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EVALUATION OF BUILDING SITE CATEGORY DISTRIBUTION FOR LAND-USE PLANNING IN THE ORLOVÁ REGION

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Abstract: The paper presents the results of a study dealing with the land-use planning in the mining landscape affected by underground mining of black coal. It is indubitable that conditions for future structures have been changing there and this fact must be taken into account and future activities in the affected areas have to be undertaken in such a way as to protect future engineering structures from damage. A selected criterion for this evaluation is the distribution of the so-called building sites that reflects a potential influence on future constructions. Overlay analyses with the current built-up area, planned future built-up area according to the land-use plan and engineering-geological zones were carried out. It is discovered that the existing land-use plans for the mining area of the Orlová town (map sheet 15-44-02), north-east of the Czech Republic, fail to tally with the reality.

1. INTRODUCTION

The paper focuses on a case study of undermining impact evaluation on the current, planned built-up area according to the land-use plan and in relation to the occurrence of slope movements and engineering-geological zones for the needs of land-use planning. The undermining impact evaluation is based on the distribution of building sites shown by the vectorization of maps of the mining company OKD within the town of Orlová in the active mining section of the Karviná part of the Ostrava-Karviná District.

There are five categories of building sites that represent areas with a similar impact of the undermining on the future sites for construction foundation and characterize the measures that make the foundation as secure and strong as to meet the requirements of ČSN 73 00 39 [3] standard for the structures built on undermined areas. The mining companies have to set the values of the parameters characterizing the terrain deformation, i.e. a horizontal unit deformation that is positive in the convex section of a subsidence basin slope (action of traction force) and the negative radius of concave curvature (action of compressive force). Next, these are the radiis of curvature that represents the circle radius circumscribing the slope of the subsidence basin and the so-called delevelling, i.e. the inclination of a subsidence basin slope, while it corresponds to the proportion of the maximum ground surface subsidence to the radius of the area of extraction. Its value changes from zero to the maximum at the point of inflection of the subsidence basin slope.

The geological structure of the area of interest can be characterized by Brunovistulicum rock 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). The roof is formed by Badenian deposits, whose sedimentation was caused by the formation of the Carpathian Foredeep in the foreland of the Outer Flysch Carpathians. It is the Miocene (Badenian) sediments that form a large part of the slope deformation of Doubrava Vrchovec. In the surface sections, there are Quaternary deposits of various types and thicknesses [1], [2], [4], [6], [9]–[11], [13]–[15].

2. SLOPE DEFORMATIONS IN THE AREA OF INTEREST

In terms of the evaluation of a future built-up area, according to the land-use plan [5], [7], [8], [12] in the localities affected by mining activities, one of the most important geofactors is slope deformation being affected by undermining when compared with the areas without such impacts. In order to take those impacts in the area of interest into account, overlay analyses were carried out in the geographic information systems of selected isocatabases of forecast subsidence with slope deformation and the current and planned built-up area according to the land-use plan (figure 1).

The most extensive active slope deformation occurs in the sites affected by subsidence at the interval from 0 to 100 cm. In the two localities, the most intense declining ended before 2005, which was apparent based on the chronology of the subsidence basin development manifested by declines that are subject of a separate study. The area of interest is a part of the town of Orlová, by the most direct north-eastern route about one kilometre from the Old Square between Dr. M. Tyrše and Bezručova streets. Both landslides are mainly in the zone of moraine sediments Gm (98.5% and 78.5%).

Another active landslide territory is situated in the eastern part of the area of interest in the locality of Doubrava near Orlová and it has been affected by forecast declines of 100 and 200 cm. The landslide is in the zone of moraine sediment Gm (97.7%). The slope movement has been affected by underground mining as well, but the size of declines does not reach such vales as those mentioned in the case of the landslides described above.

The third landslide territory is near the northern edge of the area in the locality of Horní Lutyně. It is a stabilized landslide in a locality without subsidence, found in the zone of polygenetic loess sediments Lp (100%).

In the northern part of the area of interest, there is the largest, partially built up, region affected by slope movements that under current conditions falls into the category of potential, buried and stabilized territories. This territory has been monitored since 1974 and its overall area covers the zone of polygenetic loess sediments Lp (100%). It may be inferred that their existence has not been influenced by either current or past mining activities, and their stability has been affected by other factors, or possibly a combination of factors, which are not related to this anthropogenic phenomenon.

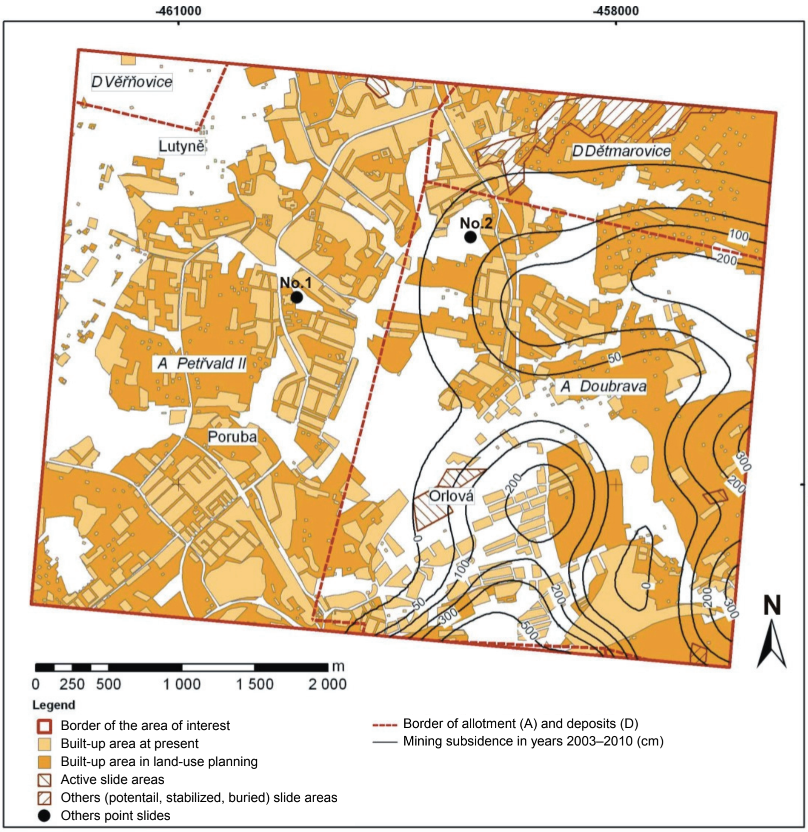

Fig. 1. Mining subsidence between 2003 and 2010 with marked current and future built-up area and slope deformation

In the area of interest, very small sites influenced by slope movements are registered as points. The first is in the locality of Poruba near Orlová, in the vicinity of the Přespolní Street, in the afforested part, and it is classified as a stream-like landslide with a potential degree of activity. The second, also found in the afforested part, eastwards from the Zelená Street, in the locality of Horní Lutyně, is a stream-like landslide with a potential degree of activity. The first one has not been affected by undermining and there is no such prognosis for a close future. The second landslide was not influenced by potential impacts in the subsidence basin before 2005, while by 2010 this impact will have been expected to decline, 50 cm at the maximum.

An unpleasant surprise is the fact that 40.85% of the territories with slope movement are situated in the sites whose development takes place according to the land-use plan.

3. EVALUATION OF BUILDING SITE CATEGORIES IN AN UNDERMINED TERRITORY

This part of the study evaluates the state of the undermined territory in terms of the distribution of building site categories which allows the state of a site affected by mining activities to be described in relation to the needs of future structure foundation. This means that, based on a given category, it is possible to ascertain what must be done to protect a future structure from damage in such affected territory or whether it can ever be erected. On the contrary, a small influence with undemanding modifications can be considered to be an advantage. Usually only a specific site is evaluated during each individual evaluation of one structure within the engineering-geological survey. However, the study shows the distribution of this characteristic within the overall area of interest.

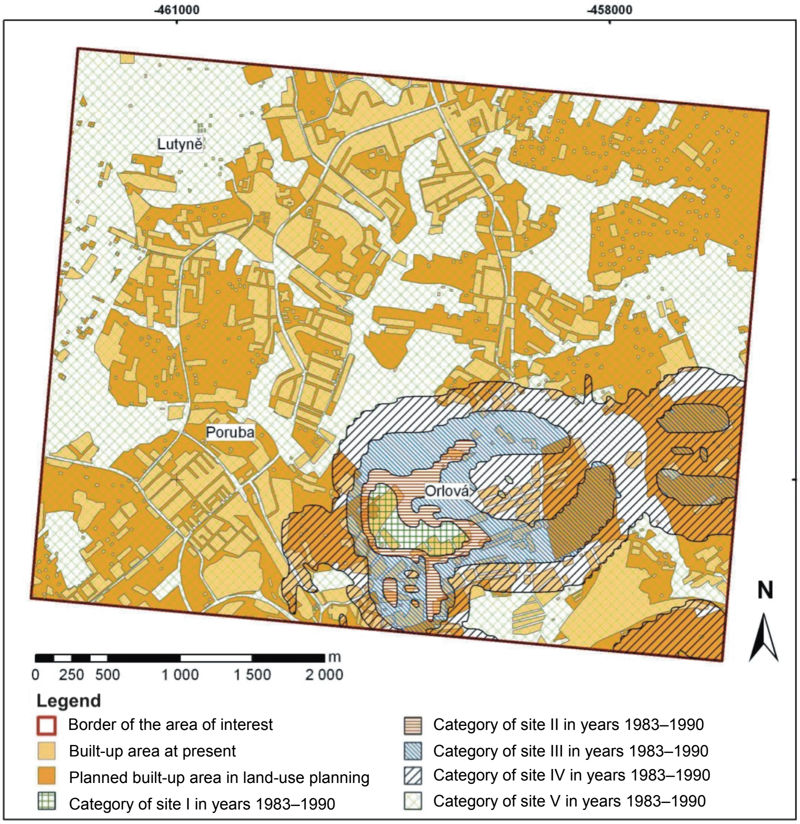

Fig. 2. Map of the individual building site categories in 1983–1990

In total, five possible building site categories were evaluated in four time periods: 1983–1990 (figure 2), 1983–1995 (figure 3), 1983–2000 (figure 4), 1983–2005 (figure 5) in order to understand their chronological changes and to demonstrate the existence of such a case in the sense of understanding the variability of this characteristic.

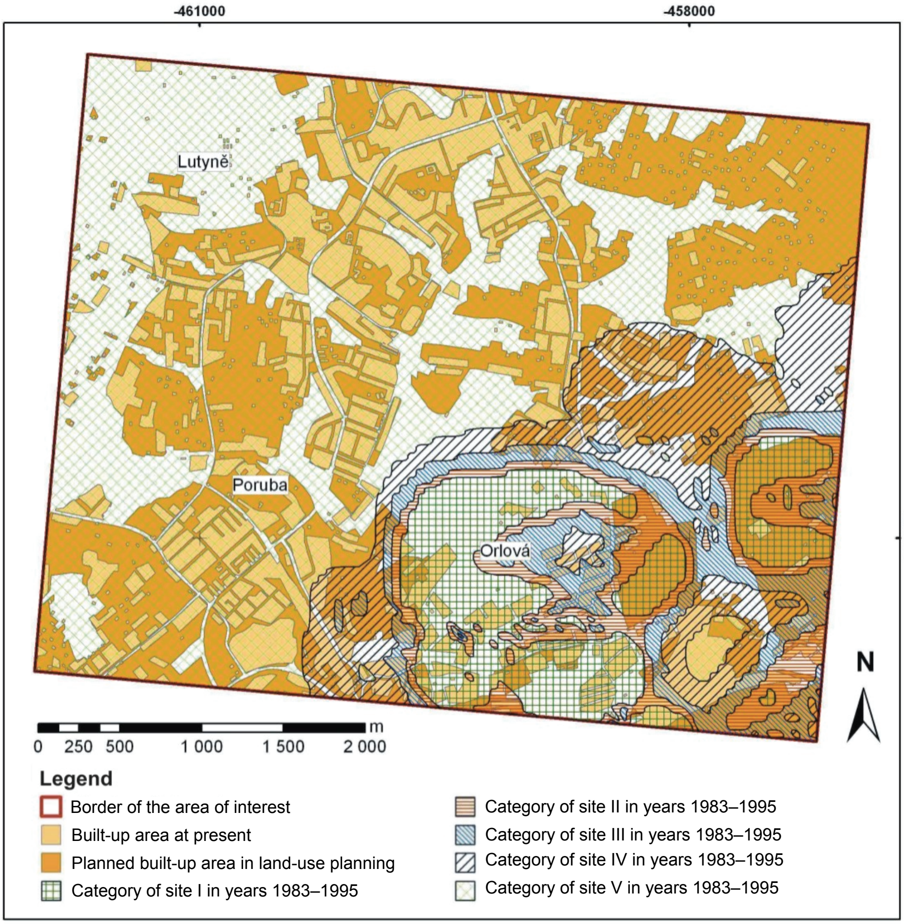

Fig. 3. Map of the individual building site categories in 1983–1995

Overlay analyses in the ArcGis program were carried out based on the individual data layers of vectorized subsidence maps (OKD, 2008), showing building site categories in the time periods with vectorized built-up areas according to the land-use plan and the current built-up area.

The first part evaluates the distribution of building site categories in relation to the *overall area of interest* (figure 6), while individual groups are gradually assessed, beginning from the more favourable state (category V) to the most negative one with the most prominent impact (category I). The premises and constructions in the building site group five (V) do not require any arrangements counteracting the effects of undermining, except for the constructions especially sensitive to the set parameters of terrain deformation, depending on mining conditions (e.g. underground constructions wider than 6 m, pressure pipe conduit, large tanks, etc.), while requirements for constructions must be met. Moreover, the effects of higher groundwater levels must be evaluated taking into account the expected value of ground subsidence (ČSN 73 0039). The category V of building sites represents the territories where strain from undermining is very small, smaller than 30% of the strain caused by other effects. The majority of the area of interest falls into this category. During the monitoring period the size of the territory decreased from the original 77.7% (14.19 km^2) via 72.9% (13.31 km^2) and 68.2% (12.46 km^2) to 65.8% (12.01 km^2) in 2005. This implies a spatial reduction of this more suitable category of building sites.

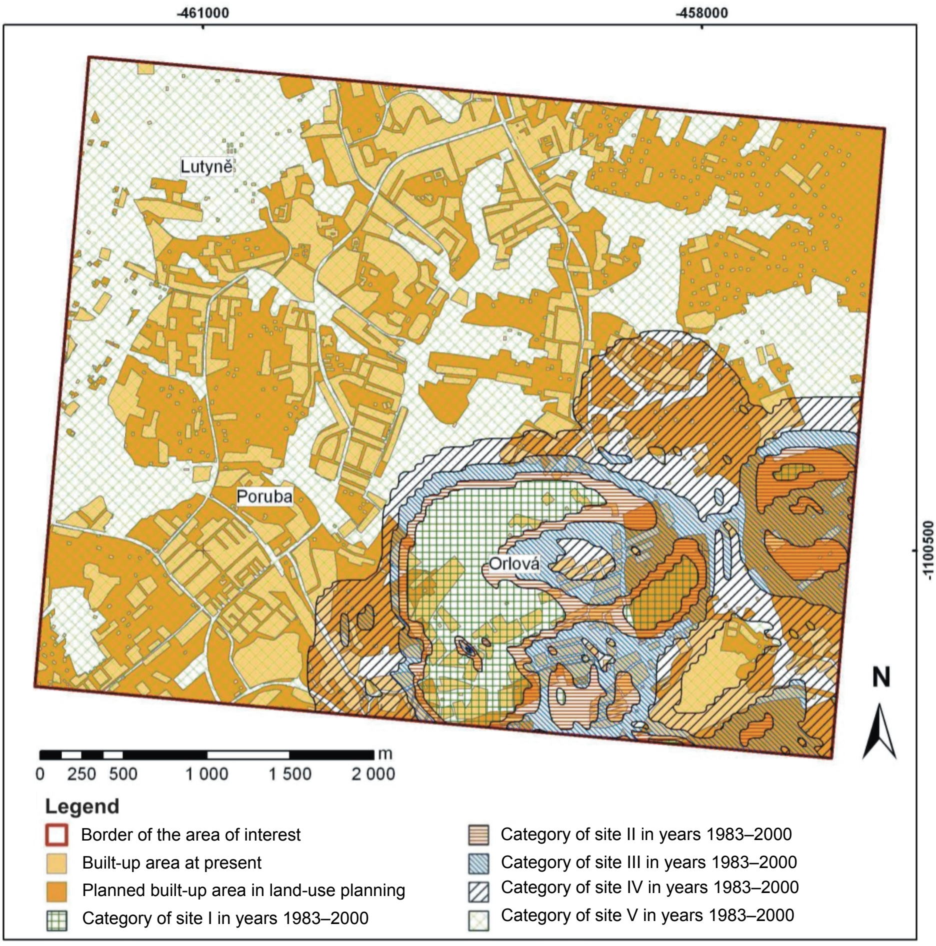

Fig. 4. Map of the individual building site categories in 1983–2000

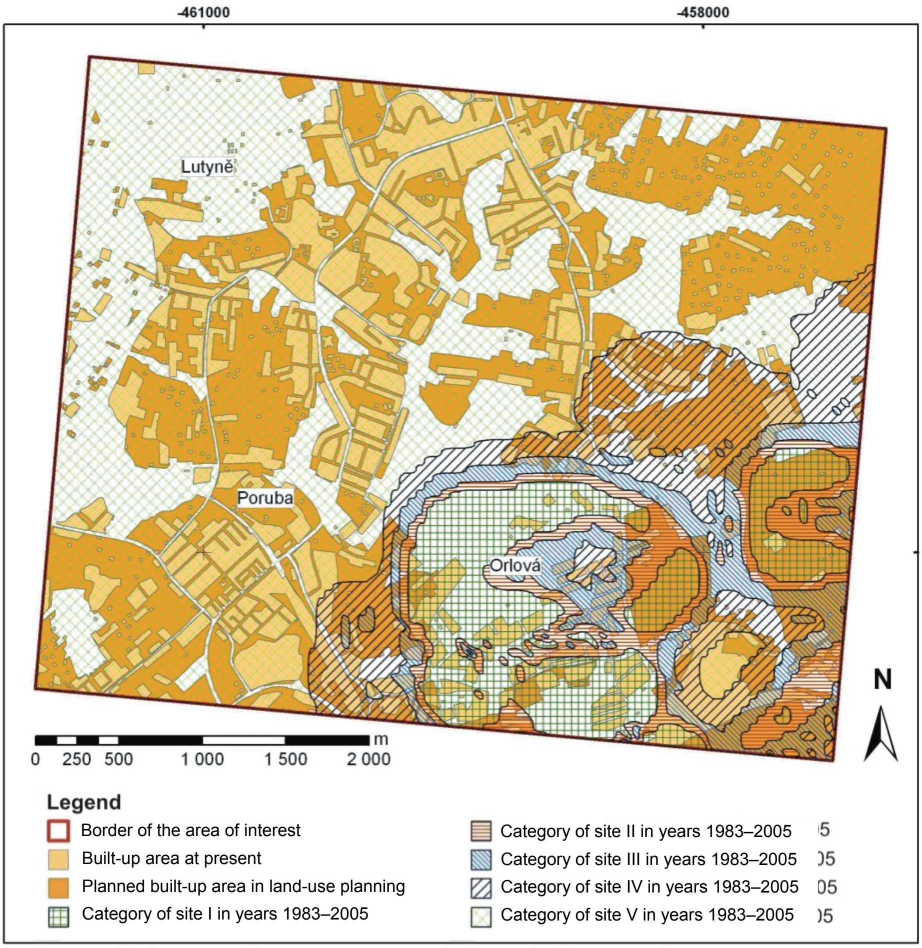

Fig. 5. Map of the individual building site categories in 1983–2005

In the building site groups of the categories III and IV, all premises and constructions can usually be made secure against the impacts of undermining in an economically acceptable manner if recommended construction principles apply to ČSN 73 0039. The second most frequent interval is the category IV that represents a balanced group of values over the years (13% – 2.37 km^2, 12.7% – 2.33 km^2, 12.5% – 2.27 km^2 and 12.2% – 2.23 km^2 of the area). With its percentage representation, the category III is almost half of the previous group (6.8% – 1.25 km^2, 8.3% – 1.51 km^2, 8.7% – 1.59 km^2 and 6.5% – 1.18 km^2 of the area). Of all the categories the category IV shows the smallest change, and in the case of the category III a deteriorating change in the trend can be observed, which is apparent from the overall comparison with all other groups.

The use of the building site groups of the categories I and II must be justified and carefully thought over. It is not recommended to place any engineering structure there with the exception of such that are vital to secure the operation of a mining company. The other exceptions are simple structures resistant to the effects of undermining or structures of a prime importance for a local community (e.g. railway station). Building sites with the expected occurrence of ground downthrows cannot be used for construction (ČSN 73 0039). In the category II, a trend fully shown in the last category (I) can be observed. This is the case of a gradually growing extent of territories with such risky groups. The category II has the values from 1.6% (0.28 km^2) in the first time interval to 5.6% (1.02 km^2) in the last one, and in the category I the territory area between the first and last time intervals increases over tenfold from 0.9% (0.17 km^2) to 10% (1.82 km^2) because of the increasing influence of mining processes with time. This finding shows that this area has enlarged to one tenth of the overall area compared with the original 0.9% of the area with the possible occurrence of compound faults and extraordinarily large deformations.

The chart implies that the majority of the area falls into the category V and thus offers relatively good conditions for all types of constructions.

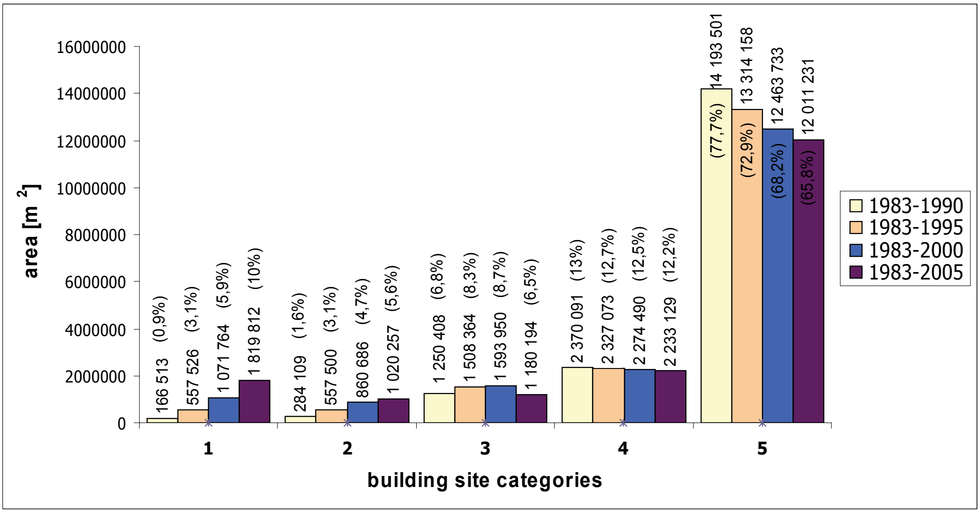

Fig. 6. Spatial distribution of the individual building site categories in the overall area in the monitored time periods

The second part focuses on the distribution of building site categories in relation to the *current built-up area* (figure 7).

The area of the current building site category V decreased in four time periods from the original 82.8% (3.68 km^2) to 70.1% (3.11 km^2). This shrinkage in area of over 12% can be explained by classifying the built-up area, originally falling into category V, into other categories. The built-up area located on the building site category IV makes up the second largest group representing approximately one tenth of the area. Throughout the years, the values ranged from 9.6% (0.42 km^2) via 12.5% (0.55 km^2), 12.5% (0.56 km^2) to 10.9% (0.49 km^2) of the built-up area.

In terms of the values, the built-up area assigned to the building site category III constitutes an unbalanced group. The area sizes range from 4.7% (0.21 km^2) via 3.9% (0.18 km^2), 6.8% (0.3 km^2) to 5.4% (0.24 km^2). The last two worse categories (I and II) have a character similar to that described in the previous subchapter and they become worse with time. The area of the development assigned to the building site category II increased from 1.4% (0.06 km^2) to a double value of 2.8% (0.12 km^2), then to 3.4% (0.15 km^2) and finally to 4.6% (0.21 km^2).

In the case of the category I, the increase in the area was not as prominent as when evaluating the groups distribution within the overall area. Nevertheless, the strongest growing trend is apparent there, i.e. from the 1.6% (0.07 km^2) via 3.7% (0.17 km^2) and 5.6% (0.25 km^2) all the way to 9% (0.4 km^2) of the built-up area assigned to the individual building site categories.

Comparing the evaluation of the development with regard to the evaluation of the overall area, it may be stated that the trends in the building site category distribution are similar and the difference is especially visible in the change in the trend where in the first mentioned situation there is a change in the category III, and in the second – in the category IV.

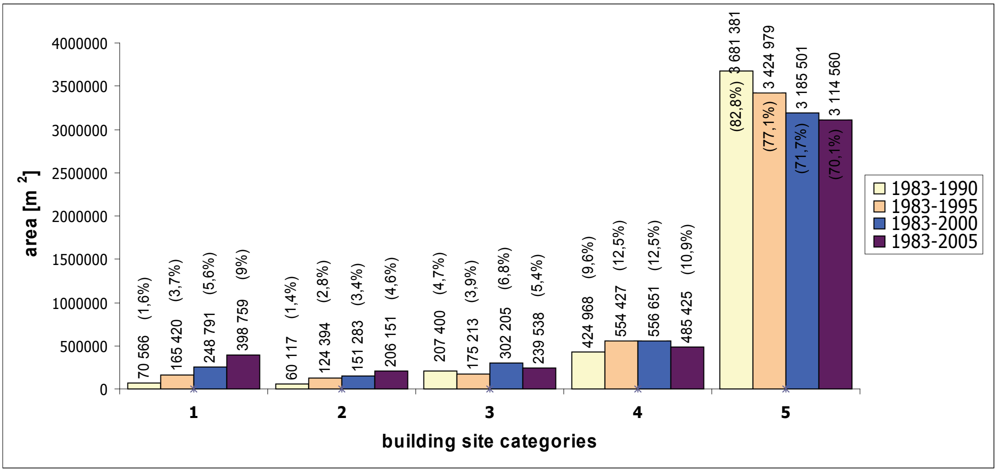

Fig. 7. Spatial distribution of the individual building site categories in the current built-up area in the map sheet 15_44_02 in the time periods monitored

The third part evaluated the building site category distribution in relation to the *planned built-up area, depending on the land-use plan* (figures 8 and 1). The required data layer of the land-use plans of the individual municipalities was made by means of vectorization of raster maps and later consolidation in the ArcGis program applications.

It is apparent from the identified situation that a prevailing part (65.03% – 4.35 km^2) of the planned built-up area will be in the building site category V., i.e. in the most suitable locality for development in terms of territories affected by undermining (figure 8). More than one fifth (21.98% – 1.47 km^2) of the area on the land-use plan will be in the category IV. The third substantial area will be occupied by future structures erected on the building site of the category III (11.33% – 0.76 km^2). The smallest planned built-up area sizes (0.58% – 0.038 km^2) will be assigned to the category II. However, almost double (1.07% – 0.071 km^2) built-up area is planned for the least suitable category I. This is the case of the planned development in the southern part of the map sheet in the surroundings of the Streets of Petra Cingra and Fr. Palackého in the town quarter of Orlová–Město. Based on this information the land-use plan should be corrected.

It is apparent from the results (figure 8) that the majority of the territory in this map sheet falls into the category V and thus it offers relatively good conditions for all types of constructions.

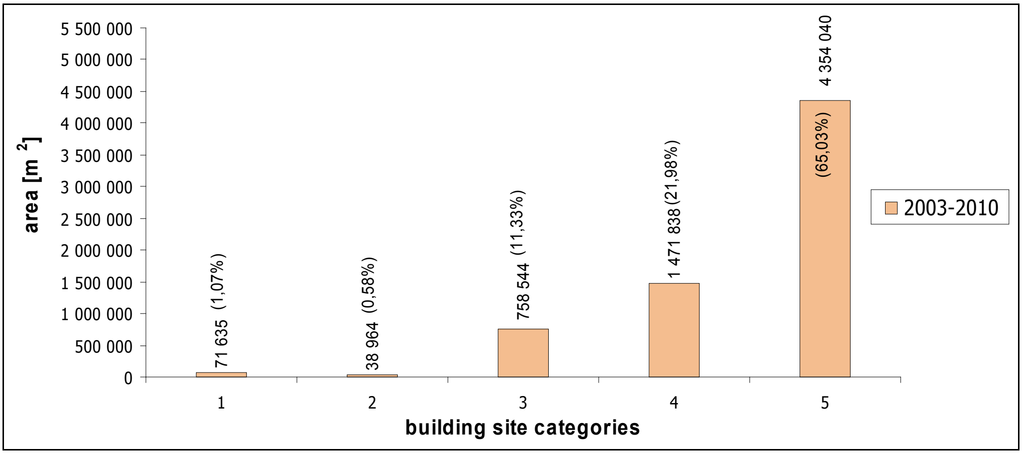

Fig. 8. Distribution of the building site categories in 2003–2010
in relation to the future development according to the land-use plan

Evaluating the *distribution of the engineering-geological zones in the individual building site categories* (figure 9), it may be stated that in the affected area there are the following zones: 1) polygenetic loess sediments Lp, 2) spoil banks, stock piles and dumps, 3) settling basins and waste dumps An-Ao, 4) moraine sediments Gm and 5) deluvial sediments D.

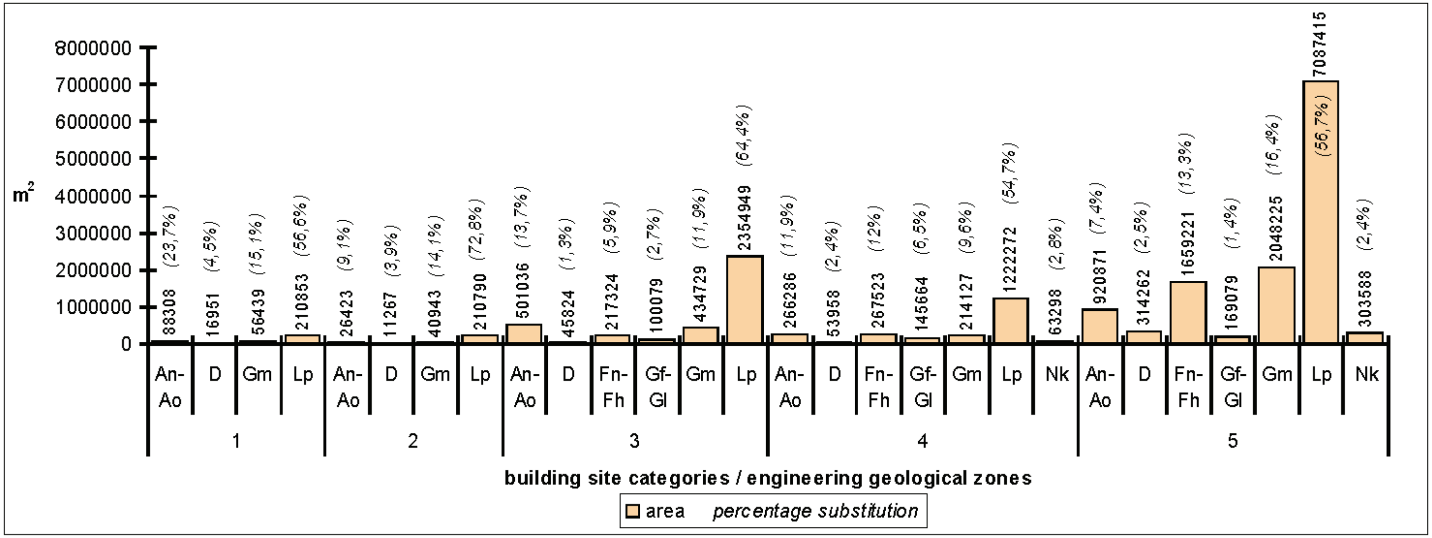

Fig. 9. Distribution of the engineering-geological zones in the individual forecast building site categories (2003–2010).
Legend: An-Ao – spoil banks, dump and settling basin zone, Gm – zone of moraine sediments, D – deluvial sediment zone, Lp – zone of polygenetic loess sediments, Fn-Fh – zone of alluvium lowland streams and mountain streams, Nk – zone of alternating (combined) fine-grained sandy and gravelly sediments, Gf-Gl – glaciofluvial and glaciolacustrine sediment zone

If we consider the most important influence over the geological environment, e.g. that of undermining, then it is the territory of the building site category I with the zone of moraine sediments, zone of polygenetic loess sediments, zone of deluvial sediments, zone of spoil banks, stock piles and dumps and the zone of settling basins and waste dumps, while their order corresponds to the hierarchical sequence according to the spatial distribution.

The most significant negative changes in the physical-mechanical properties must be taken into consideration in the zone, especially the changes in porosity, bulk density, bulking, relative density that most influence the mechanical properties in terms of shear strength, deformation modules, which will consequently influence the calculation of load-bearing capacity and settlement. The effects of the changes cannot be unambiguously quantified, but they will have different impact on the geological environment, especially in relation to the mineralogical composition and the granulometric character of the foundation soils. On the contrary, the least important impacts may be expected in the building site category V and localities without any impacts. What must be stressed is the fact that also in the territories with minimum subsidence with relatively suitable building site categories, we may encounter the situations where changes in the load-bearing capacity and settlement of the premises will not occur, but we may deal with, for example, changes in the horizontal stress that can lead to the alternations in the slope stability or to the initiation of slope movements.

4. CONCLUSION

Taking account of a future development and the land-use plan, the territories with *slope movements* are included in the plans for built-up area occupying up to 40.85% out of the total slope movement territory. This fact has to be known by the authorized land-use planning department so that they will not place any similar functionally-oriented sites in such territories.

Evaluating the changes in the area of interest, as for the distribution of building site categories, it is possible to state that there occurs a gradual reduction in the localities with a more suitable building site category V and the areas without any impacts and conditionally suitable localities IV and III during the monitored time periods. Unsuitable building site categories I and II experienced a growth with time.

In terms of a planned development, the land-use plan concerns up to 1.6% of the area falling into the least suitable categories I and II and 34% of conditionally suitable categories III and IV, which means that the authorized land-use planning department had not sufficiently taken this anthropogenic factor into consideration in respect of the future safety of engineering structures.

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