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Statistical evaluation of physical and index properties of Vistula Marshlands deltaic soft soils

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Abstract. This paper provides statistical evaluation of physical and index parameters of the Vistula Marshlands deltaic soft soils using three datasets. Soft soils from the Vistula Marshlands are grouped into the four categories: (1) silty/sandy loams, (2) organic clays, (3) organic silts and (4) peats. Variability of basic and derivative physical properties as well as Atterberg's limits and plasticity index is studied. It is found that index properties for all soil groups are characterized by large scatter (COV about 50%). The most reliable parameters for silty loams, organic clays and silts are soil density (COV<10%) and specific gravity (COV about 2%). Physical/index parameters of peats are characterized by large scatter, which indicates very local properties and individual formation process. Most of the data points for physical/index quantity are within ±1SD range regardless normality of data distribution. In the main body of this paper, the quantitative physical/index properties variability is evaluated and some practical design guidelines concerning variability of deltaic soil in the Vistula Marshlands are given.

1. Introduction

In geotechnical engineering, there is urgent need for reliable data and informations about level of variability and uncertainty (e.g., [1-4]). Geomaterials, and soft soils in particular, are naturally complex media with high heterogeneity [5]. That includes heterogeneity in micro-scale (particles, soil structure) and macro-scale (geological formation and region). This paper is focused on variability of physical and index properties of soft, deltaic soils from the Vistula Marshland, Northern Poland. The geotechnical investigations conducted in that region in the recent years are combined and analyzed. The aims of this paper are: (1) to characterize geological formation of soft soils based on collected data, (2) to classify soil according to Unified Soil Classification System (USCS), (3) to perform statistical evaluation of the index properties, (4) to perform statistical evaluation of the basic/derivative physical soil parameters, (5) to provide qualitative and quantitative description of soft soil variability in the Vistula Marshlands, (6) and to verify if Jazowa testing site, located in the central part of the Marshlands, is representative research location for the Vistula Marshlands based on physical and index properties.

The statistical evaluation presented in this paper is based on first order, second-moment analysis, i.e., the random variables are investigated using the mean value and standard deviation. The quantitative physical/index properties variability is evaluated using coefficient of variation and standard deviation. The chi squared Goodness-Of-Fit test is used to investigate if variables follow the normal distribution. The shape of no-normal distributions is investigated using more advanced statistics parameters such as skewness and kurtosis. The percentage of data points within the range of one standard deviation from the mean value is calculated. The practical guidelines concerning the variability of the physical/index properties of soft deltaic soils are given in suitable sections of manuscript.

2. Deltaic soft soils from the Vistula Marshlands

The Vistula Marshlands is low-plain area of Gdańsk Shoreland which stretches over approximately 1700 km2, see Figure 1. The plain was formed by alluvial mud brought by Vistula River during formation of the Vistula Delta [6]. The formation of the Vistula delta started 6 ka BP, during the Littorina Sea phase. The ancient post glacial bay in the mouth of the Vistula river was gradually filled with fluvial deposits. The bay was closed by marine currents and eolian transport forming a sandy Vistula spit. From that moment on, the majority of the fluvial debris was deposited in the inner delta. Three geological facies can be recognized in the Vistula Marshlands: (1) riverbed (generally sands, and occasionally gravels), (2) marsh-swamp-lake (clays, loams, muds, peats) and (3) flood (muds) [7]. Consequently, the soft soils from the Vistula Marshlands usually include loams (inorganic soils), muds (moderately organic soils) and peats (highly organic soils).

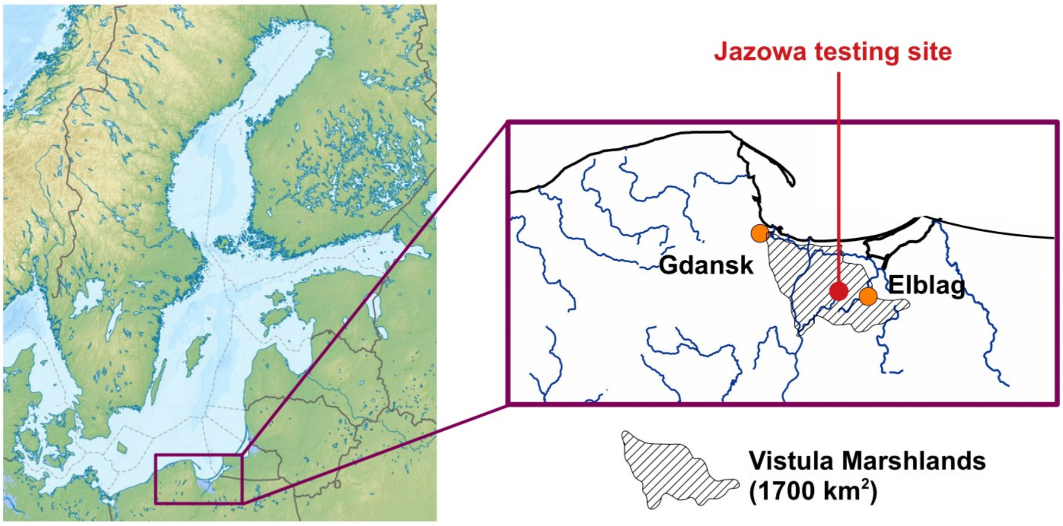

Figure 1. The Vistula Marshlands localization.

2.1. Geotechnical investigations in the Vistula Marshlands

The geotechnical investigations carried out in the Vistula Marshlands are related with S7 highway construction in 2015-2019. The first geotechnical investigation was carried out in 2010 (dataset A) and covers extensive investigation of soil physical and index properties. The second geotechnical investigation was carried out in 2013-2014 (dataset B). Here, also the physical and index properties were tested but more emphasis was paid on strength parameters. During construction phase the supplementary soil testing was conducted, which formed dataset C. In 2016-2018, Gdańsk University of Technology (GUT) carried out research project on CMC columns design at the Jazowa site. The soil lab tests during this period formed dataset D and they constitute reference/control data for the rest of datasets. The summary of geotechnical investigation in the Vistula Marshlands is presented in Table 1 with a given number of tests for each physical/index property.

2.2. Soft soils deposits extracted form datasets

Analysis of datasets A, B and C, supported with dataset D, allows to distinguish 4 groups of soils. These are as follows:

(1) Silty/sandy loams with small organic clay and peat inserts. These are shallow soil layers, located above water table level with low organic matter content (LOI<5%). The granulometric analysis provides approx. 35% content of clay and 65% content of silt.
(2) Organic clays (clayey muds) with small peat inserts. These are moderately shallow layers, located usually below water table with high organic matter content (10%<LOI<30%). The granulometric analysis results in approx. 50% content of clay and silt.
(3) Organic silts (silty muds) with small peats and calcium carbonate content inserts. These are deep layers, always located below water table with low to moderate organic matter content (5%<LOI<10%). They are formed with silts (above 95%) with very low content of clay and/or sand.
(4) Peats. These soils are located at different depths, usually below water table level. They present fibrous structure and include very high content of organic matter (LOI>30%).

The soils which cannot be assigned to one of the group listed above are neglected in further analysis. Authors would like to notice, that neglected data does not exceed 20% of total.

Table 1. Geotechnical investigation in the Vistula Marshlands with physical/index properties determined.

Dataset	Physical/index properties [number of tests]						Notes
	LOI	w_c	ρ	G_s	*PL*	*LL*	
A (2010) (1)	214	637	196	N/A	561	561	All Marshlands
B (2013) (1)	331	341	341	N/A	25	25	All Marshlands
C (2015-16) (1)	N/A	221	141	141	N/A	N/A	All Marshlands
D (2016-17) (2)	8	88	52	18	7	7	Single location

Note: LOI = loss on ignition (equivalent to organic matter content); w_c = water content; ρ = soil density; Gs = specific gravity; PL = plastic limit; LL = liquid limit, (1) = datasets for statistical evaluation, (2) = reference/control dataset.

Table 2. Soft soil deposits from the Vistula Marshlands with number of samples for statistical evaluation.

Deposit	Dataset	Physical/index properties [number of samples]									
		Basic		Derivative					Index		
		w_c	ρ	G_s	ρ_d	n	e	S_r	$LL^{(1)}$	*PL*	*IP*
Silty/sandy loam with organic clay and peat inserts	A	52	5	N/A	N/A	N/A	N/A	N/A	52	52	52
	B	31	31	N/A	N/A	N/A	N/A	N/A	2	2	2
	C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic Clay (clayey mud) with peat inserts	A	122	47	N/A	N/A	N/A	N/A	N/A	112	112	112
	B	71	71	N/A	N/A	N/A	N/A	N/A	6	6	6
	C	42	42	42	42	42	42	42	N/A	N/A	N/A
Organic silt (silty mud) with peat inserts and calcium carbonate content	A	306	40	N/A	N/A	N/A	N/A	N/A	303	303	303
	B	164	164	N/A	N/A	N/A	N/A	N/A	13	13	13
	C	62	62	62	62	62	62	62	N/A	N/A	N/A
Peat	A	101	93	N/A	N/A	N/A	N/A	N/A	(40)(2)	(40)(2)	(40)(2)
	B	49	49	N/A	N/A	N/A	N/A	N/A	(2)(2)	(2)(2)	(2)(2)
	C	36	36	36	36	36	36	36	N/A	N/A	N/A

Note: w_c = water content; ρ = soil density; G_s = specific gravity; ρd = bulk density; n = porosity; e = void ratio; S_r = saturation ratio. PL = plastic limit; LL = liquid limit, IP = plasticity index. (1) = LL obtained from Casagrande method; (2) = Atterberg's limit for peats were determined only for soils on boundary between peat and mud with emphasis on peat. However, validity of these tests can be questionable [8].

2.3. Physical and index properties under investigation

In Table 2, basic and derivative physical soil properties as well as index properties, extracted from each dataset, are provided. It should be pointed out that the overall number of samples is highly sufficient (sample number is ranging between 36 to 532 depending on variable) to perform statistical evaluation.

3. Methods used for statistical evaluation

3.1. Second-moment statistical analysis

The statistical evaluation is performed using first order, second-moment analysis, i.e., reliability is investigated using mean (AVG) and coefficient of variation (COV):

$$COV = SD / AVG \tag{1}$$

where: SD = standard deviation, AVG = mean (average value).

Low values of COV suggest low variability of the considered parameter. Uzielli et. al. [1] report COV=5÷30% for physical properties and COV ≈ 50% for index properties as typical encountered values.

3.2. Chi Square Test for Normal Distribution

The normality of the data is important issue is statistical evaluation. If data is normally distributed than one can expect that 68% of samples is within ±1SD range and 95% is within ±2SD range. This is very useful in reliability analysis, where one can establish the characteristic value of considered parameter, e.g., AVG minus SD, and apply suitable safety factors, e.g., based on COV. The normality of the data is verified using the chi squared (χ^2) Goodness-Of-Fit test in which the differences between the observed and expected distribution are calculated with the value of the test-statistic (χ^2) defined as:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \tag{2}$$

where: χ^2 = Pearson's cumulative test statistic, which asymptotically approaches a χ2 distribution; O_i = number of observations (samples); E_i = expected (theoretical) number of observation if null hypothesis (herein: normal distribution) is true; n = number of cells in the table.

The next step is to calculate p-value using χ^2 and number of degrees of freedom which is equal n minus t. The reduction in degrees of freedom (t) is calculated as t = s +1, where s = number of co-varies used in fitting distribution. For normal distribution s = 2, which counts AVG and SD. The p>0,05 suggests very high probability of null hypothesis (distribution is normal), the 0,02<p<0,05 suggests the null hypothesis probable when high number of samples is available (e.g., [9 ,10]). For p<0,02 the null-hypothesis is rejected.

If data distribution is not normal, the issue is more complex. By applying Bienaymé-Chebyshev inequality rule one can be confident that 75% of data is within ±2SD range regardless distribution. In this paper the analysis of percentage of data that lies within ±1SD range is performed and the qualitative evaluation of the data is made. Firstly, the skewness (SK) and kurtosis (RKU) are calculated. Negative SK suggests the mass of distribution concentrated on the right of the histogram, i.e. mode is higher than average. Positive SK suggests the opposite. Positive and relatively high value of RKU is typical where most of the data is located around the AVG. Negative value can be interpreted as a large scatter of data. Analysis of SK and RKU allows to qualitatively evaluate the discrepancies between actual, non-normal distribution and the normal one.

4. Results and interpretation

4.1. Soil classification according to Casagrande charts

Casagrande plasticity chart [11] is used in Unified Soil Classification System (USCS) [12] and European Soil Classification System (ESCS) [13]. The classification of the Vistula Marshlands soft soils (peats are excluded from the diagrams) according to USCS and ESCS is presented in Figure 2.

Sandy/silty loams are classified as a clays of different plasticity, which is quite accurate. Classification of organic clays and silts does not differ much and all these soils lies between A-line and U-line, and they are classified as a organic soils of low to high plasticity. Here, one can see that for organic silt a significant discrepancy occurs between behavioral classification (USCS and ESCS) and classification based on grain-size.

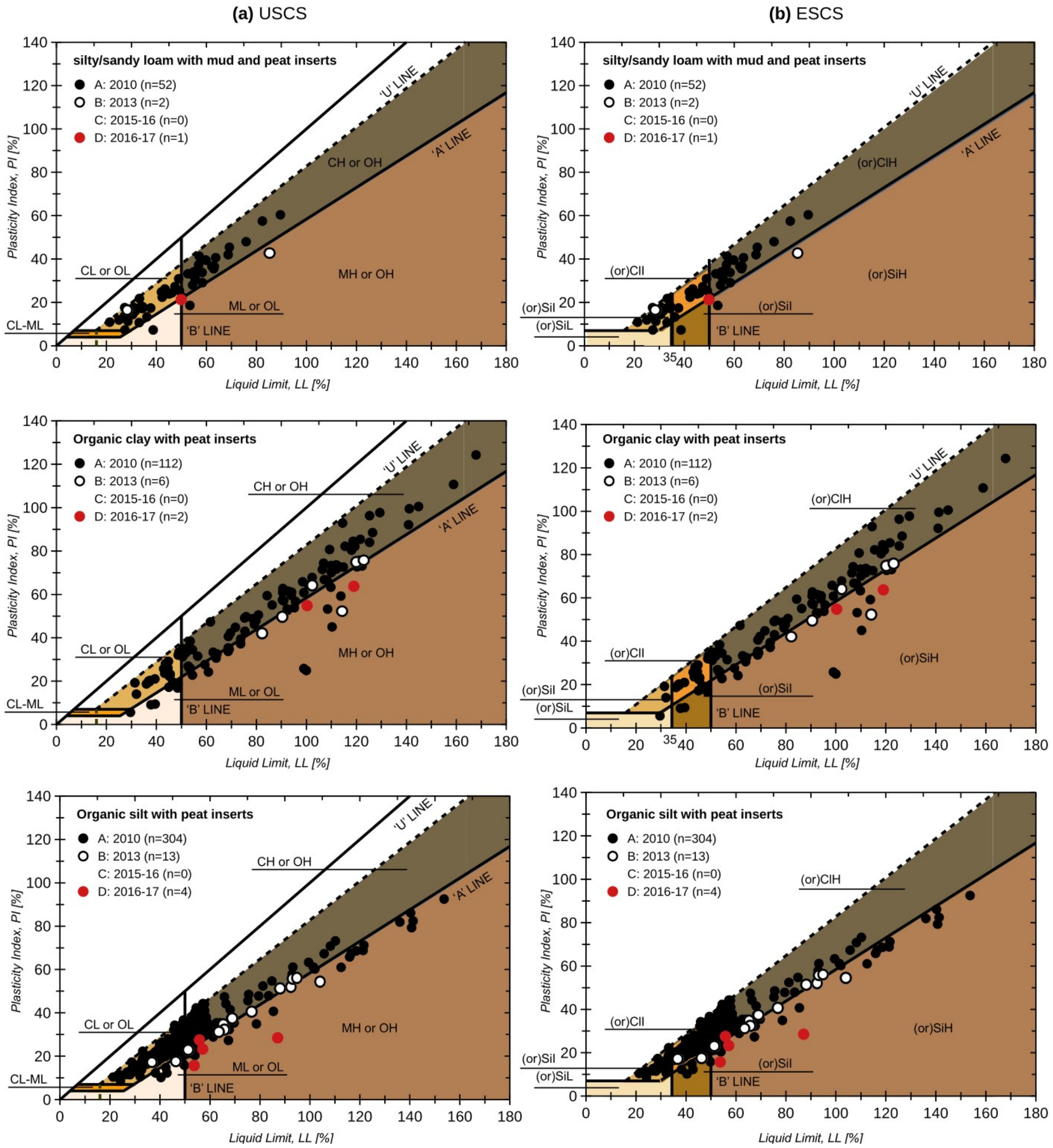

Figure 2. The Vistula Marshlands soft soils classification according to (a) USCS and (b) ESCS.

The high variability in plasticity index (PI) and Liquid limit (LL) is usually caused by different content of organic matter [14] and soil granulometry [14, 15]. These effects can be seen in data presented in Figure 2. The relationship between Loss on Ignition (LOI) and LL was firstly introduced by Skempton and Petley [16]. Relationships between LOI and LL for peats and clays for the Vistula Marshlands soft soils is presented in Figure 3 (data for peats included). The data are characterized by large scatter, but general trend can be described (by linear or power regression curve). The increase in LL with LOI for low organic content (LOI<5%) seems to be negligible. The relations between LOI and IP, and LOI vs PL were not obvious, as it was already noticed by DeJong et al. [14].

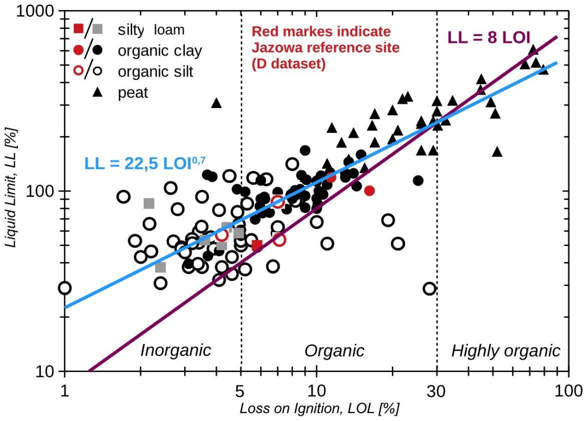

Figure 3. Two propositions of LOI vs. LL relationships for the Vistula Marshlands soft soils.

4.2. Statistics of index properties
The statistical evaluation of index properties of Vistula Marshlands soft soils is presented in Tables 3, 4 and 5 where statistics for LL, PL and IP are summarized, respectively. Most of the samples (60 to 80%) is in ±1SD range. However, the high COV (about 40÷50%) is usually obtained. In terms of LL and PL, COV=30÷35% for inorganic soils (loams), COV=35÷40% for organic soils and COV>40% for peats were calculated. COV for IP for all soils is about 50%. The normal distribution of these parameters is rarely observed. The unreliable of LL and IP may be induced be natural variability of organic content that results in increase of LL with LOI (Figure 3). It should be also noted that the results for Vistula Marshlands soils are in agreement with statistical evaluation of organic soils in other locations, e.g., for Szegzed soils [17].

4.3. Statistics of basic physical properties
Evaluation of variability of basic soil properties includes statistics of water content (w_c), soil density (ρ), and specific gravity (G_s) is presented in Tables 5, 6, and 7, respectively. COV for w_c is between 27% (inorganic soils) and 40% (highly organic soils). This is typical variation for this kind of soils [17]. The distributions are normal for loams and organic clays. For organic silts and peats most of results are around the mean value (positive RKU) and mode is lower than average. COV for ρ is about 10% except of peats where COV=23%. High percentage of results is in ±1SD range and only peat samples are not normally distributed. However, high RKU values indicate most of results around the AVG, which is an advantage. Consequently, ρ is one of the most reliable soil parameter for organic soils. Low COV (2%) and high ±1SD percentage (above 75%) for G_s can be observed. The data are not normal for the organic silt, but the high RKU, low COV allow to make a statement, that G_s can be treated as a point value. The case of peats is more complex. Data distribution is not normal, COV is high (15%), only 52% of data is in ±1SD range and there is scatter from the mean (RKU<0). This suggests that for peats G_s is very local, depending on decomposition. However, the datasets do not contain peat decomposition data and more detailed analysis cannot be done.

4.4. Statistics of basic physical properties
Variability evaluation of derivative soil properties includes statistics of bulk density (ρ_d), porosity (n), void ratio (e) and saturation ratio (S_r) presented in Tables 9, 10, 11 and 12, respectively. Quite good reliability in terms of ρ_d for organic clay and silt (COV=19÷24%) is obtained with 60% of samples in ±1SD and with normal data distribution. The scatter is significantly larger for peats. Porosity is quite highly reliable (COV =6÷17%) with approx. 60% of samples in ±1SD range. All data are probable to be normal. Void ratio variability is moderate to high (COV between 30% to 45%). That is usually caused by small fraction of peat and calcium carbonate content. Data are usually scattered from the mean value with exception of organic silt. S_r is about 100% with low COV (approx 10%) for all soil

groups. High an positive RKU for S_r suggests almost full saturation of the majority of samples subjected to lab testing.

Table 3. Statistical evaluation of LL

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	54	47,2	16,4	0,35	46,8	0,57	-0,23	0,294	v. probable	68,5
Organic clay	118	82,5	32,1	0,39	81,5	0,23	-0,89	0,007	No	61,0
Organic silt	316	52,0	21,0	0,40	47,8	2,24	5,91	0,000	No	83,9
Peat	42	268,9	115,7	0,43	233,8	1,3	1,19	0,005	No	76,2

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 4. Statistical evaluation of PL

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	54	20,9	6,3	0,30	20,3	0,73	1,24	0,690	v. probable	68,5
Organic clay	118	32,5	11,8	0,36	32,2	0,90	1,74	0,071	v. probable	67,8
Organic silt	316	22,6	9,0	0,40	19,8	1,90	4,08	0,000	No	84,2
Peat	42	103,7	55,7	0,54	88,0	1,20	0,86	0,013	No	76,2

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 5. Statistical evaluation of IP

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	54	26,3	12,3	0,47	24,6	0,66	0,03	0,014	No	66,7
Organic clay	118	50,1	25,1	0,50	32,2	0,47	-0,45	0,027	probable	65,3
Organic silt	316	29,4	13,8	0,47	25,4	1,81	4,05	0,000	No	81,0
Peat	42	159,4	87,5	0,55	134,9	1,15	2,18	0,000	No	81,0

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 6. Statistical evaluation of w_c

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	83	33,4	9,0	0,27	33,2	0,22	-0,41	0,500	v. probable	67,5
Organic clay	235	63,5	21,0	0,33	61,3	0,57	0,03	0,065	v. probable	66,0
Organic silt	532	45,5	18,5	0,41	41,2	2,06	6,67	0,000	No	79,0
Peat	186	261,0	110,4	0,42	249,7	0,96	1,05	0,000	No	68,8

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 7. Statistical evaluation of ρ

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	36	1,83	0,12	0,07	1,82	-0,01	1,97	0,443	v. probable	72,2
Organic clay	160	1,58	0,16	0,10	1,59	-0,56	1,87	0,032	v. probable	78,8
Organic silt	266	1,74	0,18	0,10	1,76	-0,73	1,49	0,409	probable	67,7
Peat	178	1,17	0,27	0,23	1,12	1,59	8,33	0,000	No	91,0

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 8. Statistical evaluation of G_s

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic clay	42	2,61	0,06	0,02	2,62	-1,69	5,85	0,552	v. probable	76,2
Organic silt	62	2,60	0,06	0,02	2,61	-1,62	3,49	0,001	No	79,0
Peat	36	2,04	0,32	0,15	2,16	-0,38	-1,24	0,001	No	52,8

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 9. Statistical evaluation of ρ_d

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic clay	42	1,02	0,19	0,19	1,01	0,24	-0,54	0,361	v. probable	61,9
Organic silt	62	1,10	0,26	0,24	1,09	-0,17	-0,64	0,169	v. probable	64,5
Peat	36	0,38	0,15	0,40	0,41	-0,10	-1,56	0,001	No	47,2

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 10. Statistical evaluation of n

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic clay	42	0,61	0,07	0,11	0,61	-0,26	-0,75	0,816	v. probable	61,9
Organic silt	62	0,58	0,10	0,17	0,58	0,16	-0,60	0,280	v. probable	64,5
Peat	36	0,82	0,05	0,06	0,81	0,21	-1,37	0,062	v. probable	55,6

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 11. Statistical evaluation of e

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic clay	42	1,64	0,47	0,29	1,58	0,32	-0,92	0,524	v. probable	61,9
Organic silt	62	1,51	0,68	0,45	1,38	1,38	2,04	0,000	No	82,3
Peat	36	5,05	1,94	0,38	4,18	0,83	-0,57	0,004	No	69,4

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

Table 12. Statistical evaluation of S_r

Group of soils	n	Statistic parameter								±1SD [%]
		AVG	*SD*	*COV*	*MED*	*SK*	*RKU*	*p-value*	*NORMAL*	
Silty loams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic clay	42	98,4	10,2	0,10	95,6	2,13	5,94	0,000	No	83,3
Organic silt	62	98,7	6,78	0,07	98,8	-2,51	14,75	0,000	No	83,9
Peat	36	98,1	6,9	0,07	99,7	-1,95	4,99	0,106	v. probable	75,0

Note: AVG = average value; SD = standard deviation; COV = coefficient of variation; MED = median; SK = Skewness; RKU = kurtosis; Normal = chi-squared test for normality.

4.5. Datasets (A, B, C) comparison with reference Jazowa site (D)

The AVG values of basic soil parameters (with error bars based on SD) obtained from combined A,B and C datasets are compared with Jazowa reference site in the Figure 4. The Jazowa reference site was

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chosen for research project concerning CMC columns design and was assumed 'a-priori' as a representative for the Vistula Marshlands. The comparison presented in Figure 4 supports that assumption. The only significant difference is specific gravity for peats. However, results are still in ones each ±1SD range.

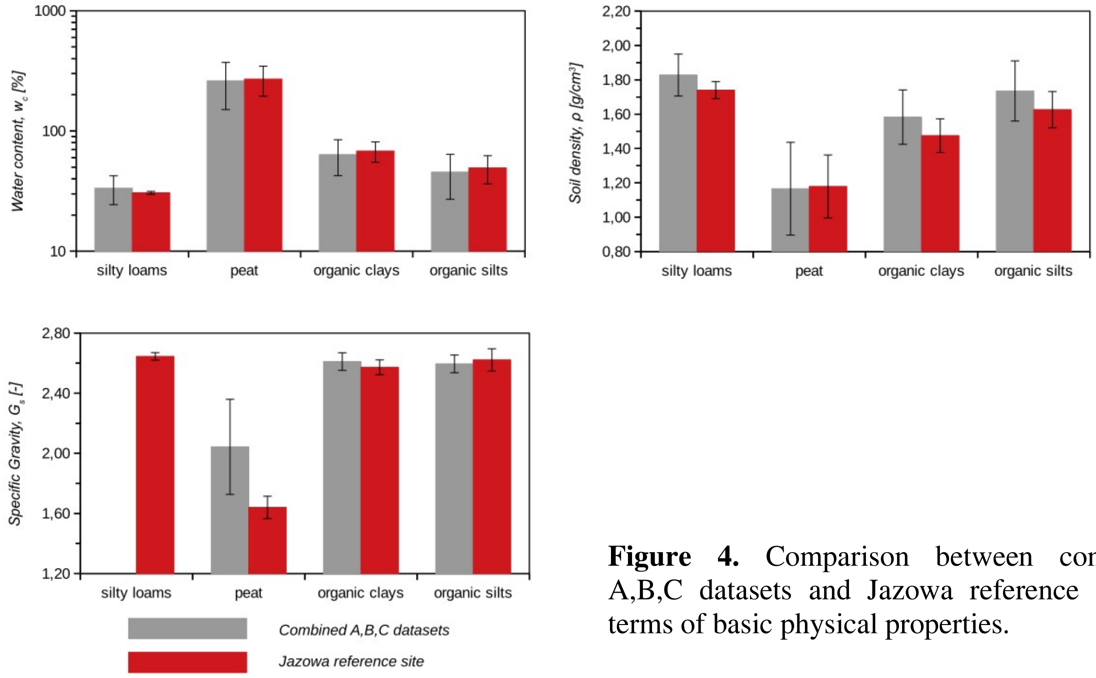

Figure 4. Comparison between combined A,B,C datasets and Jazowa reference site in terms of basic physical properties.

5. Closing remarks

This paper presents the results of statistical evaluation of the Vistula Marshlands deltaic soft soils. Based on presented results, the following general conclusions can be drawn (order according to the content of paper):

(1) Casagrande chart does not allow to distinguish organic silt from organic clay. In USCS this issue is less important as all organic soils are denoted with the same symbol (OL or OH). In ESCS the problem is more crucial as orCl instead of orSi can be obtained. Authors would like to notice, that soils assembled as organic ones were usually recognized correctly with macroscopic descriptions is geotechnical reports for Vistula Marshlands.

(2) LL increases with LOI. Two equations are proposed for average trend for all soft soils:

$$LL = 8LOI \tag{3}$$

$$LL = 22.5LOI^{0,7} \tag{4}$$

(3) Index properties are characterized by a large scatter (*COV* about 50%), which indicates high local heterogeneity of organic soils.

(4) The most reliable parameters for organic clay and silt are soil density (*COV* <10%) and specific gravity (*COV* about 2%).

(5) Peats parameters are characterized by large scatter which usually indicates very local properties influenced by decomposition and formation history.

(6) Most of the data points for physical/index quantities are within ±*1SD* range regardless distribution is normal or not. Normal distribution is expected for 80% of cases for silty/sandy loams parameters, 80% of cases for organic clays parameters, 30% of cases for organic silt parameters, and 20% cases for peats parameters.

(7) Jazowa testing is representative research location for the Vistula Marshlands based on the basic physical (Figure 4) and index properties (Figures 2 and 3).

Presented data makes a step towards the qualitative and quantitative description of reliability based design.

6. References

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