

Geotechnical study of the requisite information on the workability of rocks and the Pre-Quaternary bedrock

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AGEOS Geotechnická studie potřeby informací o těžitelnosti a předkvartérním podkladu

Abstract: At present, it is vital to take into account certain geological factors when planning the future development within the land-use planning. The case study attempts it concerns only the evaluation of two selected geofactors out of many, namely the workability of rocks and the Pre-Quaternary bedrock. It was implemented in the town quarters of the city of Ostrava making use of overlay analyses in the Geographic Information Systems in three time periods of the current built-up area, the state in 1946 and their inter-period to identify the trend of changes. The study area concerns five map sheets in a scale of 1:10 000. The workability of rocks is important in the projection activities for the reference identification of the amount of the necessary work to do the earthwork. The analysis of rock workability was proved that the dominant rock workability classes are 1 to 4 (97.4% – more suitable rock). The Pre-Quaternary bedrock is important especially in the design of demanding constructions as it is where structures are usually founded or, in other cases, when the Quaternary rocks have unsuitable geotechnical parameters. The Pre-Quaternary cover type analysis showed that the most wide-spread type in the study area is the type of alternation of cohesive and non-cohesive soils (90%), namely with the base depth within 5–10 m (45.8%) and over 10 m (26.1%).

Key words: workability of rocks, pre-Quaternary bedrock, town planning, foundation engineering, GIS, geofactors, Ostrava region

1. INTRODUCTION

The study makes part of a more extensive project dealing with a whole number of geofactors that are evaluated from the point of view of their necessary implementation into the land-use planning process (United Nations, 2001) or the information system for building offices. The paper assesses two selected geofactors of the Pre-Quaternary bedrock and the rock workability in the study area in the city of Ostrava with the demarcation in five map sheets in a scale of 1:10 000 in the town quarters of „Slezská Ostrava, Moravská Ostrava, Přívoz, Mariánské Hory, Nová Ves, Vítkovice, Heřmanice, Muglinov, Koblov, Hrušov, Antošovice, Vrbice nad Odrou, Ludgeřovice, Pudlov, Petřkovice and Lhotka“. As for geomorphology, the study area makes part of the complex of the Ostrava Basin and its surroundings; as for the districts these are Ostravská, Oderská Flood Plain, Orlovská Plateau, Novobělská, Antošovická plain, Děhylovská, Vřesinská Hilly lands.

From point of view of geology (Macoun et al., 1965; Macoun, 1989; Matula & Pašek, 1986; Sloboda, 1990; Dopita et al., 1997; Chlupáč et al., 2002), there is a contact of two geological units in the deeper, older positions of the Bohemian Massif in the so-called Upper-Silesian Basin of the Moravia-Silesian Region (“Moravosilezika”) and later Carpathian Fore-deep of the Western Carpathians. From the point of the Quaternary, there is a wide range of various genetic types, such as fluvial, glacial, glacialustrine and eolic ones, combined with a whole

number of anthropogenic sediments reflecting a long mining and industrial history of perhaps the most important industrial city of the Czech Republic. Methodically, the study is predominantly grounded in the utilization of tools of the Geographic Information Systems, especially the overlay analyses that were predate the registration of map sources and aerial photos by means of the methods of absolute and relative positions, followed by needed vectorization. The study was parallelly complemented by field research and archive study in order to find out the problem sites as for the identification of the real state of the observed parameters.

2. STUDY OF WORKABILITY OF ROCKS AND PRE-QUATERNARY BEDROCK

The workability of rocks is the first observed geofactor and makes an inseparable part of the determination of the suitable method, intensity of labour, financial costs and time demands for the implementation of the earthwork. Earthwork is an important stage in the construction of engineering structures and represents shifting of rock materials during activities connected with construction. It includes excavation of the foundation pits and other spaces (e.g., modification of the beds, banks and reservoirs), work in the building of earth constructions (embankments for roads, earth and rock dams), modification of surface areas of particular earth constructions (slope work, alternation

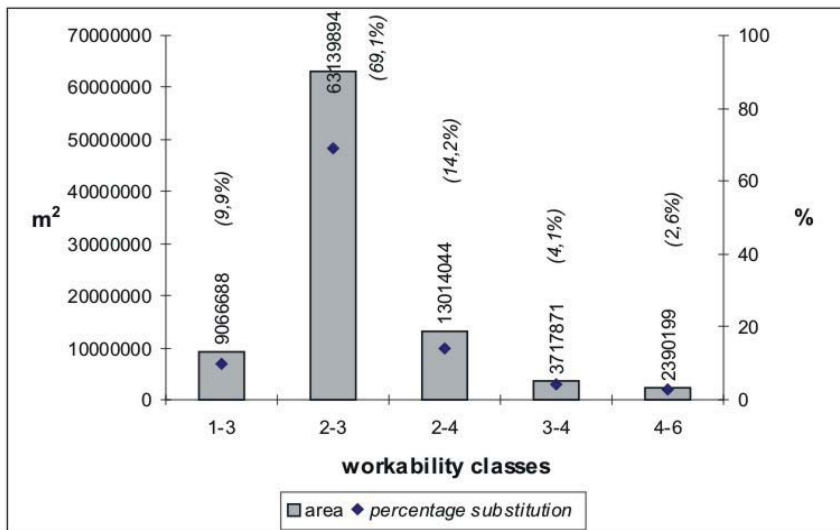


Fig. 1. Areal and percentage representation of the workability classes within the whole study area.

Obr. 1. Plošné a procentuální zastoupení tříd těžitelnosti v rámci celkového modelového území.

of the excavation bottoms, compaction), work connected with the handling of rock material, its loading, discharge, reloading and last but not least, land reclamation.

The workability of rocks does not only characterize the single property of the breaking characteristic of rocks (thus it is not determined by a laboratory or field test), but it comprises everything that is connected with loosening, loading and transport of soil. The rate of the rock workability is expressed by means of seven classes of workability (according to ČSN 73 3050), which reflect the amount of work necessary for the most functional methods of extraction of the rock in question, i.e. for its loosening, loading onto a vehicle and transport of the dug earth to the edge of the foundation pit or possibly another building site.

In the study area there are engineering-geological zones for which are characteristic workability classes within a certain range (e.g., 1 to 3 or 2 to 4), and thus an analysis cannot be determined strictly for each separate unit. Such an analysis has its own significance as it distinguishes areas with better or worse workability of rocks.

The rocks of the rock workability class 2–3 take up (Figs. 1, 2) a substantial part (69.1%) within the overall study area. The most wide-spread landscape element in this workability class is the built-up area (40.6%), followed by fields and meadows (32%), and forests (21.8%). A significant proportion of the area (14.2%) is occupied with rocks of the rock workability class 2–4. The dominant landscape element of this class is also the built-up area (37.3%), followed by forests (24.7%), fields and meadows (22.1%) and anthropogenic features (15.2%). The rock workability class 1–3 covers an area of 9.9% of the study area while it is the built-up area that prevails (66.2%), followed by fields and meadows (16.4%) and anthropogenic features (12.6%). In the rock workability class 3–4 (4.1%) the dominant are fields and meadows (37.5%) and water areas (27.1%). The rock workability of those landscape elements, except for the built-up area, was studied due to future expansion of the development into those territories.

The workability class 1 is formed by fine soils of soft consistency (e.g., top soil, loam, sandy loam, sandy and gravel soils),

which is closely connected with getting characteristic method as soils of this class can be shovelled or loaded by a loader. The workability class 2 is characteristic for fine soils of firm consistency (e.g., top soil, loam, silty loam, sandy loam, peat, etc.). The soils of this class are workable by a spade or a loader. Fine soil of stiff and hard consistency, soft and firm (loam, loess, clay loam, sandy loam, sandy clay, clay) are characteristic for workability class 3. The rocks are defined as diggable, workable by a spade or an excavator. Solid rocks of workability class 4 are partially mouldered to mouldered. The soils are again of fine, stiff and hard consistency (clay, sandy clay, clay loam, sandy loam). The rocks of this class are workable by a wedge or an excavator.

The rocks of the workability class 4–6 are very scarce (2.6% of the area) in the study area, but they must be localized due to their more difficult breaking characteristic of rocks. In this class there are dominant forests (47.4%), followed by fields and meadows (40.3%), and the built-up area takes up mere 11.9% of the area.

Description according to the valid ČSN 73 3050 Standard is rather out-of-date as currently there are machines which are able to extract rocks of workability classes 1–4 directly without prior loosening. Solid rocks of classes 5 to 7 still must be loosened before own excavation by digging, breaking or blasting, while rocks of classes 5 to 6 can be loosened and excavated by current high-performance heavy excavators due to their digging power. Apart from controlled blasting, rocks of workability classes 5–7 can be loosened also by hydraulic wrecking hammers.

The evaluation of the rock workability in the currently built-up area showed (Figs. 2, 3) that the most built over rock workability class are the classes 2–3, on which 68.9% of the built-up area is situated. This is caused not only by its dominant position within the overall study area, but also due to its suitable characteristics for excavation work. On the rock workability classes 1–3 there is only 16.1% of the built-up area, and on the classes 2–4 there is mere 13% of the built-up area. The rock workability classes 4–6 are covered by 0.8% of the built-up area.

The study of the rock workability on the newly built-up area (1946–present) again confirmed the results of the previous

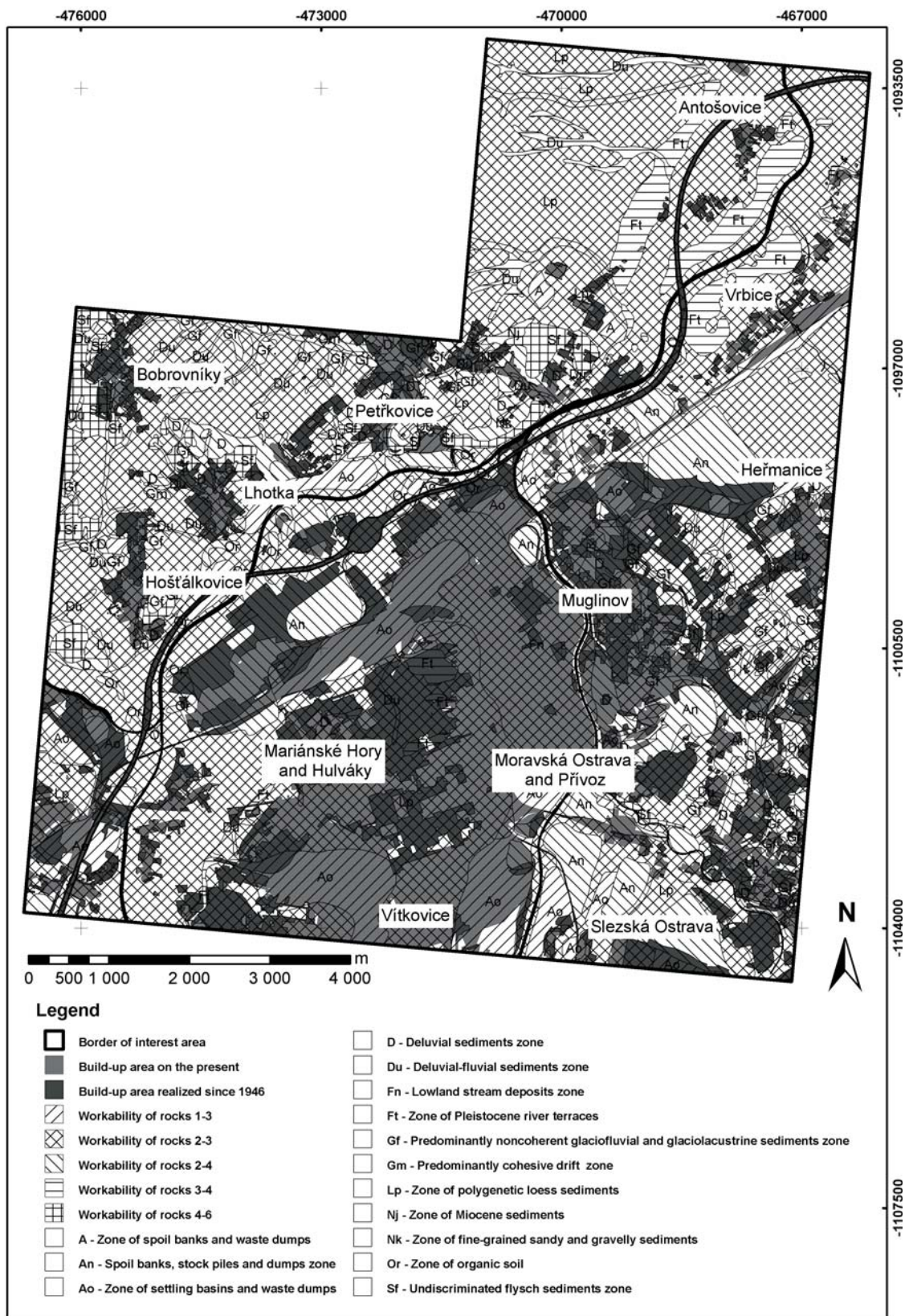


Fig. 2. Workability classes on the built-up area.

Obr. 2. Třídy těžitelnosti na zastavěné ploše.

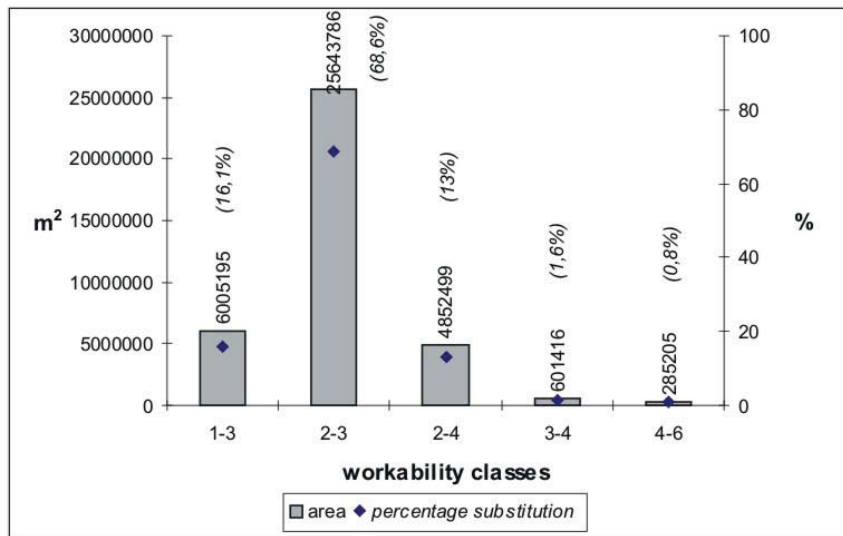


Fig. 3. Areal and percentage representation of the workability classes within the current built-up area.

Obr. 3. Plošné a procentuální zastoupení tříd těžitelnosti v rámci současně zastavěného území.

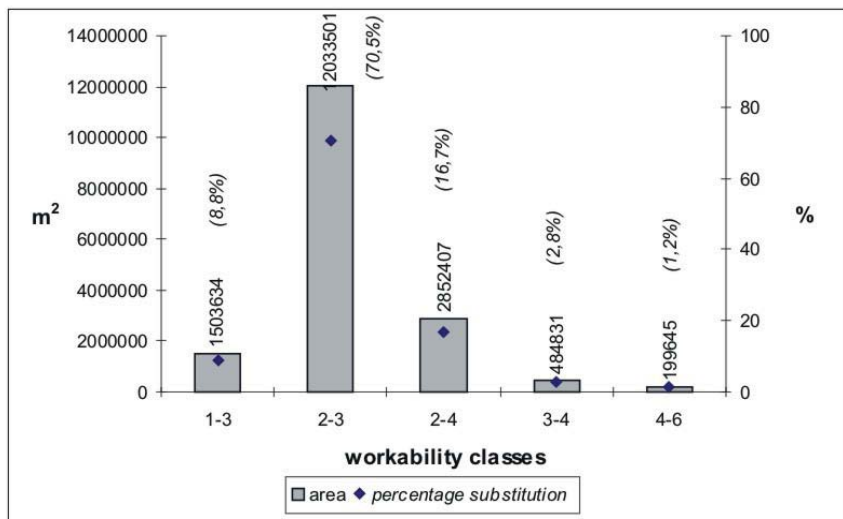


Fig. 4. Areal and percentage representation of the workability classes within the newly built-up area (1946–present).

Obr. 4. Plošné a procentuální zastoupení tříd těžitelnosti v rámci novo zastavěného území (1946–současnost).

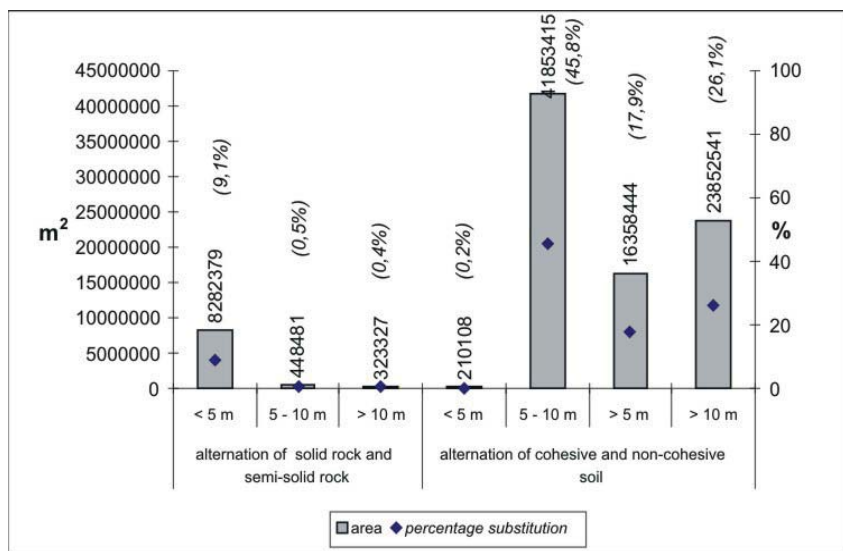


Fig. 5. Areal and percentage representation of the types of pre-Quaternary bedrock rock within the whole study area.

Obr. 5. Plošné a procentuální zastoupení typu hornin předkvartérního podkladu v rámci celkového modelového území.

analyses (Figs. 2, 4) that the built-up area is situated mainly on the rocks with the rock workability classes 2–3 (70.5%); 78.2% of the area is located near the newly constructed motorway D47. The following rocks are of the rock workability classes 2–4 (16.7%), where 9.1% of the motorway area is located, followed by the rocks of the workability class 1–3 (8.8%). On the rocks of the rock workability class 4–6 there is only 1.2% of the newly built-up area, while the smallest section of the D47 is found there (3.3% of the motorway area).

From the point of view of geological conditions, different stratigraphic positions are generally distinguished. However, for the needs of foundation engineering it is necessary to distinguish the Pre-Quaternary bedrock and Quaternary cover in particular, namely with respect to the possible depth of the engineering structure foundations. As a rule, the more demanding construction, the bigger pressure and higher probability of foundation into the Pre-Quaternary bedrock, all with regard to the geotechnical characteristics of the Quaternary. Regarding the less suitable characteristics of the Quaternary in the sense of load-bearing capacity and settlement, it is more necessary to found structures into the Pre-Quaternary bedrock, naturally with respect to the selected or available technology of foundation. The above mentioned facts predispose to the vital identification of the Pre-Quaternary bedrock.

The largest type within the overall study area (Figs. 5, 6) is the type of alternation of cohesive and non-cohesive soils with the Pre-Quaternary bedrock depth of 5–10 m (45.8% of the area), followed by an identical type with the depth over 10 m (26.1%). An identical type with the base depth over 5 m covers 17.9% of the area and with the depth below 5 m covers only 0.2% of the area. A relatively big area is made up by the type of alternation of solid rock and semi-rock with the base depth below 5 m (9.1%), with the depth of 5–10 m only 0.5% of the study area. From the point of view of the methodology of depth determination, there are three categories of depths (below 5 m, 5 to 10 m, over 10 m) and their combinations as above the mentioned combination of the second and third categories, the result of which is depth over 5 m. This classification is conditioned by various alternations of pre-Quaternary bedrock depths affected by geological structure, quantity and character of surveys which were the ground for their identification (with certain test holes there was no need for the foundation engineering to go as deep as the pre-Quaternary bedrock).

It was identified that *on the current built-up area* (Figs. 6, 7) the majority of the built-up area is on the type of alternation of cohesive and non-cohesive soils with the Pre-Quaternary bedrock depth of 5–10 m (52.5% of the built-up area), followed by an identical type with the depth over 5 m (22.6%). On the type of the alternation of solid rock and semi-rock there is almost 5% of the built-up area. The most built over type is the type with the base depth below 5 m (3.6%).

The analysis of the newly built-up area (1946–present) showed an identical trend as in the previous analysis (Figs. 6, 8). The most built over type since 1946 has been the type of alternation of cohesive and non-cohesive soils with the base depth of 5–10 m (44.2%), an identical type with the base depth over 5 m covers 26.9% of the newly built-up area and with the depth over

10 m it covers 22.5% of the newly built-up area. The type of alternation of solid rock and semisolid with the base depth below 5 m covers 4.8% of the new development.

3. CONCLUSION

The matter-of-fact determination of the classes of rock workability implies the processing of cost calculation (costs of earthwork), time plan of the implementation and optimal choice of the method of working and in relation to the need of certain mechanisms for earthwork. The amount of work connected with the rock workability depends on the breaking characteristic of rocks (resistance of the rock at loosening), the character and extent of bulking of rocks after loosening (the loosened soil increases its volume in contrast to its natural placement) and the intensity of labour during loosening and shifting the rock materials. The intensity depends for example on the climatic conditions in relation to the adhesive power of the soil, frozen soils of the classes 1 to 4 are placed into the class 5, and the character of rocks (e.g., there is a problem with hard cement in the conglomerates as for the efficiency of blasting, etc.). The correct classification of rocks according to their workability permits the processing of a technological procedure of the earthwork, blasting project, and schedule of smooth implementation of the earthwork. Apart from the rock workability classes, it also depends on the extent of work, executing of work on land or in the water, character of excavation work in the sense of necessary sheeting of the pits, width of the furrow, etc.

The analysis of rock workability was carried out on the basis of the rock workability class ranges (e.g., the rock workability class 1–3, etc.). It has proved that the dominant rock workability class, not only within the overall study area but in the current built-up area (also in the newly built-up area, i.e. built over since 1946), are the rock workability classes 2–3. With a prominent gap, in all the types of the studied territory (overall study area, current built-up area and newly built-up area) there are rock workability classes 1–3 and 2–4. This means that overall more suitable rock workability classes 1 to 4 prevail (97.4%). In the study area the rock workability classes 4–6 are found on a limited area, but due to financial demands and intensity of labour (e.g. during excavation work) their localization is important (similarly to the zones). For this purpose, well-arranged maps of rock workability were prepared (with the overlay of the built-up area and the newly built-up area).

From the point of view of foundation engineering and landscape planning the character of the pre-Quaternary bedrock must be identified as buildings will be founded in it (e.g., piles, underground garages, underground collectors, etc.). The rocks of the Quaternary mostly have the character of soils, while the solid rocks are rare (e.g., travertines). It is different with the rocks of the Pre-Quaternary bedrock as both the alternatives are possible. Very often, developers or sometimes others experts who are involved in foundation engineering, automatically assume that the Pre-Quaternary bedrock is the rock substratum, which is of course true only in some areas with regard to the regional geological structure. In general, in case of the Pre-

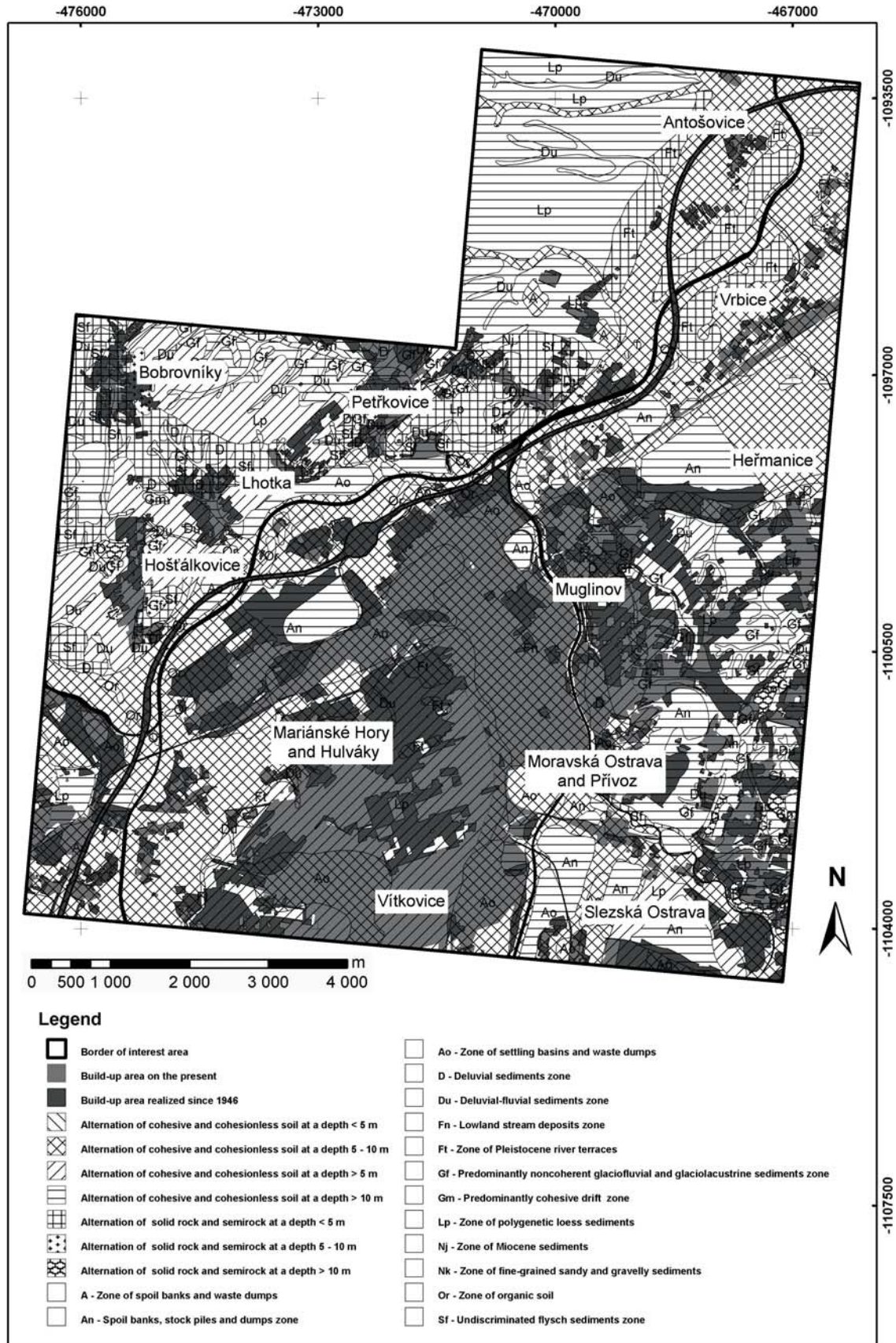


Fig. 6. Type of pre-Quaternary bedrock on the built-up area.

Obr. 6. Typ předkvartérního podkladu na zastavěné ploše.

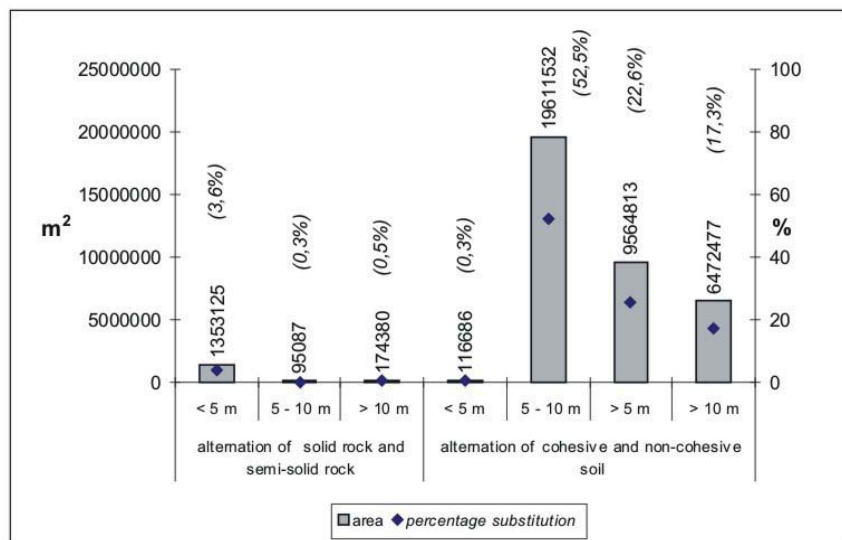


Fig. 7. Areal and percentage representation of the types of pre-Quaternary bedrock rock and soils within the current built-up area.

Obr. 7. Plošné a procentuální zastoupení typu hornin a zemin předkvartérního podkladu v rámci současně zastavěného území.

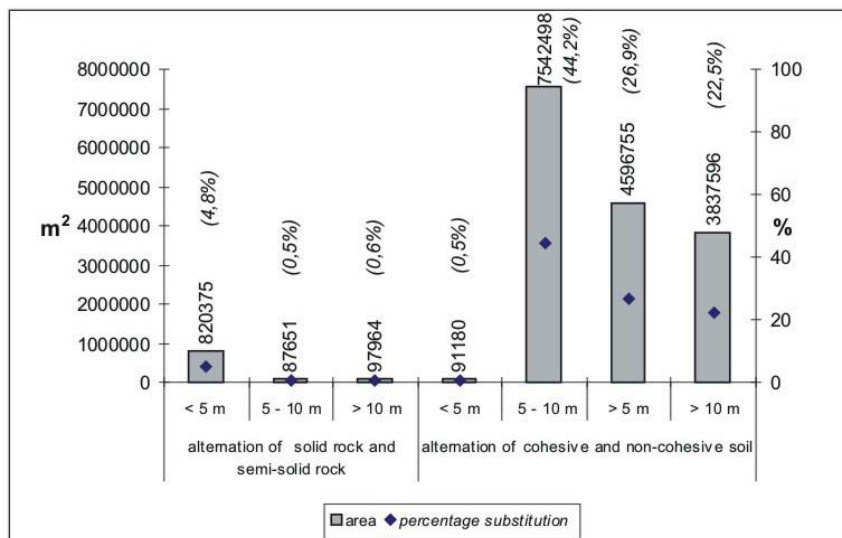


Fig. 8. Areal and percentage representation of the types of pre-Quaternary bedrock rock and soils within the newly built-up area (1946–present).

Obr. 8. Plošné a procentuální zastoupení typu hornin a zemin předkvartérního podkladu v rámci novo zastavěného území (1946–současnost).

Quaternary bedrock soil character there is a higher precondition of a stronger stage of diagenetic stabilization with regard to their age and their depth of placement and other factors compared with the Quaternary soils. However, we must not forget that the load-bearing capacity of the submerged piles is not given only by their load-bearing capacity in the toe, but the skin friction, making also an integral part, significantly participates in the total load-bearing capacity of the foundation by means of piles or pile walls. Mentioned facts generate the necessity of learning about the character of the Pre-Quaternary bedrock.

In the study area there are two types of the Pre-Quaternary cover, cohesive and non-cohesive soils and rocks and semisolid rocks. The types are further divided according to the depth of the Pre-Quaternary bedrock. The Pre-Quaternary cover type analysis showed that the most wide-spread type in the study area is the type of alternation of cohesive and non-cohesive soils (90%), namely with the base depth within 5–10 m (45.8%) and over 10 m (26.1%). During the monitored period since 1946 to date we observed (GIS comparison of state 1946 and

present of building areas by aerial photographs) an identical trend of building development (the type of alternation of cohesive and non-cohesive soils dominated with the depth over 10 m in the total built-up area as well as in the newly built-up area since 1946).

Acknowledgment: The publication was supported by the grant project GAČR-205/07/1313.

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Resumé: V současné době existuje potřeba zohledňovat určité geologické faktory při plánování budoucí zástavby v rámci územního plánování. Předložená případová studie součásti těchto snah a týká se pouze hodnocení dvou vybraných geofaktorů z mnoha, a to těžitelnosti a předkvartérního podkladu. Byla realizovaná v části města Ostrava, která má výrazné antropogenní ovlivnění především pomocí překryvných analýz v geografických informačních systémech ve třech časových řezech současné zástavby, situace v roce 1946 a v jejich meziobdobí pro zjištění trendu změn. Zájmové území se týká pěti mapových listů v měřítku 1:10 000.

Těžitelnost je důležitá při projekčních činnostech pro orientační zjištění množství potřebné práce pro realizaci zemních prací. Analýza těžitelnosti byla prováděna na základě rozmezí tříd těžitelnosti (např. třída těžitelnosti 1–3, atd.). Ukázala, že dominantou třídou těžitelnosti, nejen v rámci celého zájmového území, ale také na zastavěné ploše v současnosti (i na novo zastavěné ploše, tzn. zastavěné od roku 1946), je třída těžitelnosti 2–3. S velikým odstupem se na všech typech zkoumaného území (celkové modelové území, zastavěná plocha v současnosti a novo zastavěná plocha) objevují třídy těžitelnosti 1–3 a 2–4. To znamená, že celkově převládají vhodnější třídy těžitelnosti 1 až 4 (97,4%). Třída těžitelnosti 4–6 se na modelovém území nachází na omezené ploše, ale z důvodu finanční a pracovní náročnosti (např. při výkopových pracích) je důležitá jejich lokalizace. Pro tento účel byly zhotoveny přehledné mapy těžitelnosti (s překryvem se zástavbou, i s novo zastavěným územím).

Předkvartérní podklad je důležitý zejména při projektování náročných staveb, protože do něj většinou zakládáme nebo i v ostatních případech mají li kvartérní horniny nevhodné geotechnické parametry. Na modelovém území se nachází dva základní typy předkvartérního pokryvu, soudržné a nesoudržné zeminy a skalní a poloskalní horniny. Tyto typy byly dále rozčleněny dle hloubky předkvartérního podkladu. Analýza dle typu předkvartérního pokryvu ukázala, že nejrozsáhlejším typem na modelovém území je typ střídání soudržných a nesoudržných zemin (90%), a to zejména s hloubkami podkladu v rozmezí 5–10 m (45,8%) a větší 10 m (26,1%). V sledovaném období od roku 1946 do současnosti byl sledován stejný trend zastavěnosti (dominoval typ střídání soudržných a nesoudržných zemin s hloubkou větší 10 m na celkovém zastavěném území i na zastavěném území od roku 1946).