OPTIMUM METHODOLOGY OF HARD STRUCTURES RESEARCH IN THE MOST BASIN CONDITION

OPTYMALNA TECHNOLOGIA BADAŃ SKAŁ TRUDNO URABIALNYCH W ZAGŁĘBIU WĘGLOWYM MOST

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The Brown Coal Research Institute is the participant of the European Commission - Research Fund for Coal and Steel project "Bucket wheel excavators operating under difficult mining conditions including unmineable inclusions and geological structures with excessive mining resistance" The geological problems are the important part of the project solving. The article briefly summarises geological situation of the Most Basin, situation of coal mining and geotechnical parameters of hard rocks. The main attention is devoted to the optimum methodology of geological and geophysical survey of hard rocks..

Keywords: bucket hard rocks, geology, geophysics, survey

Brown Coal Research Institute jest partnerem projektu realizowanego w ramach Funduszu Badawczego Węgla i Stali „Praca koparek kołowych w warunkach występowania w urabianym ośrodku utworów o nadmiernych oporach urabiania jak i wtrąceń nieurabialnych" Problematyka rozpoznania geologicznego stanowi ważną część projektu. Artykuł krótko podsumowuje sytuację geologiczną zagłębia, wydobycie węgla i parametry geotechniczne skał. Główną uwagę poświęcono optymalnej metodologii badań geologicznych i geofizycznych skał trudno urabialnych.

Słowa kluczowe: skały trudno urabialne, geologia, geofizyka, ankieta

INTRODUCTION

The Brown Coal Research Institute is the participant of the European Commission Research Programme of the Research Fund for Coal and Steel project "Bucket wheel excavators operating under difficult mining conditions including unmineable inclusions and geological structures with excessive mining resistance.

The main aim of the project is to develop solutions aiming at as large as possible decrease of bucket wheel excavator failure frequency. That is why it was necessary to gain knowledge about hard rocks parameters and to prepare optimum methodology of these structures survey.

The first step of the research was realised from 2015 to 2016. It was summarisation of geological situation of the Most Basin, locating of the Most Basin hard rocks, and characteristic of the main parameters of these rocks. The second step of the research was realised from 2016 to 2017. It was testing of geophysical and drilling survey methods in mining localities of the Most Basin, primarily in the Bílina open pit mine. The result of this research is the determination of optimum methodology of hard structures research in the Most Basin condition.

The progress and results of this research are briefly described in this article.

GEOLOGICAL SITUATION OF THE MOST BASIN

The sedimentation in the Most Basin began in the Eocene period when several rather small depressions were gradually filled with gravels, sands and variegated silts and clays. These materials were deposited on mostly weathered basement represented by Cretaceous and Permocarbonicerous sediments and crystalline rocks of the Krušné hory Mountains. Individual depressions are thought to have been functioning most probably as lakes with outlets. This fluviolacustrine sedimentation was during the Oligocene interrupted by volcanic activity which, during the first volcanic phase, caused the formation of the Doupovské hory Mts. and the České středohoří Mts. Together with volcanism some new depressions were formed or the original depressions began sinking to the filled with volcano – detrital material. Another interruption of sedimentation is believed to have occurred during the Early Miocene when lakes with outlets and erratic sedimentation were formed. More solid products of weathering derived from neovolcanites and the majority of underlying units were deposited during this period. The fine sedimentation was disturbed by supply of coarse detrital material from the south.

Layers of the productive series in the roof were deposited in a shallow whole – basin lake which became gradually overgrown with vegetation due to favourable climatic conditions. Among huge conifers, the trees of genus Taxodium are thought to have been the most abundant. This productive period occurred during the Early Miocene which led to the formation of a thick seam which in the Žatec region, at the southern margin of the basin, was split into several unmineable benches. Mineral assemblages then originated under the above mentioned conditions and were completely confined to a coal seam and isochronous with the origin of the coal. The origin of mineral assemblages confined to the so – called overlying clays was also affected by the underlying coal seam. These rocks consist of mostly grey and or brown lacustrine aleurolites, i. e. clay sediments with a silty fraction and locally containing huge nodules of clay ironstone. These sediments were deposited in deeper lake in covering the entire basin in which several streams have emptied (the Žatec delta, the Bílina delta). These overlying layers were affected by second volcanic phase which brought in pyroclastic material. Quaternary period is characteristic of formation of loess, development of the recent river system and the origin of oxyhumolites during alternating frost penetration of the upper parts of the coal seam at outcrops.

The overburden soils and rocks lying over the coal seam in the research area consists of Libkovické layers of siltstones and complex of sand-clay sediments of the fossil river delta, which together with the coal seams are ranked with the Holešovické layers. These rocks are the source of all types of hard rocks.

SITUATION OF BROWN COAL MINING

Brown coal is mined in four general mining localities which in principle differ in geological terms, overburden rocks parameters, hard rocks occurrence and partially in the parameters of acquired coal. This causes different problems during overburden rocks exploitation.

The mines of Vršany and ČSA are currently owned by mining company SEVEN ENERGY and the mines of Bílina and Libouš are currently owned by mining company North Bohemian Mines. The open mine of ČSA finished mining of overburden rocks in 2016 and the open pit mine Libouš has practically no problems with hard structures. The mines of Bílina and Vršany are quite similar, but the mine of Bílina is larger, the geology of this mine is more complicated and hard structures of this mine are more dangerous. The Bílina open pit mine is the largest open pit mine in the Czech Republic with prospect of long term mining, occurrence of the most danger hard rocks. So we selected the Bílina mine as the optimum experimental locality. We realise complex research of possibilities of geophysical methods and different types of borehole drilling. The research was realised in the cooperation with geologists of the Bílina Mine.

GEOLOGICAL SITUATION OF THE BÍLINA MINE

The upper horizon consists of Quaternary rocks - topsoil, loess and loess loams. These rocks are selectively mined and used during restoration works. Underlying Tertiary horizon consists of brown, grey and grey – brown montmorillonite – illite – kaolinite clays and claystones. The thickness of this layer is about 60 m. It is a result of the lake sedimentation.

The underlying horizon is the main layer of the Bílina mine overburden. It consists of yellow sandy clays and clayey sands. The thickness of this horizon is more than 150 m. This is a result of river delta sedimentation. This horizon is an important source of unmineable inclusions and geological structures with excessive mining resistance.

Thickness of the coal seam is about 30 m. Underlying rocks consist of lower Tertiary grey claystones and Cretaceous marls [3].

The geological profile of the Bílina Mine is shown in the figure 1 [4]. The situation of the Bílina mine overburden cuts is shown in the figure 2 [4]. The main types of the overburden rocks are clays, sandy clays and sands. The value of comprehensive strength ranges between 0 (sands) to 2.5 MPa, the content of clay minerals ranges between 10 to 70%, the value of density ranges between 1900 to 2050 kg/m^3 and the texture of rocks is layered or clastic.

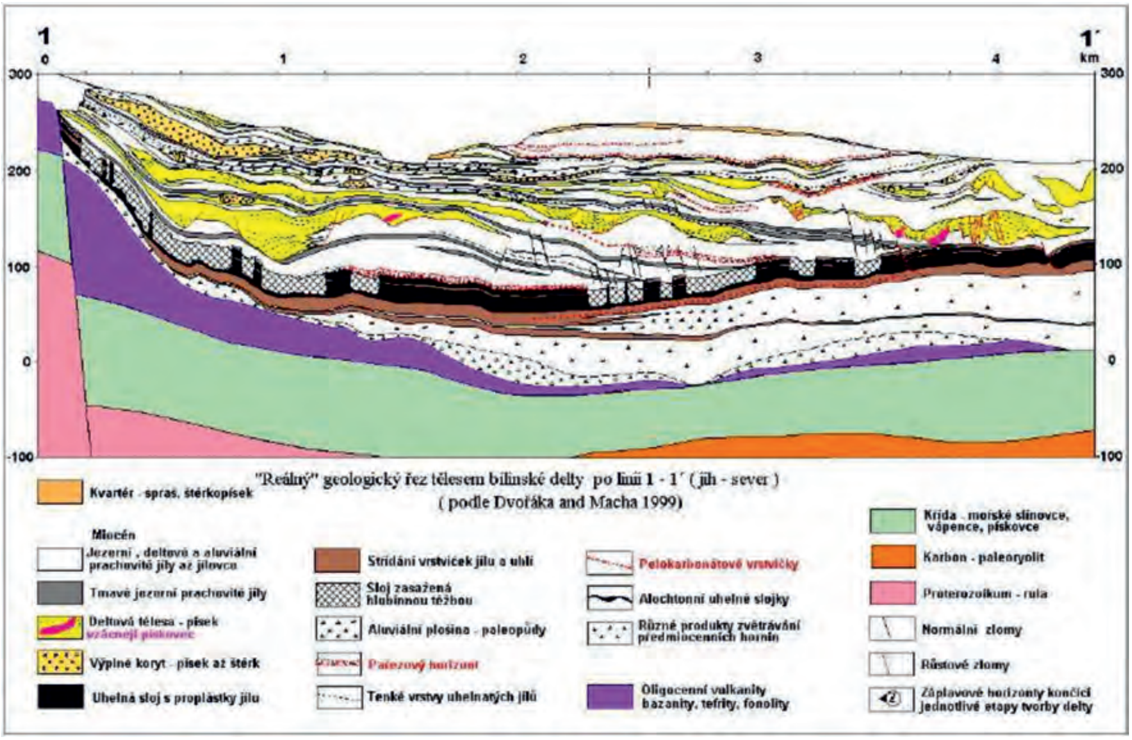

Fig. 1. The Bílina Mine – geological situation of overburden cuts
Rys. 1. Kopalnia Bílina – sytuacja geologiczna w piętrach nadkładowych

Fig. 2. The Bílina Mine – situation of the overburden cuts
Rys. 2. Kopalnia Bílina – piętra nadkładowe

Tab. 1. Main parameters of the Bílina mine hard structure
Tab. 1. Główne parametry utworów trudno urabialnych w kopalni Bílina

Material type	Sandstone with carbonate cement	Clay with high content of carbonate	Carbonate concretions
Continuous	No	yes	No
Material type (source)	sandy claystone, sands	claystone	clays, claystones
Boulders	yes	**No**	yes
Size distribution (m) (min – mode – max)	0,2 – 1,5 – 10 (exceptionally 15)	0,1 – 0,2 – 0,4	0,2 – 0,4 - 1
Shape	roundness, slabs	layer	Roundness, slabs
Composition Mineral A	quartz	kaolinite	siderite
Mineral B	dolomite	siderite	kaolinite
Mineral C	siderite	quartz	quartz
Mineral D	kaolinite		
Density (kg/m3)	2200	2200	2500
Compressive strength (MPa)	15 – 40 (exceptionally 60)	5 - 15	5 - 40
Resistivity (Ωm)	200	100	150

Occurrence, geological situation and characteristic of hard structures

Four types of hard structures were discovered during the whole period of mining process in the Bilina mine.

Thin (thickness from 0.1 to 0.4 m) small continuous layers of clay with high content of carbonates are the first type of hard structures. These solid-rock positions are problematic for extraction, although mineable with large-scale excavator technologies. The occurrence of this hard rock type is connected with the base of upper Tertiary brown – grey clays (lake sedimentation).

Pelocarbonatic concretions (thickness from 0.5 to 2 m) are the second type of hard structures. These solid-rock inclusions are more problematic for extraction, although mineable with any excavator technologies. The occurrence of this hard rock type is connected with the base of upper Tertiary brown – grey clays (lake sedimentation).

Sandstones with dolomite cement (thickness from 0.5 to 15 m) are the third type of hard structures. It is the most frequent and the most dangerous hard structure type. This sandstone with dolomitic cement, which reaches up to 30% volume of solids can reach surface sizes of 100 to 10 000 m^2. These solid-rock inclusions are extremely problematic for extraction and blasting is necessary in most cases. The occurrence of this hard rock type is connected with yellow sands and sandy clays (river delta sedimentation).

Sandstones with limonite cement (thickness from 0.5 to 2 m) are the last hard structure type. This type is not so danger because it is quite rare in the Bílina mine overburden cuts [4].

The main parameters of the Bílina mine hard structures are shown in the table 1. The situation of the Bílina mine sandstones (after blasting and before crushing) is shown in the figure 3.

We started the testing of survey method after finishing of the Bílina Mine hard structures research. The large boulder of sandstone with dolomite cement is shown in the figure 3.

TESTING OF SURVEY METHODS

We tested geophysical methods, core drilling and full-hole drilling. Results are shown below. The description of detailed results is shown in the literature [5], [6].

Geophysical survey

We tested geoelectric survey, georadar method and seismic survey [1] in the Vršany mine and primarily in the Bílina Mine.

Geoelectric survey

The Brown Coal Research Institute applied this method in the Bílina mine. The method is problematic because of similar values of sand resistivity and hard structure resistivity.

Georadar method

The company Geonika Ltd. applied this method in the Vršany locality. The results were very good, but the depth of the survey was only to about 10 m. The mining companies required the depth of about 30 m (thickness of the overburden cut) [2].

Seismic survey

The Brown Coal Research Institute (cooperation with the company Geonika Ltd.) used this method in the Bílina and Vršany localities. The results of this method application were the most interesting.

The results of overburden cut surface seismic survey before mining are shown in the table 2. The comparison of seismic survey interpretation and real situation verified by mining is shown in this table.

The success rate of this survey was 75 %. Application of seismic method is quite expensive. Seismic survey is prospective as a supplementary method.

Research of borehole drilling methodology

We realised the evaluation of results of core drilling, full-hole drilling and borehole geophysics: Experimental localities were the open pit mine Bílina (full-hole drilling) and the open pit mine Vršany (core drilling).

The main parameters of core drilling

Depth >300 m
Core - yes
Borehole geophysics - possible
Prize of drilling 2000 – 3000 Kč/m
External provider
Speed of boring about 10 –30 m/day

Full hole drilling

Depth <30 m
Only crushed stone
Borehole geophysics
Drilling 100 Kč/m
Own drill machine
Speed of boring – 800 m/day

Core drilling is very expensive, very slow, but we can gain very good core and very good depth of drilling. Full-hole drilling

Fig. 3. Boulder of sandstone with dolomite cement
Rys. 3. Głaz piaskowcowy ze spoiwem dolomitowym

Tab. 2. Determination of the effectiveness of obtained results of seismic surveys
Tab. 2. Określenie skuteczności otrzymanych wyników badan sejsmicznych

No. of anomaly	Seismic interpretation	Real situation according to mining
A 1	Medium intensive anomaly	• situated in evaluated place • hard structure (sandstone boulder)
A 2	Very intensive anomaly	• situated in evaluated place • hard structure (sandstone boulder)
A 3	Medium intensive anomaly	• situated in evaluated place • water bearing sand (quick sand)
A 4	Medium intensive anomaly	• situated in evaluated place • hard structure (sandstone boulder)
A 5	Very intensive anomaly	• situated in evaluated place • hard structure (sandstone boulder)
A 6	Very intensive anomaly	• situated in evaluated place • hard structure (sandstone boulder)
A 7	Very intensive anomaly	• situated in evaluated place • hard structure (sandstone boulder)
A 8	Medium intensive anomaly	• situated in evaluated place • contact of water bearing sand – claystone

Yellow colour – occurrence of hard structure

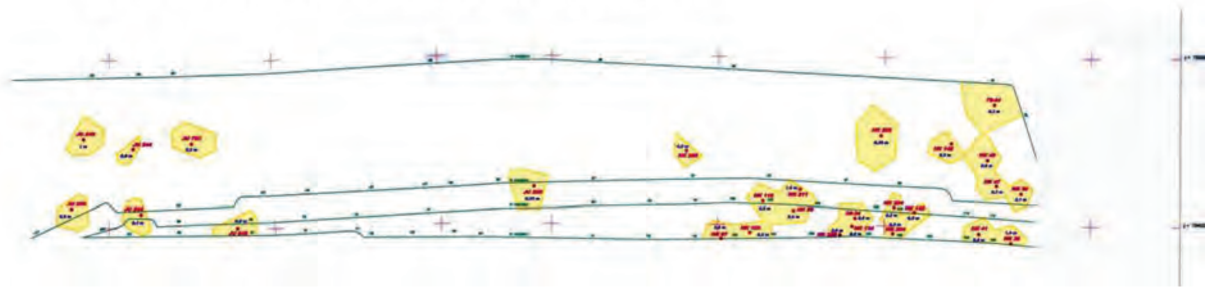

Fig. 4. Result of the overburden cut surveying (borehole survey)
Rys. 4. Wyniki przeprowadzonych badań w piętrach nadkładowych (badanie otworami wiertniczymi)

is very cheap and quick, but the quality of geological profile and the depth of boring are bad. Borehole geophysics is the same in the case of core drilling and full - hole drilling.

It is not possible to change parameters of core drilling, but the situation of full-hole drilling is different. It is possible to increase the depth of drilling up to 60 m because of application of a new drilling augers and new auxiliary compressor. It is also possible to detect parameters of drilling (bit – pressure, energy, speed of drilling, turning) including digital record and it is possible to do sampling of crushed stone.

The results of the hard rocks evaluation (both of drilling methods) are shown in the figure 4 and the situation of the drilling in the Vršany Mine is shown in the figure 5.

CONCLUSION

The result of the research is the recommendation of the following survey methods complex for the area of the Most Basin.

It is combination of full-hole drilling (with measuring of drilling parameters) and seismic survey (as a supplementary method). It is very efficient methodology. Only occurrence of water bearing horizons is problematic.

Very prospective method is to localize georadar in a the bucket with continuous measuring and depth of survey about 2 – 3 m. Development of this equipment is too difficult at this stage and the research needs to be continued, especially since mining companies are interested in this solution.

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Fig. 5. Situation of core drilling in the overburden cut of the Vršany Mine
Rys. 5. Wiercenie rdzeniowe otworów w piętrach nadkładowych w kopalni Vršany

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