Analysis of workability of rocks and type of prequarternary bedrock in the selected part of the Ostrava conurbation by means of geographic information systems

Marian Marschalko*[1], *Hynek Lahuta*[2] and *Peter Juriš

Analýza těžitelnosti hornin a typu předkvartérního podkladu ve vybrané oblasti Ostravské aglomerace pomocí geografických informačních systémů

An up-to-date topic with which engineering geology can contribute to the requirements of practice and research, in particular the needs of land use planning, state administration, building offices, developers, etc. is an analysis of new possibilities of providing reference information on the engineering-geological conditions by means of geographic information systems. The study in the presented paper deals with an evaluation of two geofactors. They are the character of rocks workability and Pre-quaternary bedrock. Workability is a significant limiting factor, which affects the used technology and financial demands of earth work. Especially in case of demanding constructions, the Pre-quaternary bedrock is a geological environment which will have to be interacted with and must be taken into account during selecting engineering foundation. The overall project was divided into five model areas (1-5), while this paper evaluates a partial model area of no. 1, which is defined by topographical map in drawing scale 1:10 1000 (topographic sheet No. 15-43-10). Namely they are Slezské, Moravské Ostravy, Vítkovic a Radvanice. The mentioned methodology was applied in the interest area for the first time.

Key words: *engineering geology, town planning, foundation engineering, GIS*

Introduction

The basic precondition for land planning [1, 3, 5, 13] or building the foundations of construction works in a certain area is the integrated knowledge of engineering-geological conditions that are a decisive factor of high-quality and effective building the foundations of potential construction works. The main reason for the study l is the insufficient use of engineering-geological data for land planning and designing activity by competent authorities.

The overall project deals with an analysis of engineering-geological zones, workability of rocks, type of preQuarternary bedrock, floodlands, subsidence caused by undermining, slope movements and radon hazard, while the presented paper rates only two of those geofactors - workability of rocks and type of preQuarternary bedrock. The applied method makes use of the possibilities of Geographical Information Systems, terrain research, documentation and study of archives.

The research is localized (Fig. 1) in the selected area of the city of Ostrava, which has been affected by former mining of black coal [1-17]. In terms of foundation engineering it has various conditions, and thus it is suitable for the above-mentioned research. The overall project was divided into five model areas (1-5), while this paper evaluates a partial model area of no. 1, which is defined by topographical map in drawing scale 1:10 1000 (topographic sheet No. 15-43-10). Namely they are Slezské, Moravské Ostravy, Vítkovic a Radvanice.

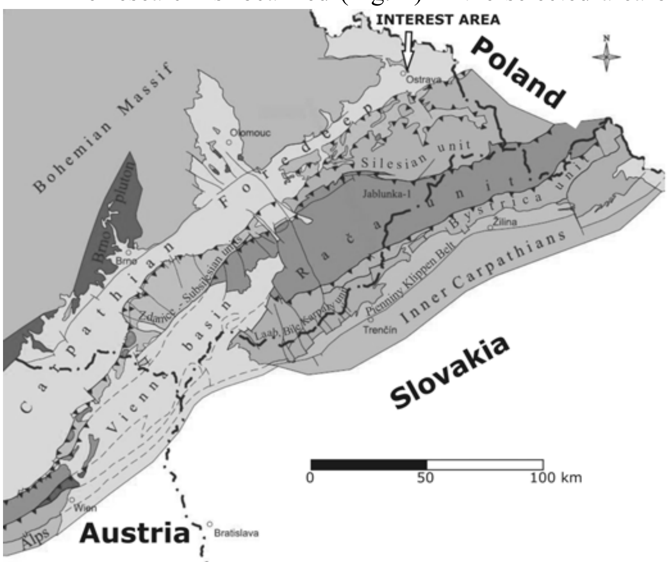

Fig. 1. Schematical geological map with position of interest area.

[1] *doc. Ing. Marian Marschalko, Ph.D.*, Institute of geological engineering, VSB-Technical University Ostrava, tř. 17. listopadu, 708 33 Ostrava-Poruba, Tel: +420/596993505, marian.marschalko@vsb.cz
[2] *doc. Dr. Ing. Hynek Lahuta, Ing. Peter Juriš*, VSB-Technical University Ostrava, tř. 17. listopadu, 708 33 Ostrava-Poruba
(Recenzovaná a revidovaná verzia dodaná 21. 2. 2008)

The geological structure of the interest locality can be characterized by the Brunovistulicum basement, which is overlapped with Devonian and Carbonian sediments. In the Upper-Silesian Basin, the Upper-Carbonian deposits are stratigraphically divided into Ostrava (paralic coal molase) and overlying Karviná strata series (continental coal molase) (Fig. 2). The roof is formed by thick Badenian deposits, the sedimentation of which caused the formation of the Carpathian Foredeep in the foreland of the Outer Flysch Carpathians.

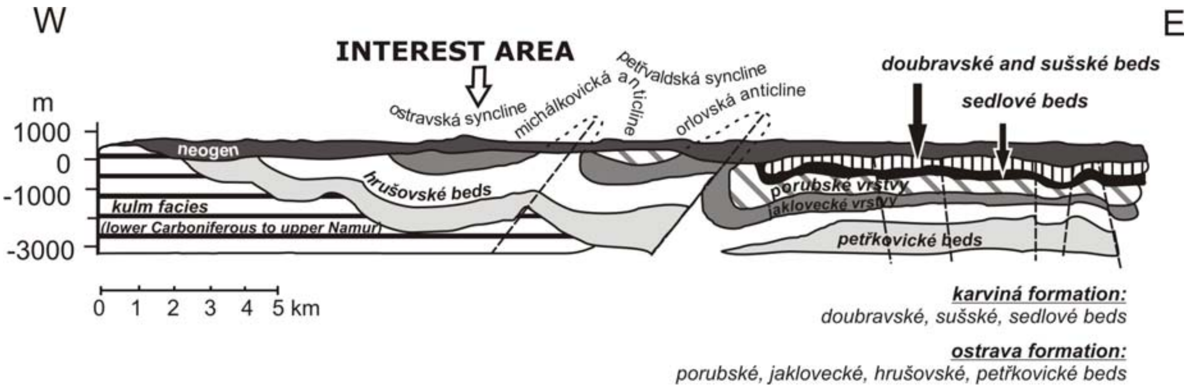

Fig. 2. Schematic geological map with position of interest area.

Quaternary sediments (Fig. 3) 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 [4].

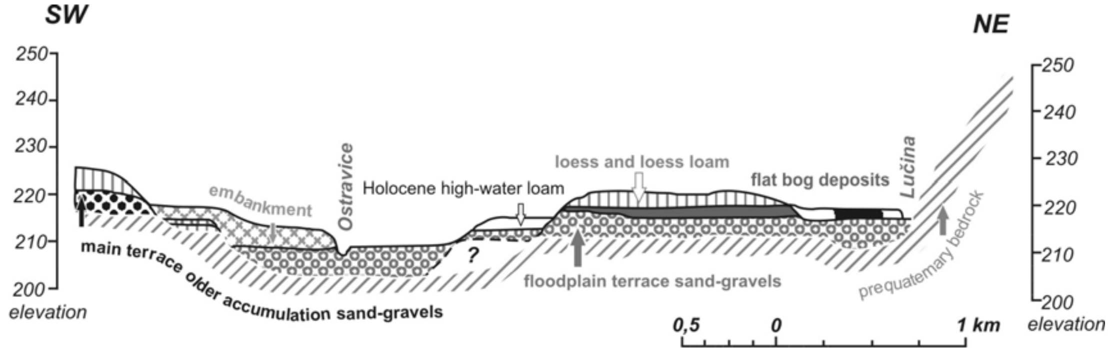

Fig. 3. Schematic Quaternary geological cross-section of part interest area (accordance with Macoun).

Based on the engineering-geological zoning map the interest zone is characteristic for the zone of polygenetic loess sediments (Lp); zone of alluviums lowland streams (Fn); spoil banks, stock piles and dumps zone (An); zone of settling basins and waste dumps (Ao); deluvial sediments zone (D); predominantly cohensionless glaciofluvial and glacial sediments zone (Gf); deluvial-fluvial sediments zone (Du); zone of Pleistocene river terraces (Ft); undiscriminated flysch sediments zone (Sf) and predominantly cohesive drift zone (Gm).

Methods applied

For proper processing in geographic information systems, the following methods were used:

Geometrical transformations

Geometric transformations (sometimes numerical transformations contrary to analytical) provide articulation of system of coordinates to maps, layers or they permit co-ordination of layer position towards one reference layer. This procedure is labelled registration or "geo-referencing" or "warping". Data layers in one area were integrated (related to one system of coordinates) so that it was possible to work with them.

In the first stage, points with a known position were selected (map points, check points, identical points) and second, transformation of a layer took place. For raster transformation we used affinor and polynomial transformation.

a) Registration by relative position

Registration by relative position was used for the attachment of chosen aerial photographs. In the course of this procedure, one data layer designated as secondary (slave) was registered with the reference layer (master).

The first step was the selection of elements (small objects, points, intersection of lines) represented in both layers. These elements were control points in both the layers (always 1 point in the reference layer and the relevant point in the secondary layer). The higher the number of reference points and the more regular distribution of them over the whole area of the layer, the better is the result of transformation. On the basis of the control points, a transform function was calculated used then for the proper transformation of the entire secondary layer. As a result of this registration, positional errors are transferred from the reference layer to the secondary layers. This operation is also called rubber sheeting.

b) Registration by absolute position

Registration by means of absolute position was used in attaching corresponding topographic maps and maps of engineering-geological zoning. In the course of this procedure, each layer is attached separately to the chosen coordinate system. The advantage of this procedure is the fact that the positional error from the reference layer is not transferred to other layers. Moreover, the accuracy of each layer may be evaluated independently. On the other hand, the disadvantage is that small positional errors in particular layers were independent, and thus objects boundaries when overlapping each other may not be accurate. These discrepancies may be removed by the procedure – conflation.

After the stage of registering these map bases, a stage of so-called "intelligent digitising" the built-up area and other territorial elements in these bases was follow. Simultaneously, the study of archive materials and engineering-geological exploration in the field was carried out.

After that phase, the analysis and assessment of engineering-geological conditions of model research area was done on the basis of results and experience of this grant project by means of geographic information systems especially for the needs of land planning and designing activity in the field of foundation engineering.

Evaluation of workability of rocks and pre-Quaternary bedrock

Identification and determination of ***workability of rocks*** is one of the most important tasks of engineering-geological survey for different construction types (road works, building foundations, tunnels, underground services, sewage systems, etc.). The extent of this property primarily depends on the type of construction, geological and geomorphological conditions of the interest locality. Apart others, the determination of workability class is important for the preparation of technological method of earthwork, time plan and financial budget for the implementation of a construction project. The workability of rocks depends on the resistance which the rock puts up to loosening, and other circumstances such as tackiness of the rocks on the working tools, bulking of rocks and resistance of rocks during their loading and tipping. The workability rate is the quantity of work needed for the performance of the above stated activities. However, the workability of rocks cannot be determined due to the absence of testing procedure. Evaluation of rocks in terms of getting characteristic and workability makes part of engineering-geological survey and is based on the classification set by ČSN 73 3050 Standard – Earthwork [11], according to which rocks are classified into 7 classes based on the difficulty of their getting characteristic and sampling. As agreed, those classes are called workability classes.

In the interest 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.

Within the *whole interest area* (Fig. 4, 7) the most widespread class is the workability class 2-3, which is on 64.9 % of the total area. The foundation soils of this class are mostly covered by built-up area (69.7 %), followed by fields and meadows (12.5 %) and forests (11.6 %). The second most widespread workability class is class 2-4, on which forests dominate (33.1 %), followed by built-up area (30.3 %) and anthropogenic shapes (21.6 %). Within the whole interest area, rocks of workability class 1-3 take up 13.1 %, out of which a half is built up (53.3 %), next are anthropogenic shapes (29.6 %), fields and meadows (9.3 %) and forests (7.9 %). Rocks of workability class 3-4 take up a minute area in the interest area (1 %), while the most common landscape element of this class is built-up area (92. 7 %). Apart from built-up area, the workability of rocks was studied for landscape elements due to the future extension of development into those localities.

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 workability class 4-6 are fractional in the interest area (0.4 %), but their localization is necessary due to more difficult getting characteristic of the rocks. They are found in the zone of undiscriminated flysch sediments and in the zone of Pleistocene river terraces. This workability class is dominated by forests (80.9 %) and built-up area takes up only 12.2% 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.

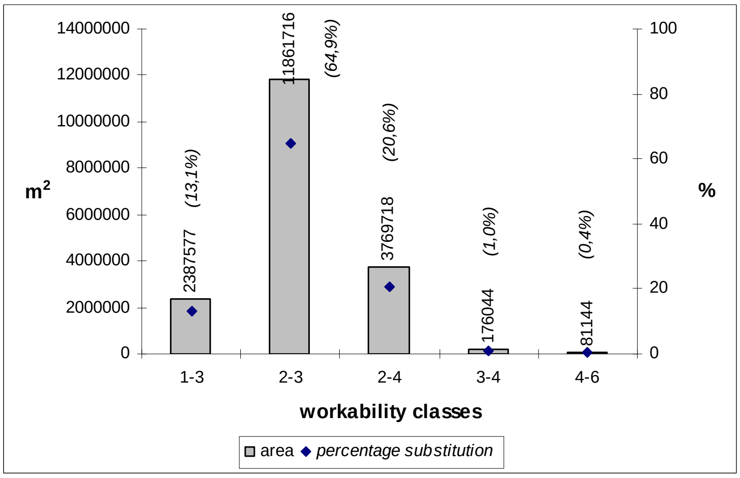

Fig. 4. Areal and percentage representation of the workability classes within the whole interest area.

The analysis of workability of rocks on the current built-up area showed (Fig. 5), that the current built-up area is mostly situated on the rocks of workability class 2-3, which is not only caused by the dominant representation of this class in the whole interest area but also by advantageous properties for general site excavation. Next are rocks with workability class 1-3 (11.7 %) and workability class 2-4 (10.5 %). The built-up area slightly covers also workability class 4-6 (0.1 %), on which the Ostrava Castle is situated.

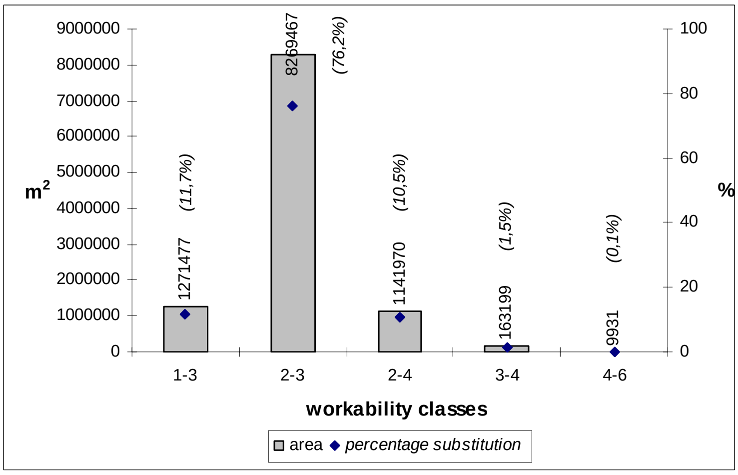

Fig. 5. Areal and percentage representation of the workability classes within the current built-up area.

The analysis of workability of rocks on the newly built-up area (1946 – present) again confirmed the previous results (Fig. 6, 7); the built-up area is also predominantly found on the rocks of workability class 2-3 (75.7 %), followed by rocks of workability class 2-4 (11.5 %) and workability class 1-3 (8.6 %). Even there the workability class 4-6 takes up only 0.1 % of the researched area.

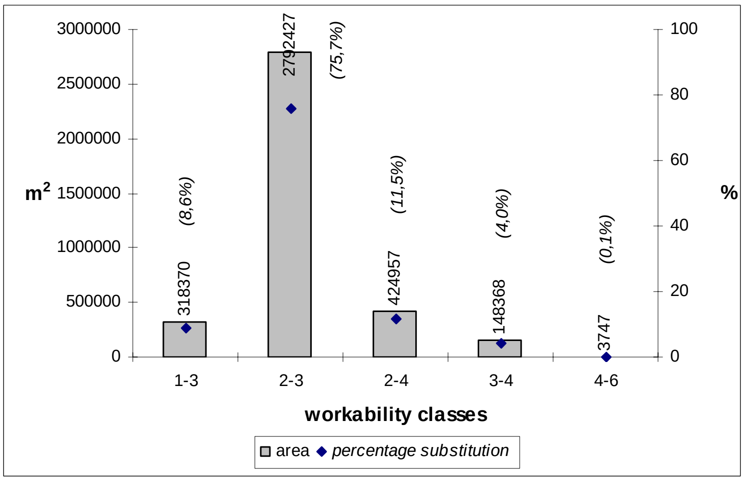

Fig. 6. Areal and percentage representation of the workability classes within the newly built-up area (1946 – present).

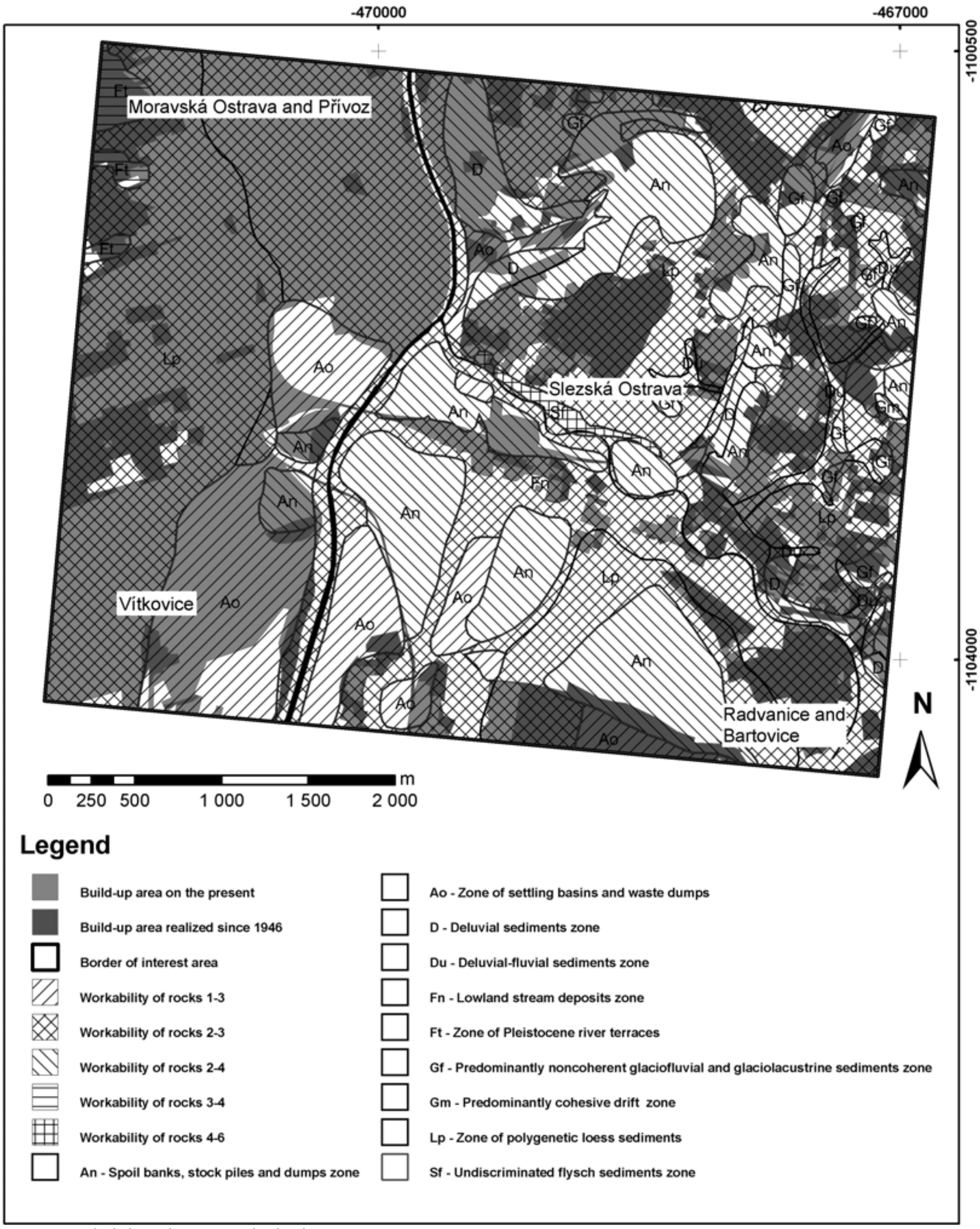

Fig. 7. Workability classes on the built-up area.

Another analyzed characteristic is the type of ***rocks of pre-Quaternary bedrock and their depth***. This characteristic is very important for foundation engineering. With a lot of constructions it is necessary to found them down to the level of pre-Quaternary bedrock, especially in cases of more demanding structures when the load must be transferred into the bedrock or in cases when the thickness of Quaternary cover is small and in terms of foundation the depth is insufficient. Another reason is the fact when Quaternary layers are not sufficiently bearing for the construction load transfer. An appreciable reason is an increasing need in founding more demanding structures, underground constructions (e.g. collectors, garages) in bigger depths and thus the depth and character of the pre-Quaternary bedrock must be identified. This necessity is most vital in the city centres, in particular.

The largest type within the whole interest area (Fig. 8, 11) is the type of alternation of cohesive and cohesionless soil at the depth of 5-10 m (40.5 %), followed by the identical type at the depth over 10 m (36.5 %) and the depth over 5 m (21.1 %). In the interest area solid rock and semirock are found on a very small area, alternation of solid rock and semirock at the bedrock depth over 10 m takes up only 1.4 % out of the total area, followed by an identical type with the bedrock depth below 5 m (0.4 %) and the bedrock depth 5-10 m (0.1 %). This type lies in the zone of undiscriminated flysch sediments and the zone of deluvial sediments and partly the zone of settling basins and waste dumps. 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).

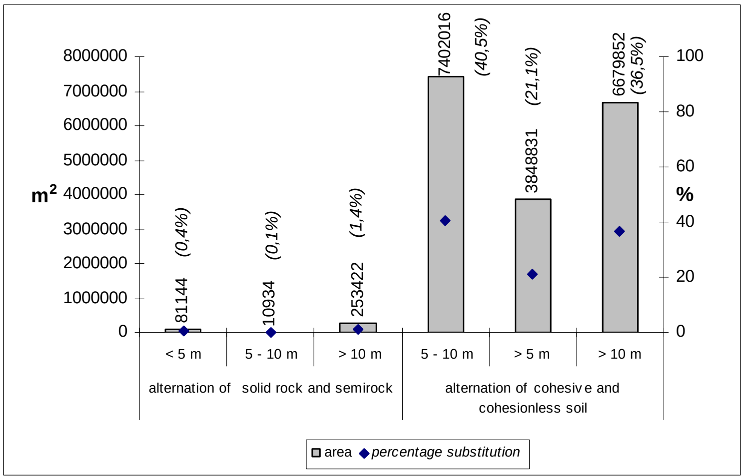

Fig. 8. Areal and percentage representation of the types of pre-Quaternary bedrock rock within the whole interest area.

The analysis on the current built-up area showed (Fig. 9) that the most built-up area is located on the type of alternation of cohesive and cohesionless soil at the bedrock depth of 5-10 m (44 % of the built-up area), followed by an identical type at the depth over 5 m (28.4 %) and the depth over 10 m (25.9 %). On the type of alternation of solid rock and semirock there is minimum built-up area and with this type the most built up is the type with the bedrock depth over 10 m (1.4 %)

The analysis on the newly built-up area (1946 –present) showed the fact (Fig. 10, 11) that since 1946 buildings have been mostly founded on the type of alternation of cohesive and cohesionless soil at the bedrock depth over 10 m (42 %), which exceeded the same type with the depth 5-10 (29.6 %), which is dominant within the whole interest area as well as within the current built-up area. The same type follows with the bedrock depth over 5 m (25.5 %). Solid rock and semirock have been little built upon during the monitored period; mostly on the type with the depth over 10 m (2.5 %).

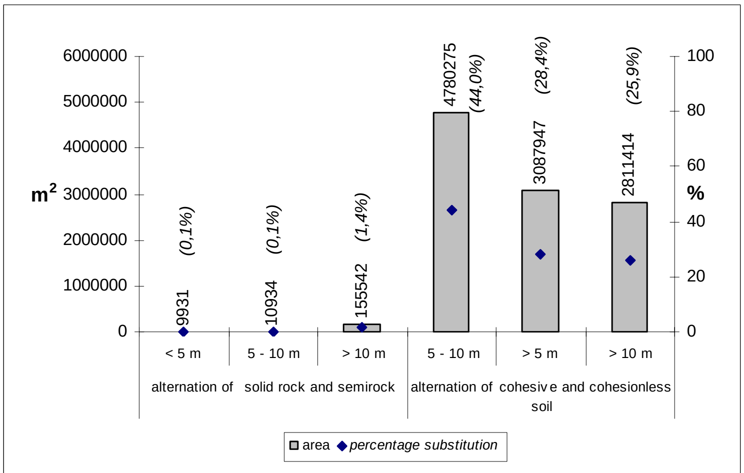

Fig. 9. Areal and percentage representation of the types of pre-Quaternary bedrock rock and soils within the current built-up area.

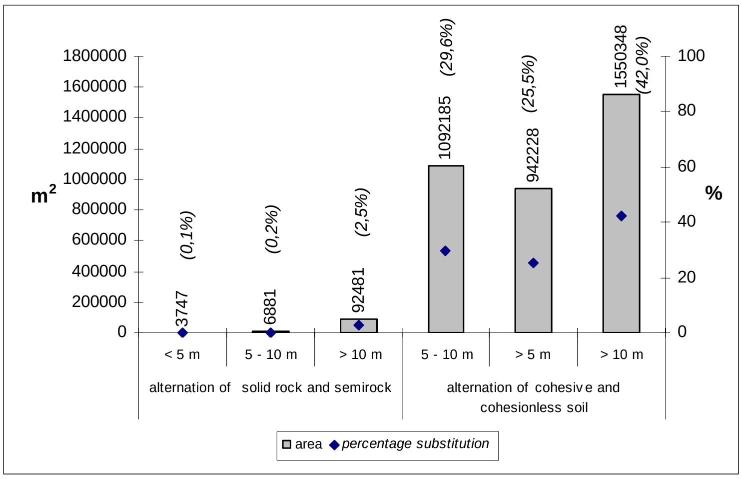

Fig. 10. Areal and percentage representation of the types of pre-Quaternary bedrock rock and soils within the newly built-up area (1946 – present).

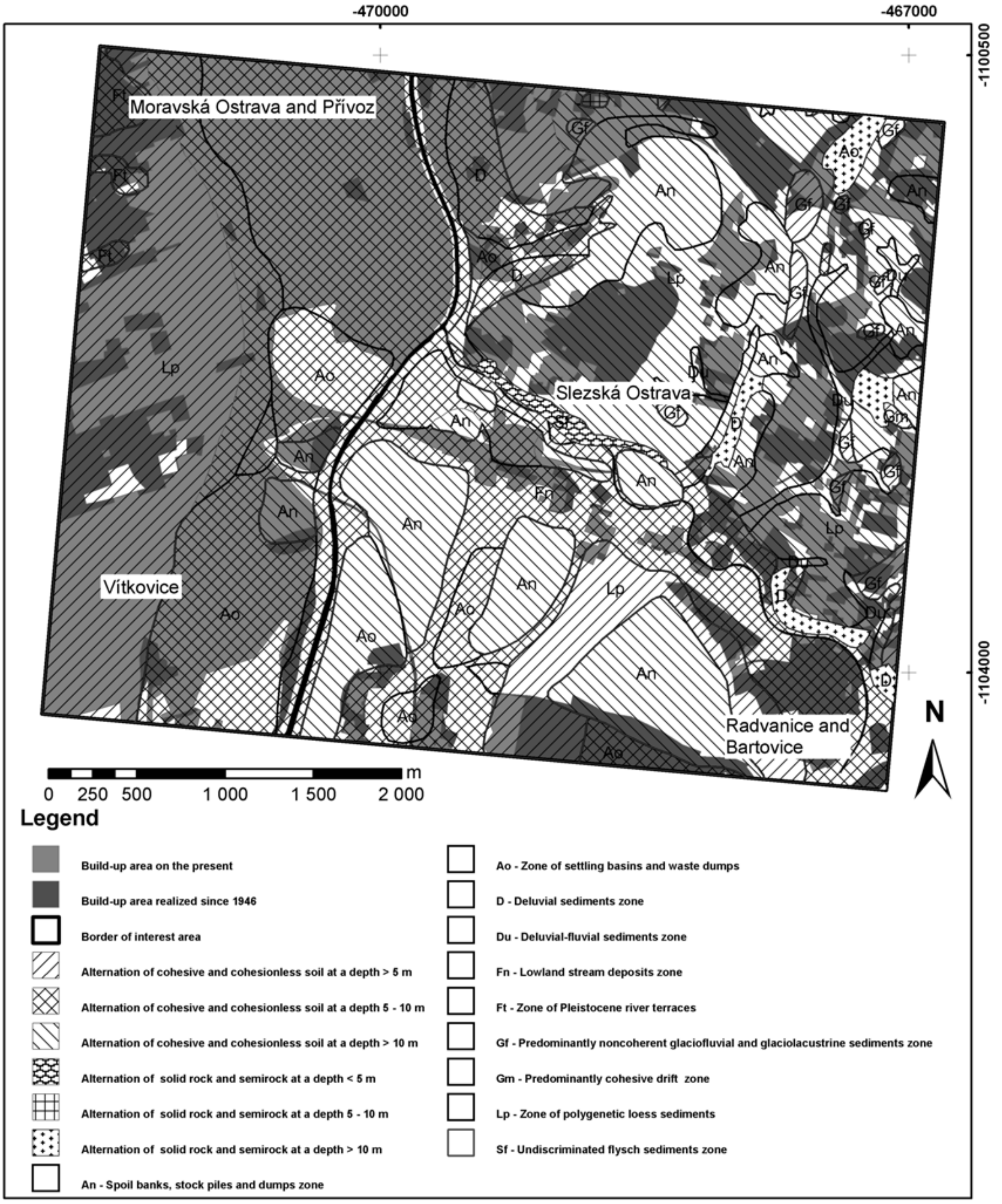

Fig. 11. Type of pre-Quaternary bedrock on the built-up area.

Conclusion

From the point of view of general site excavation during potentional future work, workability analysis is very important; defining the workability as resistance which rocks put up to loosening, loading onto a vehicle and transport of the excavated material to the edge of the foundation pit. Workability rate is the quantity of work needed for the performance of such activities. According to ČSN 73 3050 Standard there are 7 classes of workability of rocks (from cohesive soils of soft consistency and cohesionless mellow soils of the 1st class to firm, healthy, massive solid rocks belonging to class 7).

The workability analysis was carried out on the basis of the ranges of workability of rocks (e.g. workability class 1-3, etc.). It showed that the dominant workability class, not only in the whole interest area but also on the current built-up area (as well as newly built-up area, i.e. built up since 1946), is workability of rocks 2-3. On all the types of studied area (whole interest area, current built-up area and newly built-up area) there are workability class 1-3 and 2-4 in much smaller extents. This means that more suitable workability classes 1 to 4 prevail with 99.6 %. The workability class 4-6 is limited in the interest area, but due to financial reasons and intensity of labour (e.g. during general site excavation) their localization is important (similarly as in the case of zones). For this purpose detailed maps of workability of rocks have been prepared (with the overlap of built-up area and 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 building will be founded in it (e.g. piles, underground garages, underground collectors, etc.).

In the interest area there are two basic types of pre-Quaternary overlay, cohesive and cohesionless soils and solid rocks and semirocks. Those types were further classified according to the depth of the pre-Quaternary bedrock. The analysis according to the types of pre-Quaternary overlay showed that the prevalent type in the interest area is the type of alternation of cohesive and cohesionless soils (98.1 %), namely at the depths within 5-10 m (40.5 %) and over 10 m (36.5 %).

Alternation of solid rocks and semirocks is found on a very small area (1.9 %), while the predominant type is with the bedrock depth over 10 m (1.4 %).

During the monitored period since 1946 to date, the trend of development has changed in terms of pre-Quaternary bedrock depth with soil character, while the depth over 10 m was dominant. However, in the whole interest area and in terms of current built-up area the trend of development was in the category down to 5 to 10m.

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

References

[1] Doornkamp, J. C., Lee, E. M.: Geology and land use planning, St Helens, Merseyside. summary report Rendel Geotechnics, *Birmingham, 64 pp., 1992.*

[2] Dopita, M. a kol.: Geologie české části hornoslezské pánve. *Ministerstvo životního prostředí, Praha 1997.*

[3] Hack, R., Azzam, R., Charlier, R.: Engineering Geology for Infrastructure Planning in Europe A European Perspective. Series: Lecture Notes in Earth Sciences, *Vol. 104, XIX, 803 pp., Hardcover, ISBN: 3-540-21075-X, 2004.*

[4] Chlupáč, I. a kol.: Geologická minulost České republiky. 1. *vydání Praha: Academia, 2002. 436 s. ISBN 80-200-0914-0, 2002.*

[5] IAEG: Engineering geological and environmental maps and plans. 6th Intern. Congress, Amsterdam, *Vol. 1, pp. 23-281, 1990.*

[6] Macoun, J. et al.: Kvartér Ostravska a Moravské brány. Ústřední ústav geologický. *Praha, 1965, 420 s.*

[7] Macoun, J., et al.: Geologická mapa ČSR. List 15-43 Ostrava, 1:50 000, *Ústřední ústav geologický, Kolín, 1989.*

[8] Malgot J., Baliak F., Čabalová D., Bartók J., Kopecký M., Satina J.,: Analýza inžinierskogeologických príčin porušenia stavebných objektov. *Katedra geotechniky SvF STU Bratislava, 1993.*

[9] Marschalko, M., Juriš, P., Peňáz, T.: Insufficient Utilization of the Impacts of Floodlands and Radon Hazard in Slezská Ostrava, Vítkovice and Radvanice for the Landscape Planning Purposes. Proceedings of the XVIth International Scientific Symposium on Ecology in Selected Agglomerations

of Jelšava – Lubeník and Central Spiš, October 25th to 26th 2007, Hrádok, Slovakia. *Ústav geotechniky SAV Košice, 2007, s. 158-166.*
[10] Matula, M., Pašek, J.,: Regionálna inžinierska geológia ČSSR, *295 str. Alfa, Bratislava, 1986.*
[11] Motlík, M., Hofmanová, A.: ČSN 73 3050 Zemné práce. *Nahrazuje ČSN 73 3050 z 21.8.1963, účinnost od 1.9.1987. Vydavatelství ÚNM, 1987. 36 s*.
[12] Sloboda, J., et al.: Mapa inženýrskogologického rajonování ČR. List 15-43 Ostrava, 1:50 000, *Ústřední ustav geologicky, Kolín, 1990.*
[13] United Nation: Integrating Geology in Urban Planning. *Vol. 12, 170 pp., United Nations Publications, ISBN: 9211200741, 2001*.
[14] Vojenský topografický ústav: Letecký snímek, č. 548, č. 550, č. 552, č. 575, č. 577, č. 579, č. 580, č. 601, č. 603, č. 605, č. 606, č. 627, č. 629, č. 631, č. 632. *Dobruška, 1946*.
[15] Český ústav zeměměřický a katastrální: Základní mapa ČR, 15-43-10. *Katastrální úřad, Opava, 2001*.
[16] ČSN 73 1001 - Zakládání staveb. Základová půda pod plošnými základy, Validity: 1.10.1988.
[17] ČSN 72 1001 - Pomenovanie a opis hornín v inžinierskej geológii, Validity: 1.8.1990. Since 1.11.2004 replace.
[18] ČSN EN ISO 14689-1 (721005) - Geotechnický průzkum a zkoušení - Pojmenování a zatřiďování hornin - Část 1: Pojmenování a popis, Validity: 1. 11. 2004.
[19] ČSN EN ISO 14688-2 (721003) - Geotechnický průzkum a zkoušení - Pojmenování a zatřiďování zemin - Část 2: Zásady pro zatřiďování, Validity: 1. 4. 2005.