Letters to Editor

ENGINEERING GEOLOGICAL ASPECT OF UNDERMINE

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Abstract

Undermining is an important engineering geological phenomenon. Above all, the publication deals generally with the theory of undermining. Subsequently historical (Karviná, Orlová) and present examples are presented. It is especially a case of mining-induced slope deformation at Doubrava – Vrchovec and a case of the most extensive shaft collapse (Doubrava IV shaft) in the Czech Republic.

Keywords: slope stability, engineering geology, undermine

1. Introduction

Previous building regulations prescribed performing no construction activities in areas overlying deposits of fuels and mineral raw materials. To ensure the stability of important structures, specific measures used to be adopted. The measures permitted mining operations at greater depths with leaving protective pillars containing large quantities of unmined reserves in the affected area concerned. Later the mining of even those reserves became, however, necessary.
In the underground considerable worked out spaces are created; the state of stress in their surroundings changes and the empty spaces are gradually caved in, which results in great deformation in the surface area. Deformation in the surface area is transferred to constructions, roads and utility networks. Rather old structures unprepared for such deformation are thus usually damaged, which may be prevented by the additional stabilization of them.

When designing appropriate techniques of foundations construction and structural adaptations to buildings, information on deformation in the surface area due to mining activity is of paramount importance. Moreover, it is necessary to distinguish particular sequences of building works that may be done before, or after affecting the building site by mining activity.

2. Deformation of the Surface Area

Together with the mining and the caving of underground spaces a surface area is gradually transformed and a subsidence basin is formed. The basic characteristics of the basin are shown in Figure 1. Concrete values depend on many factors so that it is not practically possible to generalise them. The subsidence of the ground surface increases step by step and will reach the maximum value

\[ s_{\text{max}} = (0.8 \text{ to } 0.95) \times h \]

i.e. it depends primarily on the thickness of the excavated layer \( h \)

The critical angle of mining influence is given by the edges of the subsidence basin and the position of mining operations, his values are as follows: \( \mu = 56^\circ \) for Nováky, \( \mu = 50^\circ \) for North Bohemian Brown Coal Basin, \( \iota = 50 - 55^\circ \) for Tertiary layers of Ostrava-Karviná Coalfield and \( \iota = 70 - 80^\circ \) for the Carboniferous, \( \mu = 50 - 55^\circ \) for Tertiary layers of Ostrava-Karviná Coalfield and \( \mu = 70 - 80^\circ \) for the Carboniferous. Circles with a radius \( R \) form the slope of the subsidence basin; in its convex and concave parts tensile and compression stresses develop, respectively. Such stresses cause also deformation. Especially specific horizontal deformations that are positive in the convex part of the slope (elongation) and negative in the concave part.
(compression) are of great interest. They are given in millimetres per 1 metre, or %. The radius of the effective area

\[ r = H \cotg \mu \]

can be defined as the radius of a layer at the depth H to be mined out so that the point in the surface area may reach the maximum value of subsidence \( s_{\text{max}} \).

**Fig. 1 Basic characteristics of the subsidence basin**

The angle of slope of the subsidence basin (delevelling) moves in the range from null to the maximum value, which is the value in the inflection point, where

\[ D_{\text{max}} = \frac{s_{\text{max}}}{r} = \frac{s_{\text{max}}}{H \cotg \mu} \]

and is usually given in mm.m\(^{-1}\), or %. 

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According to the norm, ĖSN 73 0039 on Structures in the Undermined Area, building sites are classified into five categories depending upon parameters characterising the deformation of the area. The mining company provides designers with these characteristics together with another information in a form of parameters through which the mining activity affects the surface (mining conditions). Categories of building sites in mining affected areas (tab.1).

Table 1. Categories of building sites in mining affected areas
(ĖSN 73 0039)

<table>
<thead>
<tr>
<th>Category</th>
<th>ε (mm.m⁻¹)</th>
<th>R (km)</th>
<th>D (mm.m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&gt; 7</td>
<td>&lt; 3</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>II</td>
<td>5 ÷ 7</td>
<td>3 ÷ 7</td>
<td>8 ÷ 10</td>
</tr>
<tr>
<td>III</td>
<td>3 ÷ 5</td>
<td>7 ÷ 12</td>
<td>5 ÷ 8</td>
</tr>
<tr>
<td>IV</td>
<td>1 ÷ 3</td>
<td>12 ÷ 20</td>
<td>2 ÷ 5</td>
</tr>
<tr>
<td>V</td>
<td>? 1</td>
<td>? 20</td>
<td>? 2</td>
</tr>
</tbody>
</table>

Structures on building sites of the category V do not require almost any specific improvements; such building sites may be considered, from the point of view of foundation engineering, to be appropriate. On building sites of the categories III and IV, all types of structures can be ensured in an economically acceptable manner; the building sites may be considered to be conditionally appropriate. Building sites of the categories I. and II. are regarded as inappropriate to new building construction. Costs of ensuring the stability of structures usually exceed economically reasonable amounts of total costs. However, in spite of their increase they are sometimes acceptable owing to the overall effect of the structure (Hulla, J.et al, 1998).

3. Examples of undermine in Czech Republic

3.1. Historical examples of undermine

Historical examples (influences of undermining in Ostrava - Karvina coalmine distrikt) are shown in Figure 2.
Fig. 2a Destruction of church in Karvina as a result of very rapid subsidence (the main phase of mining influences took place within one week – 1964 (Grmela et al., 1999)

Fig. 2b Depression basin – groundwater level arose on the ground surface (Orlová – 1956). Apparent denivelation of individual objects – total subsidence over 20 m (Grmela et al., 1998)
Fig. 2c Church of St. Peter from Alcantra (between Karvina and Orlova) - year 1935 – the church with original tower situated on the hill and next picture is situation in year 2001.

Church of St. Peter from Alcantra
Karviná, Czech Republic

Fig. 2d The scheme of subsidence of the church in time (Grmela et al., 1998)
3.2. Influence of mine activity to slope deformation on Doubrava – Vrchovec

Slope deformation of Doubrava – Vrcholec (fig.3) that occur in distrikt Karviná in village Doubrava represent slope deformation reactivated by mining effects. Also precipitation had invincible influence on slope movement. Greatest movements temporally evidently correlate with mining (fig.4) of most thick seams of Mine Doubrava and Mine CSA. Objective area is situated in efficient distance of mining activity of both mining fields.

![Fig.3 Situation of slope deformation, Doubrava-Vrchovec](image)

The Quaternary cover consists of a broad scale of sediments. However, particular types are preserved in their original positions merely sporadically; slope movements disturb mostly their positions. Glacigenous sediments are primarily sandy, in a lesser degree clay-sandy, or gravel with the grains of quartz and erratics. The alluvium of the stream, Kotlinský potok, and sediments of small water reservoirs form the deluvio-fluvial sediments. They are represented prevailingly by clays with a content of organic matters and plant remains. Sediments formed due to sliding activity are very variable; their character depending upon the original type of soils. They are characterised by
various grain size distribution, variable calcareous contents, and often by the presence of plant remains and wood substance.

From the hydrogeological point of view, it is the case of a complex of insulators that is, as a result of landslide movements, redeposited and intercalated with layers of glacigenous sediments that fulfil here the function of a collector. The level of underground water is unconfined; in the zone of sliding it is a slightly pressure level. The flowing of underground water follows the NE and E directions in accord with a hydraulic gradient. For the area of interest, the total subsidence of the land surface due to mining activity from the year 1986 to the year 1995 was expected to be less than 150 cm (with minima at the crown of the slope and maxima at the toe of the slope) according to calculations. If we compare this value with the results of real subsidence measurement, we shall obtain almost equal data in the grid of points of the Section of Mine Surveying and Geology of the ÈSA Mine.

*Fig. 4 Mining-induced ground subsidence, years 1987 – 1996 (Section of Mine Surveying and Geology, ÈSA Mine, 1998)*
3.3. Breakdown of the Shift Doubrava-IV

In July 1999 the largest breakdown (fig.5) of the shaft in the history of Czech mining industry occurred. Thousand and hundred meters deep shaft Do-IV, of 8.5 m of inner diameter, was buried in its whole length and the crater of volume 65 000 m³ occurred on the surface during less than 24 hours.

Which edification can be evaluated as the result of this case? It is possible to form them into a few points (Grmela, Aldorf, 1999):

The destructive influence of possible suffosion of the sands from the sand layers in the shaft surrounding was underestimated by the project and the maintain technology,

The excavation and reinforcement technology was not chosen adequately to the complicated geological and geotechnical conditions,

It was not possible to check the stage of the shaft (daily),

The necessity of the absolute reliability of the dewatering bores liquidation in the shaft surrounding was underestimated,

The suffosion was supported by the influence of the previous breakdown during the shaft excavation and by non-correct way of the pumping from the dewatering bores,

The influence of the hydraulic connection of Quarternary water areas with the sand layers of Miocene and the influence of increased precipitation (1997) to the shaft inflows through these collectors were not hydrogeologically and technically appreciated.

4. Conclusion

The influence of undermining is limited in time approximately up to five years after finishing the exploitation in the effective area and its intensity is strongly affected by: natural factors, thickness and geomechanical character of covering deposits, geomechanical character of deposited rocks, deposition depth (exploitation depth), thickness of exploited deposit (e.g. coal seam), by technical-operational factors: exploitation method (longwalling, rooming, etc.), caving or backfilling of worked-out space.

The effects of area deformation induced by mining activity on the building structure may be reduced as follows: by reducing the areas of constructions in contact with the foundation soil, by reducing frictions on horizontal and
vertical surfaces of underground parts of structures (smooth surfaces, envelopes formed by low strength materials), by designing compensating trenches on the periphery of the structure that will be filled with a compressible material, e.g. a mixture of sawdust and loam. In this way, the horizontal loading of vertical parts of underground structures is diminished.

References
