Acta Montanistica Slovaca Ročník **14** (2009), číslo **3**, 232-240

Impact of underground mining to slope deformation genesis at Doubrava Ujala

Marian Marschalko[1] *and* ***Lubomír Třeslín***

The study deals with the evaluation of possible impact of undermining on a slope deformation Doubrava Ujala nearby the city of Karviná in the north-east of the Czech Republic. Undermining is a phenomenon caused by underground mining of black coal in the active Karviná part of the Ostrava-Karviná District. It is on the boundary of the working districts Karviná – Mines I and Poruba, which are operated by the Karviná Mine. In order to assess the possible impact, isocatabase maps in different time sections were used documenting the chronology of the subsidence trough formation and next, ground deformation parameters. The activity of slope movement was registered by means of zone extensometry on the surface and in the depth by means of precise inclinometry measuring. Apart from the impact of undermining, the effects of climatic conditions were taken into consideration, correlating the movement size with precipitation depth in the nearest rainfall gauging stations. As for the mechanism of undermining impact there is an apparent influence of additional stress from undermining caused by elongation of the ground surface, which is evidenced by the position of the slope deformation in the convex part of the subsidence trough slope. All the above mentioned factors influence the stability conditions of the slope deformation.

Key words: *engineering geology, slope deformation, mining, undermine, Doubrava Ujala*

Introduction

One of the factors, which most change the engineering-geological conditions, is mining activity, both ground and underground. Underground mining that concerns the studied area forms a subsidence trough due to undermining, within which uneven settlement, slope movements [1,9,11], discontinuous deformations and changes in hydrogeological conditions can occur.

The researched slope deformation Doubrava Ujala is situated nearby the Karviná Mine, which was formed merging the former Mine of Československá armáda - ČSA (Plant ČSA at present) and Lazy Mine (Plant Lazy at present) as of 1 April 2008. The Plant ČSA producing about 2.8 million tons of black coal in 2007 is found in two working districts of DP Karviná Doly I and DP Doubrava (total area of about 26 km^2), while the interest locality is on their boundary. Originally, the Mine ČSA was established on 1 July 1995 merging two formerly independent mines ČSA and Doubrava (fig. 1). The biggest absolute depth of the Plant ČSA is in the discharge air shaft Doubrava III in the locality Doubrava –1,176 m. At pithead altitude of 281 m, with deep 895 m below the sea level.

Fig. 1. Location of the study area.

---

[1] *Doc. Ing., Marian Marschalko, Ph.D., Ing. Lubomír Třeslín*, Hornicko geologická fakulta, VŠB-Technická univerzita Ostrava, tř. 17. listopadu, 708 33 Ostrava-Poruba, Tel: +420/596993505, marian.marschalko@vsb.cz
(Review and revised version 21. 12. 2009)

Geological conditions

The Doubrava Ujala slope deformation can be characterized as active. The hazard area would, in this case, also include the house No. 55, local road from Doubrava to Dětmarovice, a whole number of underground services leading along this road and garden sheds visited on a daily basis.

The locality is situated on the boundary of the subregions of Ostrava Flat and Orlovská Plateau, which can be morphologically characterized by a slope with the gradient of 27 to 32° in the direction of the Olše River alluvial plain. The mean altitude fluctuates from 220 (Ostrava Flat) to 245 m above sea level (Orlovská Plateau). Geographically it is a margin of a flat hilly area with erosion-accumulation surface, while the terrain configuration is conditioned by the geological structure of the subsoil influenced by the modelling and accumulation activities of the salic glacier, eolian sedimentation and especially river erosion. Climatically it is a region with slightly warm, dry winter.

In the locality's bedrock there is an articulated Carboniferous paleorelief [5] covered by Tertiary, Miocene sediments of the Carpathian fore-deep. Lithologically, these are mainly claystone and clays with frequent silty to sandy fractions, the thickness of which ranges in hundreds of metres in the given territory. The slope deformation Doubrava Ujala is formed by such sediments, overlaid by Quaternary overlay in the top section. The overlaying formations represent a lithologically varied complex of glacigenous, salic sediments and superjacent loess loam.

As for geological structure of the slope deformation the following engineering-geological soil types were specified: dumps, glacigenic soils, slope loams and Miocene sediments (fig. 2).

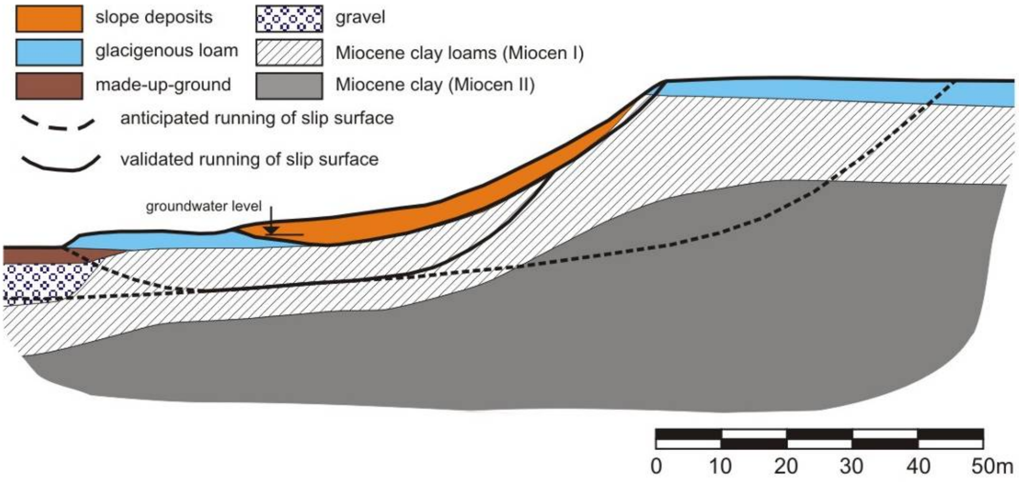

Fig. 2. Geological profile of the Doubrava Ujala slope deformation.

Waterlogging is related to relatively more permeable rocks that are on the slope foot represented by slope sediment positions and in the top slope by local occurrence of non-cohesive glacigenic sediments. In the slope head in the vicinity of the formed built-up area no groundwater level was identified by boring. With regard to the lithological variability there is not continuous waterlogging in the slope deformation area, the shallow water is limited to sandy and other coarser sediments.

On the basis of engineering-geological mapping, sliding manifestations were observed, which are typical for slope deformations such as steep wall of a tear edge, terrain deformations, cracks, trees bent from the original position and sliding blocks. What is prominent is the damage and gradual sliding of the former access road to the currently demolished house and its farm building.

Undermining areas

Previous building regulations prescribed performing no construction activities in areas overlying deposits of fuels and mineral raw materials. 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 slope deformations, 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.

Together with the mining and the caving of underground spaces a surface area is gradually transformed and a subsidence basin is formed [2, 3, 8, 12, 13, 15, 16]. The basic characteristics of the subsidence basin are shown in Fig. 3. 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_{max} = (0.8 to 0.95) 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: μ = 50 - 55° for Tertiary layers of Ostrava-Karviná Coalfield and μ = 70 - 80° 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 μ) 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_{max}.

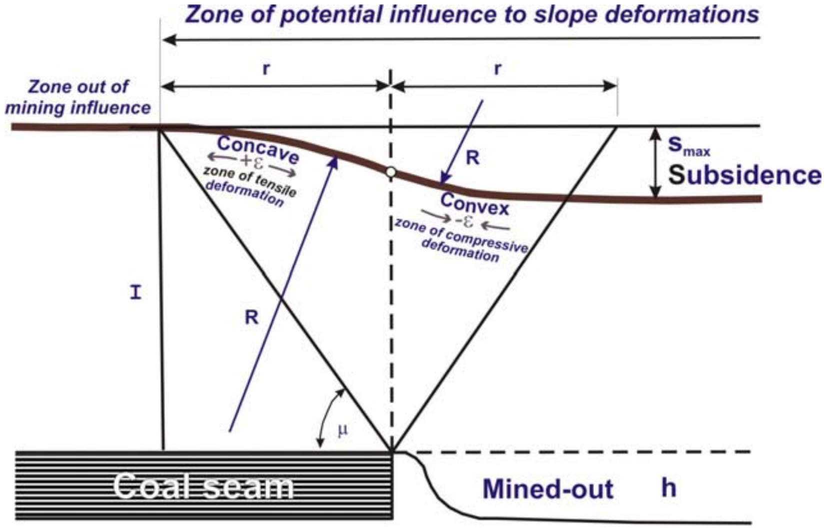

Fig. 3. Basic characteristics of the subsidence basin.

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 $D_{max}=s_{max}/r=s_{max}/(H\cot g\mu)$, and is usually given in $mm.m^{-1}$, or ‰.

According to the standard, ČSN 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).

Tab. 1. Categories of building sites in mining affected areas (ČSN 73 0039).

Category	ε [$mm.m^{-1}$]	R [km]	D [$mm.m^{-1}$]
I	> 7	< 3	> 10
II	5 ÷ 7	3 ÷ 7	8 ÷ 10
III	3 ÷ 5	7 ÷ 12	5 ÷ 8
IV	1 ÷ 3	12 ÷ 20	2 ÷ 5
V	≤ 1	≥ 20	≤ 2

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 [4,6].

Impact of undermining on the Doubrava Ujala slope deformation

The development of the subsidence trough in the site of the slope deformation Doubrava Ujala is visible from the ground subsidence maps in four chronological intervals, provided by the OKD, a.s. company. The intervals were selected approximately evenly from 1983 (beginning of levelling) to 2005. By 1995 (the first two intervals 1983 – 1990 and 1983 – 1995) no minimum subsidence had been registered nearby the slope deformation. The fifth interval represents the summary of subsidence between 1983 and 2002 and the sixth is a subsidence forecast for the period from 2003 to 2010.

Fig. 4 shows subsidence between 1983 and 2000 and between 1983 and 2005. In the first interval there is apparent sinking in the site of the landslide in the interval 0 to 5 cm. The subsidence trough slope gradient in the place of the slope deformation is faced south-eastwards; the landslide slope drops east-south-eastwards to eastwards. Despite the fact that from 1983 to 2005 the course of isocatabases changed slightly in a way the subsidence trough slope falls south-south-eastwards, there is distinct, similarly small ground subsidence up to 5 cm in the place of the slope deformation.

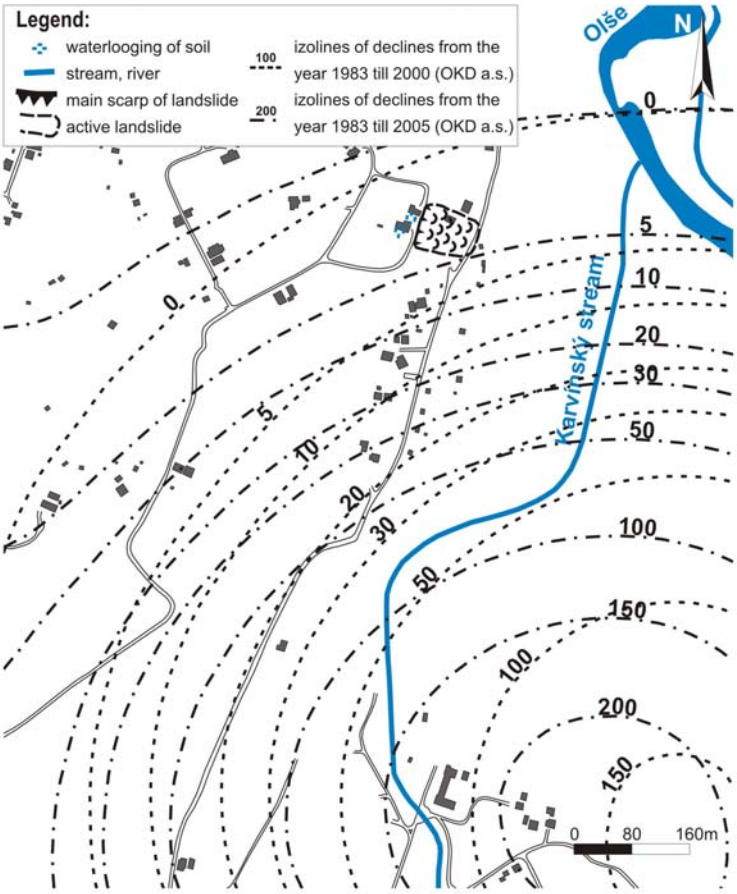

Fig. 4. Subsidence caused by undermining during 1983 – 2000 and 1983 – 2005 with marked position of the slope deformation.

The interval from 1983 to 2002 is useful from the point of view of visualization of the subsidence trough development related to the forecast for 2003 – 2010 (fig. 5). It implies a distinct increase in sinking to about 10 – 25 cm in the place of the slope deformation. The aspect of the subsidence trough slope is forecast towards the south-east, and thus its position hardly changes with regard to the slope deformation gradient.

According to ČSN 73 0039 Standard *(Design of premises on undermined areas)*, apart from engineering-geological survey and other common documentation, an analysis of mining conditions (mining assessment) must be added to the application for zoning and planning decision and for building permission subject to the provisions for undermined areas. It deals with an analysis of safety conditions for the premises built on an undermined area, which rate the character, parameters and possibly time course of the terrain transformation due to the impact of underground mining.

In terms of forecast till 2010 fig. 5 also shows the demarcation of the building site groups (subject according to ČSN 73 0039 Standard), while the landslide Doubrava Ujala should belong to he 4th group as per the forecast. In terms of the impact of undermining on the constructions are building sites of groups III and IV are conditionally suitable, namely according to the solidity and size of the load-bearing structure and the arrangement of the building; construction protection from the impacts of undermining is still financially acceptable.

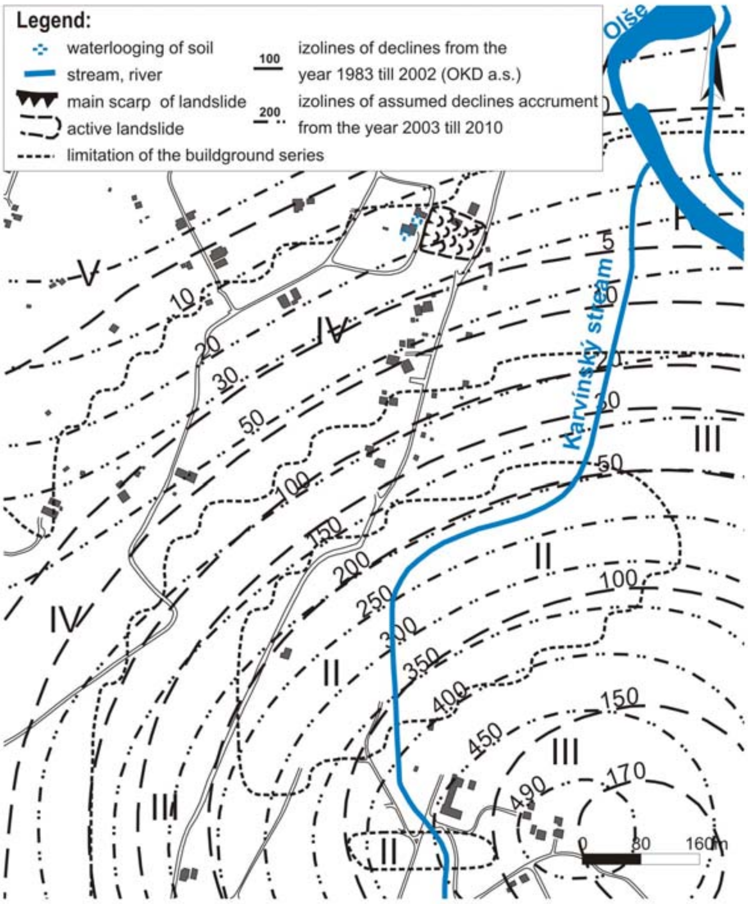

Fig. 5. Subsidence caused by undermining during 1983 – 2002 and the forecast increase in sinking by 2010 with marked position of the slope deformation.

From evaluation point of view the ***ground deformation parameters*** a representative point was selected on the surface of the slope deformation Doubrava Ujala. The reason for this is the extensive surface area of undermining related to the small area of the slope deformation, while the ground deformation parameters within this landslide do not change. Based on extrapolated values in the above mentioned time periods, changes in ground deformation parameters were noticed in the landslide, i.e. inclination, horizontal proportional deformation in the direction and perpendicularly to the subsidence trough slope gradient direction, curve radius and subsidence. Despite the parameters being related to a point, they express spatial evaluation, which may be already deduced from the definitions of the individual parameters (See below). Fig. 6 shows gradual worsening of the ground deformation parameter values, which was not sufficient to move the given area from the fifth to the fourth group of building sites in the period before 2005 (according to ČSN 73 0039 Standard).

The chart of ground deformation parameters displays the trend of subsidence, inclination, horizontal proportional deformation and curve radius in the slope deformation Ujala, while the beginning of deformation may be observed between 1995 and 2000. The subsidence characterized as the vertical component of spatial movement of a point in a subsidence trough rose to a relatively low value of 3.4 cm in 2005. The inclination of the ground from zero value in 1995 grew up approximately linearly to the final 0.4.10^{-3} rad, which may be interpreted on two points on the surface in a way that the one below which a subsidence trough began to develop dropped lower than the second one, which has not got to the influence of the arising subsidence trough yet. The horizontal proportional deformation, i.e. proportional longitudinal change of a part of the subsidence trough in the horizontal direction reached the value of 0.4 at the end of the observed period. This positive value may be confirmed by the above mentioned interpretation of the ground inclination as it expresses the initial (low value) elongation of the ground observable in the upper part of the subsidence trough slope. The curve radius values also confirm the fact of a forming subsidence trough. The pronounced positive values from 2000 and 2005 reflect the localization of the centre of the osculating circle of curvature below the ground surface, i.e. *convex curvature* of the ground observable in the upper part of the subsidence trough slope.

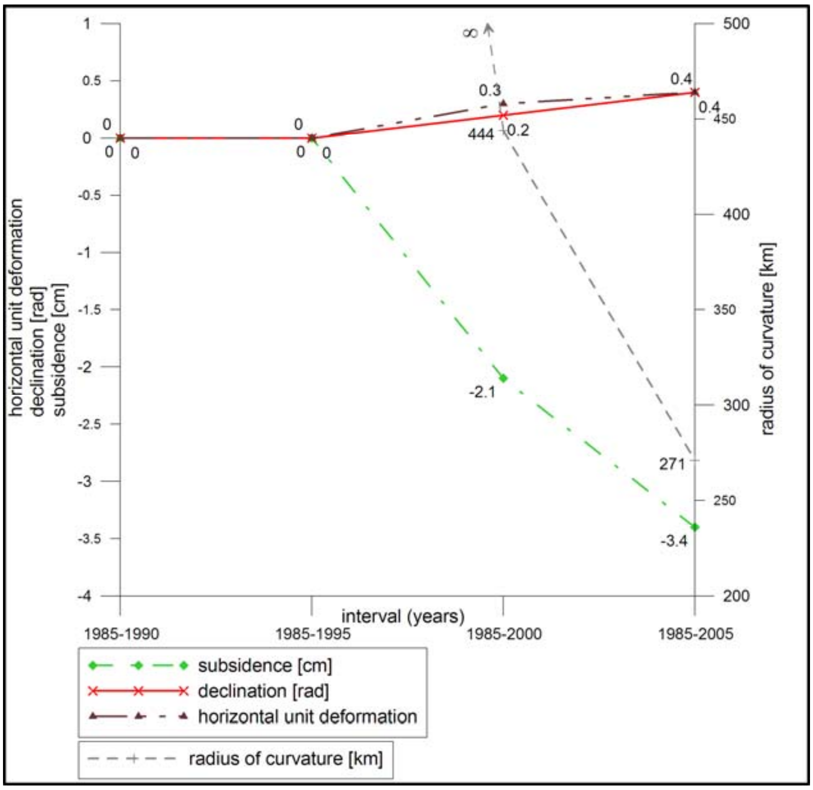

Fig. 6. Chart of changes in the ground deformation parameters in the slope deformation Ujala during the observed time period.

The slope deformation Doubrava Ujala is currently still active, which is evidenced by regular measuring using the method of precise inclinometry in two holes in the landslide body and at the same using the method of zone extensometry in the place of main scarp.

Geotechnical monitoring using the method of precise inclinometry [10] was applied to measure movements on the shear zone. Measuring was carried out in four holes which are fitted with special grooved casing. The borehole bottom should be located below the deepest slipping plane, in the so-called reference depth. A rod probe is lowered as deep as the borehole bottom into such a fitted borehole, and next it is pulled upwards in intervals determined in advance (0.5 m, 1 m), while deviation from the vertical is registered. At the first measuring, the orientation of the bore course is executed in idle condition. If movement occurs on the slipping plane, which causes deflection of the casing, measuring may identify its depth as well as the size of the movement. The implemented measuring registered the movement activity as deep as 9.5 m in the selected inclinometric borehole IV-2 in fig. 7, which corresponds with the identified geological structure of the slope deformation verified by previous borehole work.

During the selected time period the movement values range from 213– 230 mm. Their largest increase was registered between March and May 2007, namely in both pairs of the monitored points. On the point pair D - D´ there was a rise from 152.6 to the value of 213.7 between July and September 2007, while this maximum value corresponds to the maximum precipitation depth values taken at the nearest (with regard to the landslide) rainfall gauging stations and may be their consequence (fig. 8). On the second selected point pair B - B´ this maximum of rainfall did not show, which may be explained, for example, by lower permeability of the slope material in the bedrock of both points. Both point pairs are situated in the direction of the sliding slope gradient. Nevertheless, both a decrease and an increase in the mutual distances may be noticed during the monitored time period. This variability in distance that almost does not correlate with the rainfall values [7] may be especially caused by changes in the state of stress due to arising impacts of undermining or fluctuation of the ground water level, or combination of both. Moreover, there may be other factors and influences, which are difficult to determine.

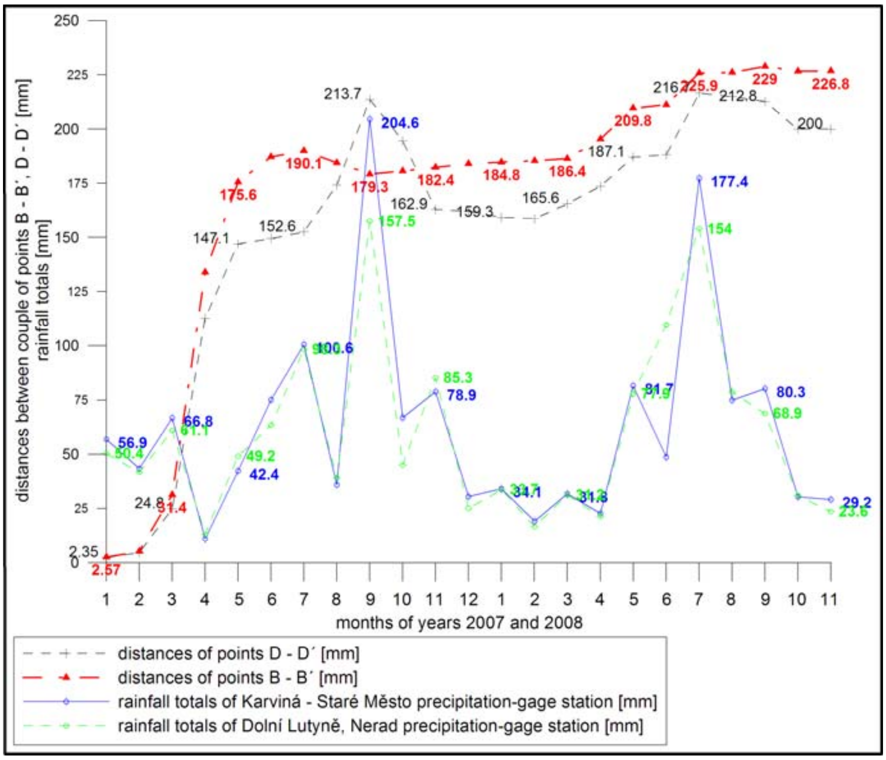

Fig. 7. Exact inclinometric measurements on the Doubrava Ujala slope deformation – difference of accumulated horizontal constituents.

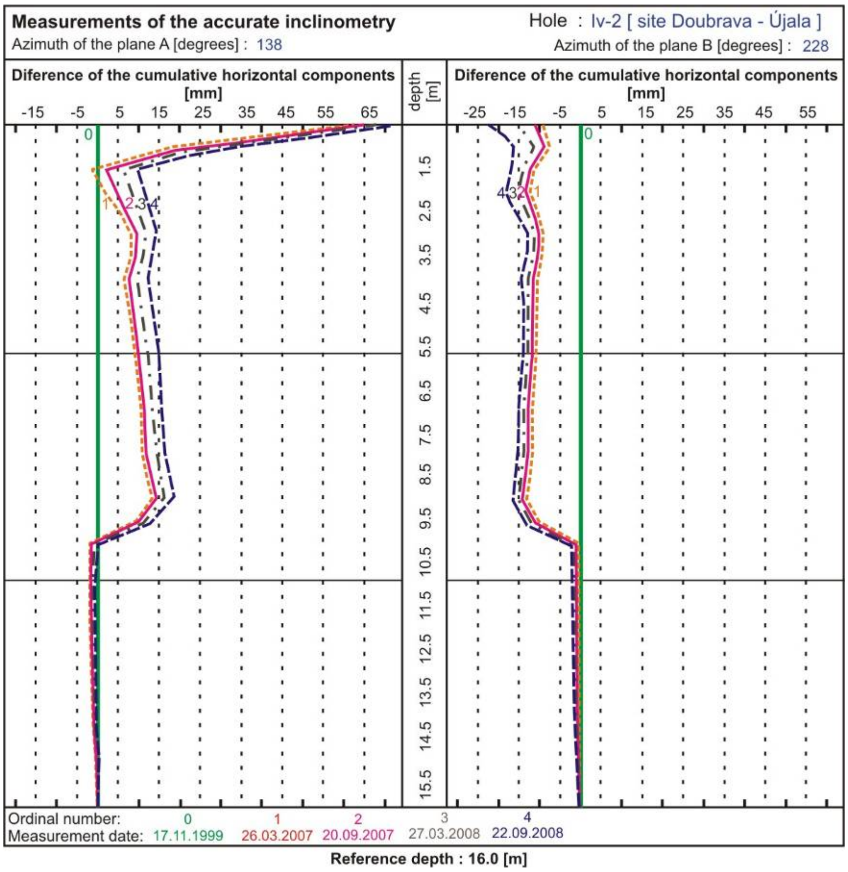

Fig. 8. Chart of measured landslide movements and monthly precipitation depth from two rainfall gauging stations nearest the slope deformation Doubrava Ujala during the observed period.

Conclusion

The stability situation of the slope deformation Doubrava Ujala has been assessed comprehensively from the point of view of the impacts of undermining and rainfall, being significant factors considerably influencing the slope movements. The activity was registered on the tear edge of the slide using the method of zone extensometry in regular monthly intervals.

The slope deformation Doubrava Ujala is an example of a forming action of advancing subsidence trough onto the already existing landslide. By 2000 the landslide had been mainly mobilized by pronounced rainfall and melting of snow, or by concurrent melting of the rock massif in the spring. It was also the change in the vegetation cover that had a probable impact on the activity as grown trees had been cut down and which may have had influenced changes in the hydrogeological conditions.

Since 2000 the impacts of undermining have become to show in the area of the slope deformation. Climatic influences have ceased to be the only destabilizing factors; their action still has a significant role, though. This action is apparent from the chart of measured movements and rainfall in March, April and less in May 2007, when there was the largest increase between the observed points on the tear edge of about 15 cm. The next rise in the distance representing the movement of one point from the pair (e.g. D) from the second one (D´) is probably related to the extreme rainfall in September 2007 with regard to the fact that during the following measuring the distance between the points D - D´ is comparable with the value before the extreme rainfall.

With regard to the almost identical orientation of the slope movement and the subsidence trough slope even relatively small sinking may be probably identified in the distance increase curve between the points B - B´. It is the case of the period from September 2007 to March 2008, when there is a distinct and gradual rise in the mutual distance B - B´.

At the next development of the subsidence trough towards the examined slope deformation and at keeping the almost identical gradients of their slopes, the landslide inclination will grow. It is quite probable that this fact shall cause the activation of the deepest slipping planes, which may have devastating consequences on the houses and garden rooms, road and the buried services situated in the lower part of the slope. Combining the impacts of undermining with extreme rainfall or high precipitation depth at concurrent melting of snow may cause an accelerated movement on the shear zone.

Acknowledgement *The publication was supported by the grant project GAČR – 105/07/1308.*

References

[1] Bednarik, M., Pauditš P.: Different ways of landslide geometry interpretation in a process of statistical landslide susceptibility and hazard assessment: Horná Súča (western Slovakia). case study, *Journal Environmental Earth Sciences, Springer Berlin, Heidelberg, 2009.*

[2] Bradáč, J.: Effects of undermining and protection of buildings, *part I. and II. Ostrava, Dům techniky, 1999.*

[3] Černý, I.: Manifestations of mining in the Karviná section of OKR. In: *Conference proceedings. Mining Ostrava, Mining Society*, *ČSVTS, Ostrava, 1987, pp. 110 – 119.*

[4] ČSN 73 0039: Design of structures in undermined areas. *Basic Regulations. 1989.*

[5] Dopita, M. et al.: Geology of the Czech section of the Upper-Silesian Basin. *Ministry of the Environment, Prague, 1997.*

[6] Hulla, J., Šimek, J., Turček, P.: Soil mechanics and foundation engineering. *Alfa, Bratislava, 1991, 336 pp.*

[7] Kopecký, M.: Impacts of climatic and hydrogeological conditions on landslide formation. *Doctoral thesis*, *Bratislava, 2001.*

[8] Malgot, J., Baliak, F., Mahr, T.: Prognosis of coal mining impacts in the Handlovo deposit on the environment. In: *Proceedings of Engineering geology and energetic construction*, *ČSVTS Brno, 1985, pp. 235-242.*

[9] Marschalko, M., Fuka, M., Třeslín, L.: Influence of Mining Activity on Selected Landslide in the Ostrava-Karviná Coalfield. *Acta Montanistica Slovaca, číslo 1, Ročník 13 (2008). Košice, pp. 58-65, 2008.*

[10] Marschalko, M., Fuka, M., Třeslín, L.: Measurements by the Method of Precise Inclinometry on Locality Affected by Mining Activity. *Archives of mining science*, *Polish Academy of Sciences, vol. 53, no. 3, pp. 397-414, 2008.*

[11] Marschalko, M., Hofrichterová, L., Lahuta, H.: Utilization of Geophysical Method of Multielectrode Resistivity Measurements on a Slope Deformation in the Mining District. In *VIIIth International Scientific Conference, SGEM 2008, Modern Management of Mine Producing, Geology and Environmental Protection, Volume I.* 16 - *20 June 2008, Sofia pp. 315-324, 2008.*

[12] NEŠVARA J., Geotechnical particularities of undermined territories, In: *Proceedings – Effects of mining on railways*, *DT ČSVTS, Žilina, 1985.*

[13] Novák J., Sedlák V.: On the issue of mining impact limit angle determination in a subsidence basin. In: *Acta Montanistica Slovaca. Volume 9 (2004), number 2, 2004, pp. 85-89.*

[14] Seznam.cz a.s. [online], [quoted on 5. 11. 2007] http://www.mapy.cz

[15] Zmítko, J.: Environmental protection as for coal mining in SHR. In: *Modern methods of rock and environment evaluation*, *III., UK Bratislava, 1989, pp. 159-167.*

[16] Žídková, S. et al.: Subsidence during estimated mining between 1996 and 2010, *Karviná section of OKD – MS IMGE, Ostrava, 1996.*