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Classification of organic soils for engineering geology

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This paper reviews the classifications of organic soils as applied in different countries, with particular attention drawn to those based on international and European norms. These norms propose the distinction of four groups of organic soils: peats (fibrous, pseudo-fibrous, and amorphous), gyttja and humic soils, which may be further divided into sub-groups. Organic soils are included within poor soils, because of their considerable susceptibility in relation to water, which causes their high compressibility, low strength and high shrinkage. Existing regional and international norms and plans appear not to characterise these soils sufficiently. The classification proposed in this paper will allow determination of the relationships between particular engineering geological parameters, which, to a large degree, will help planning of such objects as embankments or melioration structures. This is, however, possible only within particular genetic types. Organic soils developed in different conditions differ not only in organic matter content, but also in their chemical and physico-chemical character (i.e. degree of carbonisation, relation of humic acids to fulvic acids, bitumen content, degree of coagulation and decomposition of organic matter). The evaluation of organic soils requires firstly the determination of their origin, and then each genetic group should be subdivided based on the content of organic matter. The relationships between the physical, physico-chemical and mechanical properties should be then determined within these groups.

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INTRODUCTION

Building organic soils include soils containing organic matter in minimal proportions varying from 2% according to Polish norms and to 10% according to French norms.

During the preparation of new norms, based on European Normalisation Committee (CEN) as well as international (ISO) norms, the difference in criteria distinguishing organic soils are notable. According to the ISO proposal of 1996, the minimal organic matter content is 1% in the case of coarse soils and 2% in the case of fine soils. In proposals for European norms from 1999–2001, two suggestions have been made: general — organic soils are those which react to hydrogen peroxide; detailed — organic soils are those which contain over 2% of organic matter. These examples show that even a small content of organic matter (1–3%) classifies soils into separate groups, thus indicating the high activity of organic matter (comparable to the activity of clay minerals) influencing the changes in the engineering geological properties of soils.

Classifications, however, are hampered by the lack of standardised methods of determining the organic matter content. The ignition loss method, hydrogen peroxide oxidation method and the Tiurin method of potassium bichromate oxidation are most frequently employed (Myślińska, 2001).

In engineering geological investigations of organic soils the main problem is posed by their classification generalising their properties, which in many cases requires complex determinations. The classifications have not been standardised yet, and, despite many attempts (Borys, 1996; Wolski, 1996; Myślińska, 2001), the problem is still unresolved. There are two tendencies in soil classifications, including the classifications of organic soils: genetic and non-genetic classifications, the latter referred to as "descriptive" (Tobolski, 2000). Geologists, including engineering geologists, consider that the first description of soil requires determination of its origin, and further classification can be carried out within groups of the same origin basing on the different properties of soils.

GENETIC CLASSIFICATIONS

The accumulation of organic soils (referred to as biogenic and developed due to hydrogeological factors) takes place in three basic environments: fluvial, fluvial-terrestrial and terrestrial, the boundaries between which are not always distinct. Tobolski (2000) considers the fluvial environment as typical for the formation of gyttja, the fluvial-terrestrial environment as characteristic of fen peat and the terrestrial environment as responsible for the formation of bog peat and transition peat. Extending this classification (which does not cover all organic soils), muds should be referred to the fluvial-terrestrial environment and humus soils to the terrestrial environment.

West (1977) gives a detailed scheme for the formation of organic and mineral-organic soils in various environments.

The classification of biogenic deposits of lakes and bogs is complex and often unclear, which results from the different degree of carbonisation of the plant remains, thus hampering the identification of the organic compounds. Humic compounds are absorbed on the surfaces of clay minerals. Over 50% of the humic matter present in water seems to be transported with these minerals. Most of the humic matter is also assimilated directly into poorly soluble complexes of iron and manganese, which are then deposited (Gradziński *et al*., 1986).

Marks (1992) subdivides biogenic deposits into the sapropelic lake deposit, generally developed from plant and mainly planktonic animal remains, and into humic bog deposits, developed from plant remains. Sapropels are further subdivided into two main types: dy and gyttja, which can pass into lake chalk as the calcium carbonate content exceeds 80% (Ryka and Maliszewska, 1991; Marks, 1992).

Along with the organic material, mineral particles of different size and composition accumulate in lakes. According to Gradziński *et al*. (1986), because the organic matter is accumulated on the bottom as grains of different sizes, its distribution depends on the hydrodynamic conditions. Furthermore, there is a distinct link between grain size and organic content, which increases as grain size decreases.

Dy is formed in dystrophic basins and contains over 50% of brown-black, allochthonous colloidal organic matter, resembling peat. Dy is typically acid and contains only small quantities of calcium (Marks, 1992). In practice, dy is usually included within gyttja or strongly decomposed peats.

Gyttja comprises the main mass of sapropel deposits. It is formed in eutrophic lakes, rich in oxygen and organic matter. Gyttja typically contains recognisable organic particles, mainly planktonic, and is characterised by the presence of organic matter and calcium carbonate, in some cases in considerable quantities, as well as non-carbonate mineral particles.

Peats are formed in the shore zone of lakes and in overgrown but humid basins.

According to Marks (1992), muds and clays are the most typical deposits of lakes. Several definitions of lake mud exist. It is typically referred to as a silty-clayey deposit, the character of which depends on other admixtures, including that of organic matter.

NON-GENETIC (DESCRIPTIVE) CLASSIFICATIONS

In many countries, for example France (Perrin, 1974), non-genetic classifications are often employed in descriptions of organic soils. According to the latter, organic soils comprise soils containing over 10% of organic matter (OM), which are sub-divided into highly organic (OM exceeding 30%) and medium organic soils (OM between 10 and 30%). Soils containing 3–10% of organic matter are referred to as poorly organic soils and are included within fine soils and sub-divided according to the Casagrande diagram.

In the Netherlands, where peats constitute over 7% of the country's area (Hobbs, 1986), organic soils are subdivided according to the percentage content of three components: organic matter, clay and the sum of the sand and silt fraction (Venmans and den Haan, 1990), placed on a triplot diagram. According to this subdivision, prepared for the Committee for Embankments (TAW), two groups of soils are distinguished: peats (15–100% of organic matter [OM]; 0–70% clay and other fractions) and other organic soils (humus) (0–15% organic matter; 70–100% clay and other fractions). Peats are subdivided into poorly clayey (30–55% f_i — clay fraction), strongly clayey (55–70% f_i), poorly sandy (22.5–35% OM; 30–55% f_i; 0–8% f_p— sand fraction) and strongly sandy (15–22.5% OM; over 8% f_p). Humic soils are subdivided into poorly (0–2.2% OM) and strongly humic (58–15% OM).

According to the German norm DIN 18196 (10.88), sandy soils can be considered as organic when they contain over 3% of organic matter, and sandy-silty (fine) soils as organic when they contain over 5% of organic matter. The norms distinguish two groups of soils of organic origin, organic soils and organogenic soils. Organogenic soils are distinguished based on the character of their mineral content, whereas the organogenic soils are subdivided based on their origin, and peats are subdivided based on the degree of decomposition. The classification can be considered as descriptive in relation to the origin of the soil.

DESCRIPTIVE-GENETIC CLASSIFICATIONS

In the classification of organic soils of the Polish norm PN-86/B-0248, soils are subdivided based on their origin, excluding, however, previous suggestions of a detailed subdivision based on organic matter content (PN-74/B-02480). According to this subdivision, the following groups of non-rocky organic soils can be distinguished:

— humic soils (non-rocky soils containing over 2% of organic particles of plant origin and of microflora and microfauna);

— warps (soils developed during accumulation of mineral and organic particles in an aqueous environment; sandy or clayey);

— gyttja (muds with a calcium carbonate content exceeding 5%, which forms the soil skeleton, forming a rocky soil with a low value of shear strength R_c)

— peats (soils developed from decayed plant remains,undergoing carbonisation, with an organic matter content usually over 30%).

The classification applied in the Warsaw Agricultural High School, given by Wolski (1996) contains descriptive as well as genetic elements. It is based mainly on ash content (percentage

Table 1

Proposed classification of organic soils for engineering geology

<table>
<tr><td colspan="2">Bog peat and transition peat
$A_c \sim 0–10\%$</td><td colspan="2" rowspan="3">Organic gyttja
$I_{om} \sim (25–80)\ \%$</td></tr>
<tr><td>Fen peat
$A_c \sim 10–25\%$</td><td rowspan="3">Muck

Mud (?)</td></tr>
<tr><td rowspan="2">Muddy fen peat (peat soil)
$A_c \sim 25–80\%$</td></tr>
<tr><td colspan="2" rowspan="2">Mineral-organic gyttja
I_{om} 10–30 %</td></tr>
<tr><td rowspan="2">Organic- mineral soil
A_c 80–98 %</td><td rowspan="2">Warp</td></tr>
<tr><td>Mineral gyttja
I_{om} 2–10 %</td><td rowspan="2">Lake chalk</td></tr>
<tr><td colspan="3">Mineral soil
A_c 98–100 %</td></tr>
</table>

content of mineral particles) and distinguishes the following soils:

— low ash peats, containing 0–25% ash;
— medium ash peaty soils, containing 25–50% ash;
— high ash muds, containing 50–80% ash;
— organic silts and clays (mineral-organic soils), containing 80–98% ash;
— gyttja and lake marl (organic-calcareous soils, distinguished as a separate group, irrespective of ash content).

Based in the values of some parameters (soil type, degree of peat decomposition, calcium carbonate content, ash content (without calcium carbonate), humidity, angle of internal friction, *etc*.), Borys (1996) subdivided organic soils into:

— warps (ash content (A_c) 80–98%);
— muds (A_c 25–80%);
— muddy peats (A_c 25–80%);
— non-muddy peats (A_c 0–25%) (amorphous, amorphous-fibrous, fibrous);
— gyttja: organic (A_c <65%; $CaCO_3$ 0–20%), carbonate (A_c <60%; $CaCO_3$ 20–90%), mineral (A_c >65%; $CaCO_3$<20%);
— mucks (A_c 20–98%).

The genetic groups and types of peat were not included in this subdivision.

A classification and description of organic soils was presented recently for discussion by the European (CEN) based on two parts of the norms ISO (2001*a*, 2001*b*). According to these proposals, organic soils are macroscopically distinguished on the basis of their dark colour and characteristic smell, and are generally subdivided based on their organic matter content (determined in relation to the mass of the dry soil depleted in grains exceeding 2 mm in diameter). In this classification the following soils are distinguished:

— low-organic soils with an organic matter content of 2–6%;
— medium-organic soils with an organic matter content of 6–20%;
— high-organic soils with an organic matter content exceeding 20%.

The classification should be regarded thus as descriptive. The norms contain, however, also a further classification of organic soils based on their origin and some properties. The following groups are distinguished:

— fibrous peat;
— pseudo-fibrous peat;
— amorphous peat;
— gyttja;
— humic soils.

Fibrous peat is characterised by a fibrous structure, with easily recognisable plant remains, and retains some strength. Pseudo-fibrous peat has an easily recognisable plant structure but a diminution in strength. The plant structure is not visible in amorphous peat, which additionally has a mushy consistency. Gyttja comprises decomposed plant and animal remains and may contain inorganic constituents. Humic soils contain plant remains, living organisms and their excreta, as well as a large content of inorganic constituents; they form the topsoil.

PROPOSED CLASSIFICATION OF ORGANIC SOILS

In the classification of organic soils given here (Table 1) the genetic subdivision of organic soils, including the subdivision of peats into fen peats and bog peats, is the most important. Many investigations by the author (Myślińska, 2001) and also some made abroad (e.g. Hobbs, 1986) into the engineering geological evaluation of peats support this sub-division. It is based on the different chemical, physico-chemical and physical properties (e.g. pH, humic and fulvic acids contents, bitumen content, organic matter content) as well as mechanical properties (e.g. swelling, compressibility) of peats developed in different environments. Distinguishing mucks is also required, as these are formed on peats after their watering. During post-depositional transformations these soils attain different, more favourable properties, both in terms of engineering geology and environment protection. The proposed classification contains also a group of soils of diverse origin, but characterised by a low organic matter content, including flood facies alluvial deposits (muds), which due to organic matter content, diverse lithology and small degree of diagenesis should be treated differently than mineral soils. Gyttja is distinguished along with other organic soils; it represents a separate genetic group with a different lithology in comparison to other soils. The subdivision of gyttja is given following M. Długaszek (Myślińska, 2001) and is based on the organic matter content, which influences most of the physico-mechanical properties. The organic matter content (I_{om}) in gyttja was determined by the Tiurin method and is correlated with results of ignition loss. In the case of other organic soils the organic matter content is represented by its approximate reciprocal, the ash content (A_c), determined by ignition loss methods. This parameter is used in most organic soil classifications.

CONCLUSIONS

The high sensitivity of organic soils to water, which causes their high compressibility, low resistance and high shrinkage, enables one to include them within weak soils. It seems, however, that they are insufficiently dealt with in regional and international norms, as well as in their proposals. In engineering geology, evaluation of organic soils requires the determination of their origin, and then each genetic group should be subdivided on the basis of organic matter content. The relationships between the particular parameters should be then determined within these groups, which will to a large degree simplify the investigations. The proposed classification of organic soils is based in the first place on the origin of soils, and in the second place on the organic matter content. Physical and mechanical parameters important for engineering geology in such cases as foundation structures (embankments, melioration structures) on organic soils and the resistance of these soils to loading, change in relation not only to the organic matter content but also to its character resulting from the conditions of deposition and later post-depositional changes. These properties include the humus fraction content, the degree of its decomposition, the degree of coagulation, *etc*. Therefore, additional genetic subdivisions (bog peats, fen peats, mucks, alluvial soils — muds) given in Table 1 should be introduced into the existing norms or their projects.

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