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# TYPE GRAIN-SIZE CURVES FOCUSING ON THE ZONE OF POLYGENETIC LOESS SEDIMENTS IN THE SELECTED PART OF OSTRAVA BASIN

**Abstrakt**

Účelem studie bylo vytvoření typových zrnitostních křivek reprezentujících třídy zemin ve vybrané části Ostravské pánve, protože mapy inženýrskogeologického rajonování neobsahují modelové zrnitostní křivky zemin jednotlivých rajonů popř. tříd zemin. V průběhu realizace studie bylo zjištěno velké granulometrické rozpětí zemin v jednotlivých inženýrskogeologických rajonech, a proto se studie blíže zaměřila na rajon polygenetických sprašových sedimentů, ve kterém byla kromě modelové granulometrické křivky provedená studie základních geotechnických vlastností. Zjištěné údaje bude možno použít při nově prováděných průzkumech, kdy bude možná konfrontace nově stanovených zrnitostních křivek s modelovou křivkou odpovídajícího inženýrskogeologického rajonu, čímž se může zjistit případná hrubá odchylka prováděných analýz. Výsledné orientační hodnoty vybraných geotechnických vlastností rajonu polygenetických sprašových sedimentů poskytují orientační představu, s jakými vlastnostmi se může počítat při projektování v oblasti zakládání staveb.

## INTRODUCTION

In order to define engineering-geological and foundations conditions, engineering-geological zones are key factors that define the areas with similar conditions for construction foundations. These are stated in an engineering-geological zoning map in the 1: 50 000 scale, issued by the Czech Geological Service. A part of the map are comments giving the names of zones, subzones marking orientation thickness of quaternary sediments, orientations depths of ground water level, the character and orientation depth of prequaternary bottom layer. The zones are further specified by prevailing classes of foundation soils (ČSN 731001 Foundation soil under areal foundations), workability of rocks that are important in terms of potential mucking of rock materials, especially for construction purposes (ČSN 733050 Earthwork), and last but not least, there are comments explaining potential problematic conditions and suitability as for construction foundations.

The stated maps serve for an identification of orientation engineering-geological conditions of newly quested localities. However, for the purposes of engineering structures they lack the type grain-size curves of foundation soils classes which are important for the specification of foundation soils with the following implication for the relevant, selected geotechnical properties of soils. These are then the input parameters for the calculation of basic characteristics for construction foundations – ultimate bearing capacity and settlement.

Within the study an interest area was determined that is characterized by engineering-geological zones and their soil classes. It was discovered that the majority of zones have a very wide granulometric range, for which narrow envelope grain-size curves cannot be determined. This fact is proved by the quantity of foundation soil classes that are found in the zones in question. Mainly it is a zone of polygenetic loess sediments (Lp) with F6 class (according to the ČSN 73 1001 Standard); a zone of lowland stream deposits (Fn) with the following classes F6, F3, F4, S3, S4, S5, G2, G3, G4; and a zone of deluvial-fluvial sediments (Du) with the following classes F6, F3, F4, S3, S4, S5, G2,

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G3, G4. There are zones for which this determination is excluded because of the diversity of backfilled materials. It is the case of spoils banks, stockpiles and dumps (An) and the zones of settling basins and waste dumps (Ao) with Z and Y classes. The above mentioned implies that a more detailed study can be compiled a zone of polygenetic loess sediments. For this zone, selected geotechnical properties were further specified from the given surveys. In the future, type curves can be determined for other zones; with the individual zones separate envelope grain-size curves characterizing dominant classes of foundation soils will be specified.

## NATURAL CONDITIONS

The area of interest represents part of cadastral territory of Ostrava city. This is a part of industrial zone of city area Hrabová specifically. According to a regional geology, the area of interest belongs to Ostrava Glacial Basin that is a part of front Carpathian fore-deep of Outer Western Carpathians.

Quaternary sediments represent Holocene fluvial deposits of lower and upper alluvium plane and anthropogenic deposits such as backfills and dumps. Quaternary deposits represent glaci-fluvial, fluvial, deluvial deposits, loess loam, and Tertiary eluvia (Chlupáč et al, 2002).

Neogene sediments are underlying of Quaternary deposits. They contain pelite sediments especially. Pelite represents greenly grey to grey calcareous clays with the variable carbonate content.

Quaternary aquiferous systems are created a pores, incoherent sands, gravel-sands. The water is an atmospheric origin. It keeps oxidized environs within the area of intensive circulation with the earth ground (Dopita et al, 1997).

## ENGINEERING-GEOLOGICAL CONDITIONS

Based on the engineering-geological zoning map (ÚÚG, 1990) the interest zone is characteristic for the zone of polygenetic loess sediments (Lp), zone of meadow loam (Fn), deluvial-fluvial sediments zone (Du), spoil banks, stock piles and dumps zone (An) and the zone of settling basins and waste dumps (Ao). Each zone is described with age and the character of soils, subzones and orientation classification of soils into classes based on the grain-size distribution, according to Standard 73 1001 (Construction foundations), and into workability of rocks based on the characteristic properties and difficulty in disintegration, which is dealt with in ČSN 73 3050 Standard (Earthwork).

*In the zone of polygenetic loess sediments (Lp)* there are Holocene loess loams and deluvial sediments. Soils as foundation soils are intermediate-bearing, mainly of stiff consistency, low to intermediate plasticity, intermediate-permeable. The sediments can be utilized as a material for brickware. The soils in this zone are classified into F6 class – clays with a low to intermediate plasticity (ČSN 73 1001 Standard) with workability of 2$^{nd}$ to 3$^{rd}$ class (ČSN 73 3050 Standard).

Around the water courses of the Odra and the Ostravice there is a *zone of meadow loam (Fn)* represented by Holocene fluvial sandy-loamy and gravely sediments that are inhomogeneous, low-bearing and non-uniform compressible foundation soils occurring with loams of soft to stiff consistencies. It is the case of clays with a low and intermediate plasticity - F6, sandy clays and loams – F3 and F4, sands - S3, S4, S5 and gravels G2, G3, G4 (ČSN 73 1001 Standard). The workability is of the 2$^{nd}$ – 3$^{rd}$ class (ČSN 73 3050 Standard). The ground water level is shallowly under the ground surface.

In the interest area comprises small areal expanded a *zone of deluvial-fluvial sediments (Du)*, which is represented by Holocene sediments of the following classes (according to ČSN 73 1001 Standard): F6 – clays with a low and intermediate plasticity F3, F4 – sandy clays and loams, S3, S4, S5 –sands and G2, G3, G4 – gravels. According to ČSN 73 3050 Standard the soils are of the 2$^{nd}$ – 3$^{rd}$ class workability. These are inhomogeneous, low-bearing and non-uniform compressible foundation soils with loams of soft to stiff consistencies. The ground water level often occurs as shallowly as 2 metres.

In the given area there is an uneven *zone of banks, spoil banks and dumps(An).* These are recent anthropogenic deposits connected with the mining, metallurgical and chemical industries. They are characteristic for the occurrence of carboniferous waste rock, slag and fly ash. Their utilization as foundation soils is decided based on the local conditions and compaction of loose soil materials. According to ČSN 73 1001 Standard it is class Y – anthropogenic sediments and class Z – dumping ground, with the workability class 2 – 4 (ČSN 73 3050 Standard).

*The zone of setting pits and rubbish (Ao)* is typical by anthropogenic deposits, especially building and municipal rubbish. These soils are not suitable for construction foundation as they are anthropogenic sediments - Y and dumping ground - Z (ČSN 73 1001 Standard) with the 1st – 3rd workability class (ČSN 73 3050 Standard).

## METHODOLOGY OF STUDY

The project was implemented in several stages. In the first stage a representation area of the Ostrava Basin was a selected, geomorphologic unit of the Ostrava fluvial plain in particular, with a characteristic representation of the engineering-geological zones. Next, archive data were processed based on the carried out engineering-geological surveys focusing on the model curves of the selected genetic types of the individual classes of foundation soils that are stated in the next chapter.

In the second stage, the details obtained in the previous stage were processed, while the results were classified into two basic categories. The first represents engineering-geological zones with a big range of the granulometric representation of grain-size curves. With regard to the above mentioned, these zones were not studied in the next chapter. The second category was engineering-geological zones in which the foundation soils are characterized by type curves. A more detailed description of the polygenetic loess sediment zone was processed, whose geological environment had the best conditions for the study defined above, which is dealt with in the next chapter.

In the third stage, survey of the polygenetic loess sediment zone was carried out, defining relevant geotechnical parameters, which shall orientation specify their properties. Apart from the processed archive data, laboratory analyses within the carried out survey were used in the study.

## TYPE GENETIC CURVES

Granularity is the most important characteristics of the soils and it is determined by a grain-size analysis. It represents the grain distribution in the soil according to its size. The amount of the particular grain-size fraction is transferred to a percentage. The result of this analysis is represented in a mass curve – a so-called soil grain-size curve. Grains greater than 0.1 mm are screened through a standardized set of sieves and the grain-size under 0.1 mm is determined by a hydrometric test.

On the basis of the processed data within the stated engineering-geological zones in the interest area, model curves of meadow loam, Miocene sediments, loess loams and gravels of the main Odra and Ostravice river terraces were specified (See Figure 1).

From the above-mentioned genetic types, the best conditions for the determination of the orientation geotechnical properties were in the case of the model curve of loess sediments in the engineering-geological zone of polygenetic loess sediments. The next chapter deals with the typology of their properties.

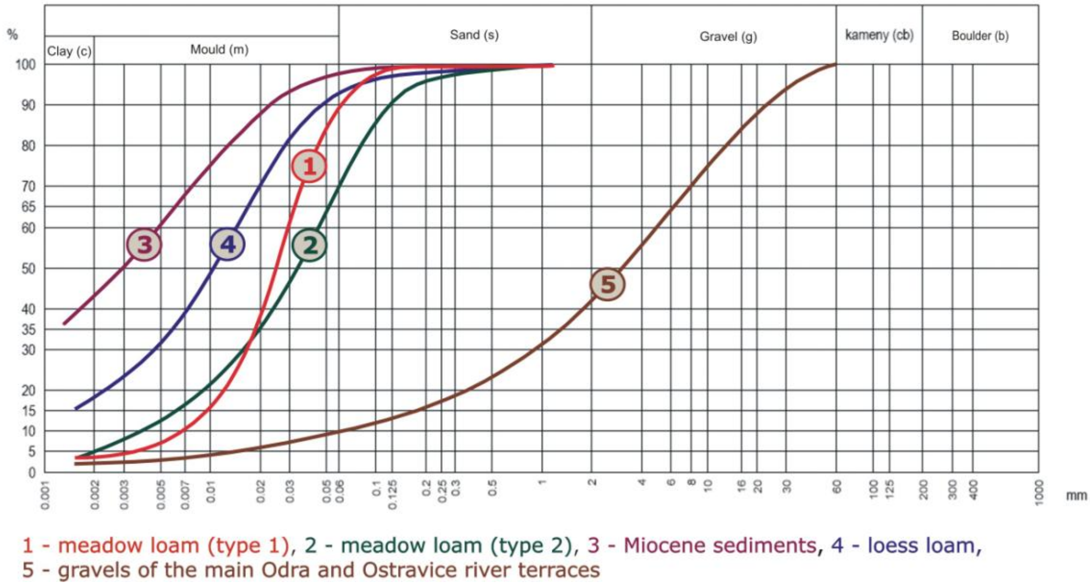


**Fig.1** Model curves of the selected genetic types of engineering-geological zone soils of the interest area

**TYPOLOGY OF LOESS SEDIMENTS ZONES**

The statistic data set includes 40 samples. These was collected from these boreholes and used to a laboratory research [7-15] of rock properties such as moisture, specific density, bulk density, dry bulk density, liquid limit, yield point, plasticity index, consistency index, porosity, saturation. In this chapter interpretion of properties is demonstrate by means graphs, whose is signalized frequency (number of samples N) of specific properties.

The samples were collected from pelite sediments with brown and darkly brown limy, humid with stiff ro semisolid consistency.

*Granularity* distribution is determined by the grain-size analysis. It represents the grain distribution in the soil according to its size. The amount of the particular grain-size fraction is transferred to a percentage. The result of this analysis represents the grain-size curve. Grains greater then 0, 1 mm is SIEVE through the set of mesh screens. Grain-size under 0.1 mm is determined by the hydrometrics test. Fig. 2 (according ČSN 73 1001 Standard) shows that loess loams are well sorted. Solid line represents the envelope curve of all determined loess soil.

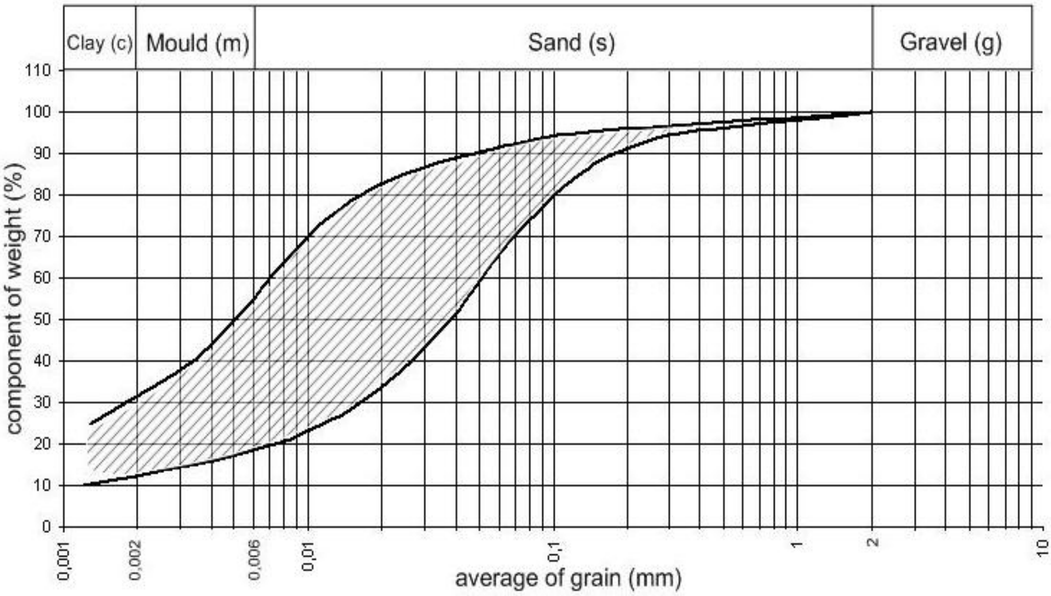


**Fig.2** Envelope curves grain-size curves determined soil

*Yield point* $w_P$ represents the moisture of yield point when the solid state soil becomes plastic. Determination of yield point is given by ČSN 72 1013 Standard. During the laboratory test, the soil sample is shaped as a cylinder with the 3 mm diameter. When the cylinder begins to fall into 1 cm long pieces, the moisture is established. Figure 3 shows the rate of yield point varies from 14 to 24 %, the most frequent rate is between 16 – 20%.

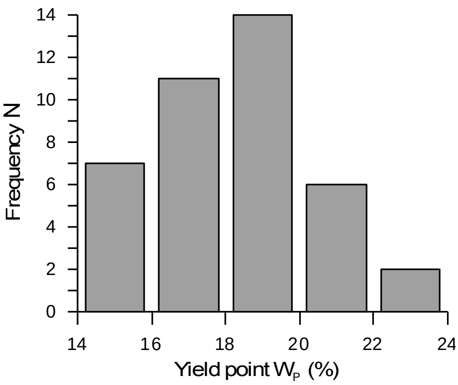


**Fig.3** Values of yield poit and their frequency

*Liquid limit* $w_L$ represents the moisture of yield point when the soil loses the yield strength and becomes liquid. This moisture rate is established by means of Cassagrande concave tool. The Cassagrande concave tool with the cut in two soil sample 25 times taps at the base block with the rate of 2 hits per second (according the ČSN 72 1014 Standard). The two parts of soil moisture should put together for 12.5 mm.

Evaluation of liquid limit is shown at the Figure 4. It seems the clayey soil is low (28 – 35%) and intermediate (35-44%) plasticity.

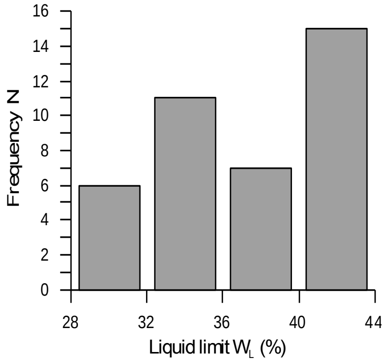


**Fig.4** Values of liquid limit and their frequency

*Plasticity index* in percentage represents the moisture range in which the soil is plastic (IP=wL-wP). It means, how much of moisture the soil should be charged to become from the moisture of yield point to liquid limit.

The plasticity index varies from 10 to 26%. The most frequent rate of plasticity index varies from 14 to 22% (Fig.5). According to Atterberg classification, this range corresponds with clayey loam to clay. Lower plasticity index (less then 17%) corresponds with sandy soil and loam.

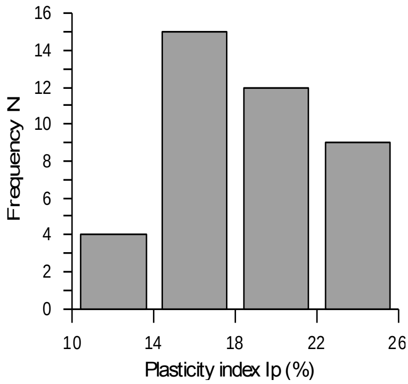


**Fig.5** Values of plasticity index and their frequency

*Consistency index $I_C$* reflects the state of consistent soil. The natural moisture of soil is compared with the consistency limits – $w_L$ and $w_P$. Consistency index helps to establish the Standard characterisation. Consistency index varies from 0.6 to 1.1 (Fig.6). This is mainly stiff consistencies (0.5 - 1.0) and lower values solid consistencies (1.0 - 1.5) according to ČSN 72 1001Standard.

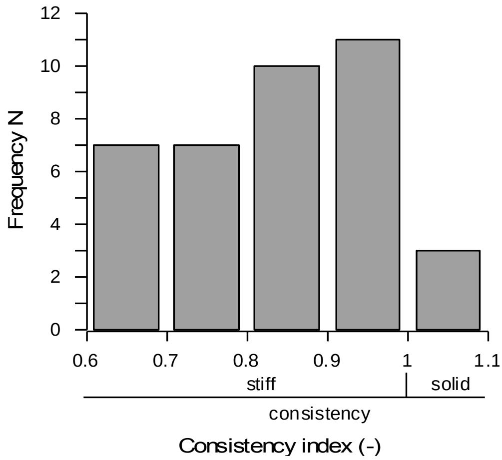


**Fig.6** Values of consistency index and their frequency

*Plasticity chart* is required for soil with the particles size less then 0.5 mm (according to ČSN 73 1001Standard). It represents the dependency of $w_L$ soil moisture on plasticity index. The plasticity chart is divided into two parts by a line Ip = 0.73 ($w_L$-20%). Fig.7 ratifies the low and intermediate plasticity of clayey soil.

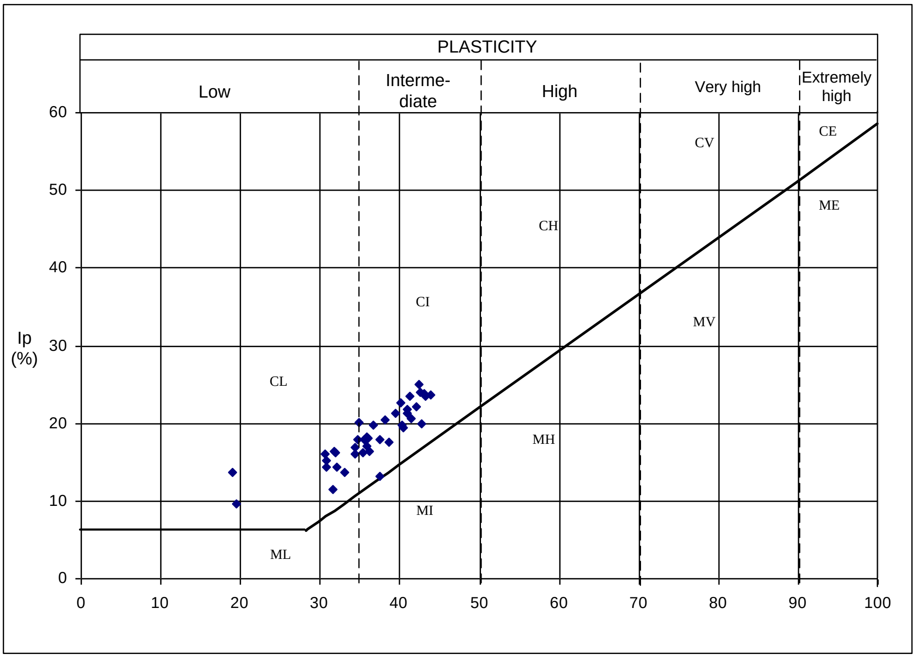


**Fig.7** Plasticity chart of loess soil grain size under 0.5 mm (according to ČSN 731001 Standard)

According to the evaluation of above mentioned characterization the soil is classified into the classes: fine grained F6 – clay with intermediate plasticity CI (26 samples), clay with low plasticity CL (14 samples).

*Physical properties* are another of descriptive properties. They influence on soil mechanical properties as compressibility, consolidation, collapsibility, settlement etc.

*Specific density* $\rho_s$ means relationship between density of soil particles and their volume. Specific density is determined according to ČSN 72 1011 Standard during the laboratory test as the weight of adjusted sample to its volume established by the pycnometer method.

Specific density of clay varies from 2.64 to 2.74 g.cm-3. It means, the area of interest contains predominately clay, less frequently there occurs clay (see Fig.8).

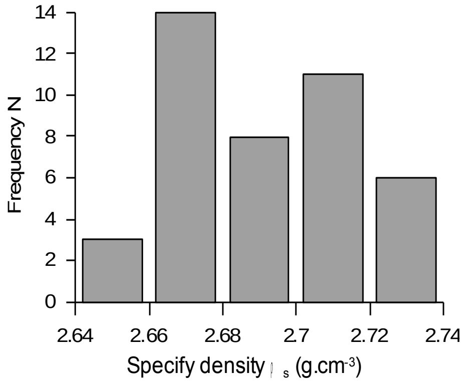


**Fig.8** Values of specific density and their frequency

*Bulk density* $\rho$ represents ratio between soil density and its wet soil volume. Bulk density is required for calculation of relative density and porosity. It is determined according ČSN 72 1010 Standard.

Fig.9 shows that the range of bulk density varies from 1.9 to 2.15 g.cm-3. The most frequent value falls into 1.95 to 2.05 g.cm-3.

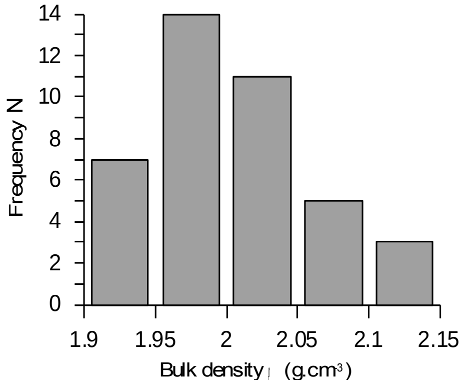


**Fig.9** Values of bulk density and their frequency

*Dry bulk density* $\rho_d$ represents ratio between dry soil density and volume of original wet soil. Dry bulk density is required for calculation of moisture or saturation. Value of dry bulk density varies from 1.6 to 1.85 g.cm-3. The most frequent value is 1.6 - 1.7 (Fig.10).

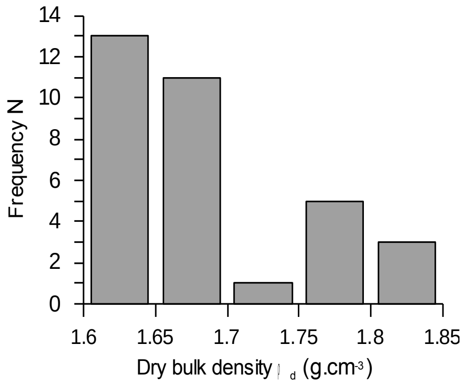


**Fig.10** Values of dry bulk density and their frequency

*Porosity n* means ration between volume of soil pores and total volume of soil. Porosity is calculated by means of bulk density and dry bulk density. It varies from 32 to 44 % (Fig.11).

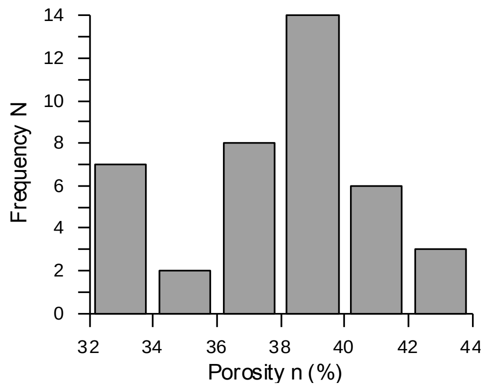


**Fig.11** Values of porosity and their frequency

*Moisture Wn* is a volume of water contained in soil. This water could be taken away by drying at temperature 105 and 110°C. Moisture could be calculated as a ratio between original soil density and dry density. Process of the laboratory test agree with ČSN 72 1012 Standard. Natural moisture content varies from 12 to 28% (Fig.12).

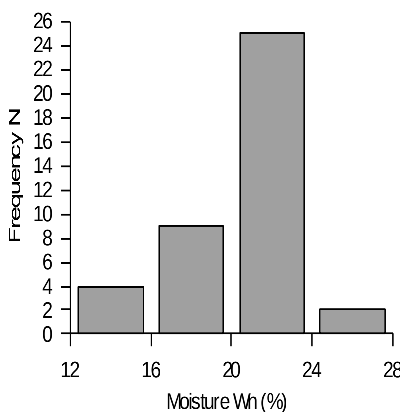


**Fig.12** Values of  moisture and their frequency

*Degree of saturation Sr* represents a rate of pore water filling. It is ratio between water volume and pore volume. Very wet soil (according Myslivec, Eichler, Jesenák) has the degree of saturation 0.7 – 1.0 (Fig.13).

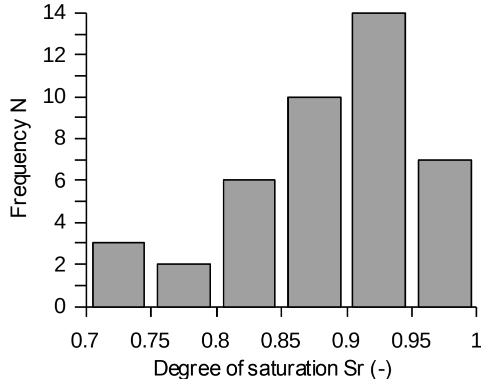


**Fig.13** Values degree of saturation and their frequency

All of sudied properties are stated in table number 1.

**Table 1** Final range value of specify properties of soil in the interest area.

| *properties of soil* | *range value* |
|---|---|
| porosity | 32% – 44% |
| moisture | 12% - 28% |
| degrese of saturation | 0,7 – 1,1 |
| bulk density | 1,9 – 2,15 g.cm$^{-3}$ |
| bulk density of dry soil | 1,6 – 1,85 g.cm$^{-3}$ |
| specific density | 2,64 - 2,74 g.cm$^{-3}$ |
| liquid limit | 28% - 44% |
| yield point | 14% - 24% |
| plasticity index | 10% - 26% |
| consistency index | 0,6 – 1,1 |

**CONCLUSION**

On the basis of the processed data in the interest area, type genetic curves of meadow loam, Miocene sediments, loess loams and gravels of the main Odra and Ostravice river terraces were made. These soil types occur in the engineering-geological zones of a part of the Ostrava Basin, among which the polygenetic loess sediments zone is the best zone for the evaluation of the grain-size curves and geotechnical properties.

In the interest area, the zone of loess sediments is represented by fine soils of F6 class – clay with intermediate plasticity and clay with low plasticity (according to ČSN 731001 Standard). The soil classes are represented by dry silty-clayey sediments with dark brown patches or lamina of predominantly stiff consistencies.

The result of the polygenetic loess sediment zone study is an evaluation of grain-size curves and physical properties of the individual soil samples. Their porosity ranges from 32% to 44%, moisture is between 12% and 28% and degree of saturation is in the interval 0,6 – 1,1. The bulk density is in the 1.9 – 2.15 g.cm$^{-3}$ range, the bulk density of dry soil is between 1.6 and 1.85 g.cm$^{-3}$ and the specific density of solid particles varies from 2.64 g.cm$^{-3}$ to 2.74 g.cm$^{-3}$. The values of liquid limit show that the clayey loams have a low (28 - 35%) and intermediate (35 – 44%) plasticity. The yield point varies from 14% to 24% and the plasticity index from 10% to 26%. The consistency index is between 0.6 and 1.1, which means predominantly stiff consistencies solid consistencies.

This engineering-geological study with created typological genetic curves of soils in a part of the Ostrava Basin and the evaluation of the selected geotechnical properties of foundation soils of loess sediments shall serve for an orientation appraisal during engineering-geological surveys and construction foundations in the geological environment in question.

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[7] ČSN 72 1001 - Pomenovanie a opis hornín v inžinierskej geológii, Validity: 1.8.1990

Since 1.11.2004 replace:

ČSN EN ISO 14689-1 (721005) - Geotechnický průzkum a zkoušení - Pojmenování a zatřiďování hornin - Část 1: Pojmenování a popis, Validity: 1.11.2004

ČSN EN ISO 14688-2 (721003) - Geotechnický průzkum a zkoušení - Pojmenování a zatřiďování zemin - Část 2: Zásady pro zatřiďování, Validity: 1.4.2005

[8] ČSN 72 1010 - Stanovení objemové hmotnosti zemin. Laboratorní a polní metody, Validity: 1.1.1991

[9] ČSN 72 1011- Laboratorní stanovení zdánlivé hustoty pevných částic zemin, Validity: 1.11.1981

Since 1.6.2006 replace:

ČSN CEN ISO/TS 17892-3 (721007) - Geotechnický průzkum a zkoušení - Laboratorní zkoušky zemin - Část 3: Stanovení zdánlivé hustoty pevných částic zemin pomocí pyknometru, Validity: 1.5.2005

[10] ČSN 72 1012 - Laboratorní stanovení vlhkosti zemin, Validity: 1.12.1981

Since 1.6.2006 replace:

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[11] ČSN 72 1013 - Laboratorní stanovení meze plasticity zemin, Validity: 1.7.1968

Since 1.6.2006 replace:

ČSN CEN ISO/TS 17892-12 (721007) - Geotechnický průzkum a zkoušení - Laboratorní zkoušky zemin - Část 12: Stanovení konzistenčních mezí, Validity: 1.5.2005

[12] ČSN 72 1014 - Laboratorní stanovení meze tekutosti zemin, Validity: 1.7.1968

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[13] ČSN 72 1027 - Laboratorní stanovení stlačitelnosti zemin v edometru, Validity: 1.7.1984

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ČSN CEN ISO/TS 17892-5 (721007) - Geotechnický průzkum a zkoušení - Laboratorní zkoušky zemin - Část 5: Stanovení stlačitelnosti zemin v edometru, Validity: 1.5.2005

[14] ČSN 72 1030 -Laboratorní metody stanovení smykové pevnosti zemin krabicovým přístrojem, Validity: 1.7.1988

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ČSN CEN ISO/TS 17892-10 (721007) - Geotechnický průzkum a zkoušení - Laboratorní zkoušky zemin - Část 10: Krabicová smyková zkouška, Validity: 1.5.2005

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