321
NOTE : OCR = ''relative OCR''. OCR below often reasonable. Accuracy can be improved if precise
       OCR values are available. Then factorize all OCR below by the ratio  OCRreference/OCR

Po     = Corrected A reading           bar      INTERPRETED GEOTECHNICAL PARAMETERS
P1     = Corrected B reading           bar      ----------------------------------
Gamma  = Bulk unit weight/GammaH2O     (-)      Ko = In situ earth press. coeff. by Lunne et al. (1997)
Sigma'= Effective overb. stress        bar      Ocr= Overconsolidation ratio by Lunne et al. (1997)
U      = Pore pressure                 bar      q  = Eroded overburden above g.s.         bar
Id     = Material Index                (-)      M  = Constrained modulus (at Sigma')      bar
Kd     = Horizontal stress index       (-)      Cu = Undrained shear strength             bar
Ed     = Dilatometer modulus           bar

 Z (m)    Po    P1 Gamma Sigma'     U     Id    Kd   Ed     Ko   Ocr     q     M     Cu   DESCRIPTION      Ko   Ocr

  0.80   0.7   2.7  1.70   0.14  0.00   3.14   4.8   71                      132          SILTY SAND
  1.00   0.7   2.7  1.70   0.17  0.00   3.14   3.8   71                      118          SILTY SAND
  1.20   0.9   4.3  1.70   0.20  0.00   3.85   4.3  118                      210          SAND
  1.40   1.2   4.8  1.80   0.24  0.00   3.08   5.0  126                      238          SILTY SAND
  1.60   1.2   4.5  1.80   0.27  0.00   2.77   4.4  115                      203          SILTY SAND
  1.80   1.2   4.5  1.80   0.31  0.00   2.77   3.9  115                      191          SILTY SAND
  2.00   1.3   5.0  1.80   0.34  0.00   2.93   3.7  129                      211          SILTY SAND
  2.20   1.2   4.4  1.80   0.38  0.00   2.67   3.2  111                      164          SILTY SAND
  2.40   1.3   4.3  1.80   0.41  0.00   2.43   3.0  106                      150          SILTY SAND
  2.60   1.3   2.5  1.60   0.45  0.00   0.93   2.9   42   0.76   1.8   0.3    52   0.16   SILT           0.60   1.0
  2.80   1.4   2.4  1.60   0.48  0.00   0.71   2.9   35   0.77   1.8   0.4    43   0.17   CLAYEY SILT    0.61   1.1
  3.00   1.5   3.1  1.60   0.51  0.00   1.03   3.0   55   0.78   1.9   0.4    71   0.19   SILT           0.61   1.1
  3.20   1.6   3.9  1.70   0.54  0.00   1.45   2.9   80                      105          SANDY SILT
  3.40   1.8   3.1  1.60   0.58  0.00   0.73   3.1   46   0.81   2.0   0.6    60   0.22   CLAYEY SILT    0.63   1.1
  3.60   1.5   2.7  1.60   0.61  0.00   0.75   2.5   40   0.68   1.5   0.3    44   0.18   CLAYEY SILT    0.56   0.9
  3.80   1.5   2.7  1.60   0.64  0.00   0.75   2.4   40   0.65   1.3   0.2    42   0.18   CLAYEY SILT    0.55   0.8
  4.00   1.9   2.9  1.60   0.67  0.00   0.55   2.8   36   0.75   1.7   0.5    44   0.23   SILTY CLAY     0.60   1.0
  4.20   1.8   2.3  1.60   0.70  0.00   0.30   2.5   18   0.68   1.4   0.3    20   0.21   CLAY           0.56   0.9
  4.40   1.8   2.5  1.60   0.73  0.00   0.42   2.4   26   0.65   1.3   0.2    27   0.20   SILTY CLAY     0.55   0.8
  4.60   1.4   6.1  1.80   0.77  0.00   3.27   1.9  162                      169          SILTY SAND
  4.80   1.4   3.3  1.70   0.80  0.00   1.43   1.7   67                       57          SANDY SILT
  5.00   2.6  14.7  1.90   0.83  0.00   4.71   3.1  421                      622          SAND
  5.20   3.0  16.4  1.90   0.87  0.00   4.44   3.5  465                      733          SAND
  5.40   2.2  15.0  1.90   0.89  0.02   5.74   2.5  443                      574          SAND
  5.60   2.9  16.2  1.90   0.91  0.04   4.61   3.2  461                      693          SAND
  5.80   1.6   9.6  1.80   0.92  0.06   5.32   1.6  279                      258          SAND
  6.00   2.2  12.1  1.90   0.94  0.08   4.73   2.2  344                      412          SAND
  6.20   1.7   8.3  1.80   0.96  0.10   4.17   1.7  230                      216          SAND
  6.40   2.4  14.2  1.90   0.97  0.12   5.20   2.3  410                      506          SAND
  6.60   2.4  14.2  1.90   0.99  0.14   5.25   2.3  410                      497          SAND
  6.80   1.6  10.2  1.80   1.01  0.16   5.76   1.5  297                      252          SAND
  7.00   2.0  12.7  1.90   1.02  0.18   5.71   1.8  370                      378          SAND
  7.20   2.0  12.2  1.90   1.04  0.20   5.60   1.7  353                      348          SAND
  7.40   2.4  14.5  1.90   1.06  0.22   5.62   2.0  421                      470          SAND
  7.60   1.8  10.3  1.90   1.08  0.24   5.24   1.5  293                      249          SAND
  7.80   1.7  13.0  1.90   1.09  0.26   7.74   1.3  392                      333          SAND
  8.00   1.8  12.2  1.90   1.11  0.27   7.07   1.3  363                      308          SAND
  8.20   1.6  19.2  1.90   1.13  0.29  13.34   1.2  610                      519          SAND

 Z (m)    Po    P1 Gamma Sigma'     U     Id    Kd   Ed     Ko   Ocr     q     M     Cu   DESCRIPTION
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Fig. 2. Dilatometer test DMT

Quantity and type of material transported by the high water. This factor varies in relation to the geological setting of the drainage basin and the transport conditions in particular sections of the river.

Geomorphology of the flood area. The flood area contains many forms of different origin, influencing the high water flow and thus the sedimentation conditions of the transported debris.

In engineering geological mapping it is essential to distinguish sub-regions within the flood plain, differing in the type of the flood facies sediment. They include:

— zones of flow channels; forms with a visible morphology and possessing lithological successions different to those other parts of the flood plain.

— zones with hampered flow and outflow of the high waters through e.g. dune zones; in this case fine sediment accumulates, which is enriched in organic matter.

CONCLUSIONS

1. The analysis of lithological and geotechnical data for flood facies sediments in the Vistula River valley in the vicinity of Warsaw indicates that they are much more diverse than may be concluded from the commonly used subdivision into two general groups (braided river muds and meandering river muds).

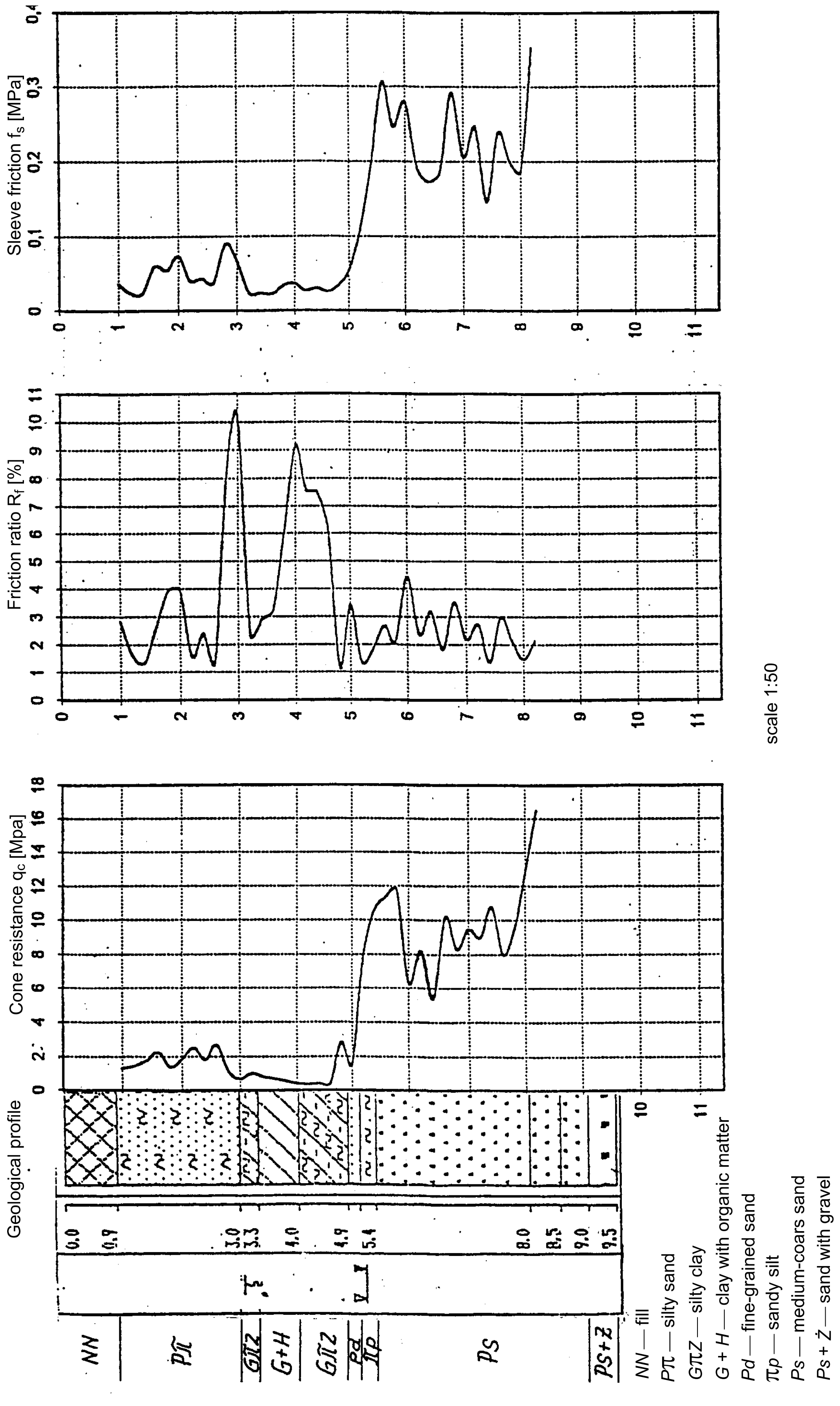

Fig. 3. CPT profile from Warsaw, Belgijska 21, 83.6 m a.s.l.

Table 2

Selected engineering geological parameters of the Vistula muds from the vicinity of Warsaw

Type of mud	Parameter	Myślińska (1984, unpubl.) Profile W-wa Świdry Małe	Szmidt (unpubl.) Profile W-wa Wilanów	Filipek (unpubl.) Profile W-wa Zawady	Kaczyński and Kraużlis (unpubl.)* Profile W-wa Saska Kępa
I Sandy silt mud	Bulk density ρ [Mg/m^3]	1.53–1.90	1.75–1.77	1.75–1.76	1.70–1.90
	Angle of internal friction Φ [°]	13.5–27.0***	20.3**	23.7**	29.7–31.3
	Cohesion c_u [kPa]	10.0–51.0***	40.6**	41.2**	–
	Undrained shear strength τ [kPa]	–	78.7** σ_n = 100 kPa	80.4** σ_n = 100 kPa	38.0–183
	Modulus of compressibility M_o [MPa]	2.30–4.50 σ_n = 0–200 kPa	5.28–5.39 σ_n = 0–200 kPa	5.29–5.38 σ_n = 0–200 kPa	4.30–23.8
	Cone resistance CPT q [MPa]	–	–	–	1.1–2.7
II Loamy mud	Bulk density ρ [Mg/m^3]	1.82–1.95	1.80–1.89	1.80–1.89	1.60–2.00
	Angle of internal friction Φ [°]	3.0–24.0	14.2	16.3	9.1–15.5
	Cohesion c_u [kPa]	10.0–72.0	19.0	15.4	12.0–23.0
	Undrained shear strength τ [kPa]	–	46.4 σ_n = 100 kPa	44.4 σ_n = 100 kPa	38.0–121.0
	Modulus of compressibility M_o [MPa]	1.40–3.30	4.07–4.63	4.08–4.55	2.0–11.1
	Cone resistance CPT q [MPa]	–	–	–	0.35–2.05

* — Parameters obtained from fieldwork "*in situ*" (CPT, Dilatometer DMT, SLVT sounding); ** — parameters obtained from direct shear apparatus; *** — parameters obtained from triaxial apparatus

Table 3

Selected engineering geological parameters of the Vistula muds (undivided) from the vicinity of Warsaw

Types of mud	Parameter	Frankowski and Wysokiński (unpubl.) Profiles W-wa Zawady, Tarchomin, Gocław, Saska Kępa	Lipińska (unpubl.) Profile W-wa Saska Kępa
I+II Undivided mud	Plasticity index I_p[%]	8.6–56.2	–
	Liquitidy index I_L	0.05–0.82	0.15–0.92
	Bulk density ρ [Mg/m^3]	1.64–2.06	1.68–2.02
	Angle of internal friction Φ [°]	1.3–15.0	1.0–12.0***
	Cohesion c_u [kPa]	10.0–100.0	10.0–50.0***
	Modulus of compressibility M_o [MPa]	–	0.5–11.5

For explanations see Table 2

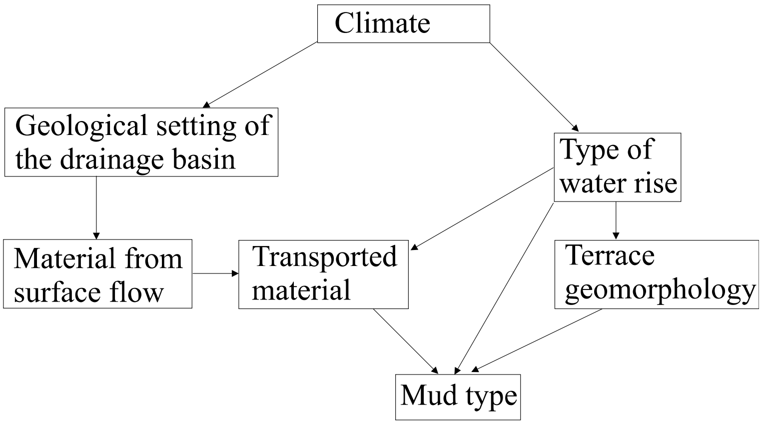

Fig. 4. Factors determining the lithology of the flood facies sediments

2. The distinct lithological variability of muds and their engineering geological parameters justifies the distinguishing of sub-regions differing in lithology and physical-mechanical parameters within the flood plain during cartographic work.

3. The high variability of the soils analysed requires field analyses, including static, dilatometric and BAT analyses to determine the engineering geological parameters.

4. For unconsolidated soils (e.g. muds), the best realiable method of characterising M_o (modulus of compressibility) is DMT sounding (Lunne *et al.*, 1997; Marchetti, 1999; Kaczyński and Kraużlis, 2000, unpubl.).

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