Acta Geodyn. Geomater., Vol. 7, No. 3 (159), 349–354, 2010

PROJECT OF A ROCK MASS SURFACE DEFORMATION MONITORING SYSTEM IN THE WALBRZYCH COAL BASIN

Jan BLACHOWSKI [1], Wojciech MILCZAREK [1] * and Stefan CACOŃ [1, 2]

[1] *Wroclaw University of Technology, Institute of Mining Engineering, Teatralny 2, 50-051 Wroclaw, Poland, phone +48 71 320 68 73, e-mail: jan.blachowski@pwr.wroc.pl*
[2] *Wroclaw University of Environmental and Life Sciences, Institute of Geodesy and Geoinformatics, Grunwaldzka 53, 53-357 Wroclaw, phone +48 71 320 56 17, e-mail: stefan.cacon@up.wroc.pl*
**Corresponding author's e-mail:* wojciech.milczarek@pwr.wroc.pl

(*Received* May 2010*, accepted* August 2010)

ABSTRACT
Underground mining hard coal in the area of Walbrzych ended in the late 90-ties of the last Century. Its effects on the state of heterogeneous rock mass (complicated geology and tectonics) is still evident and not known precisely. Analysis of levelling measurement results carried out after the end of mining activity (1997-2008) for part of the former "Thorez" mine indicates increased rock mass surface activity in tectonic zones. With the aim to continue monitoring of the rock mass surface movements on the area of former mining grounds a research satellite GPS network (7 points) has been established and supplemented with new precise levelling lines linked to the existing 2nd class levelling network. Location of these points takes into consideration, among other things geology and tectonics of the Walbrzych Basin and areas of underground mining activity.
In this paper work on the design and construction of the research satellite GPS and levelling networks has been described and the first measurement campaign carried out in September 2009 has been presented. Its results will form foundation for complex studies of rock mass surface in the next measurement epochs.

KEYWORDS: underground mining, deformation monitoring, satellite and levelling research network

1. INTRODUCTION

Analysis of the results of levelling measurements carried out in the final years of underground mining and in the period after the end of mining operations (Blachowski et al., 2009) indicate rock mass surface movements in the zones of main local tectonic faults in the area of former mining grounds in the city of Walbrzych (SW Poland). This activity is a potential threat to surface objects (e.g. buildings, infrastructure) and is also taken seriously by local authorities planning new spatial development of former mining grounds.

Further studies and identification of present day rock mass surface movements in the Walbrzych Coal Basin requires periodic geodetic measurements of former mining grounds to collect necessary quantitative data. With this intention a project of a monitoring system has been developed and a monitoring network constructed in the area of Walbrzych. Its main aim being reliable description of present day activity of rock mass surface and tectonic faults. The project is a continuation of work presented in (Blachowski et al., 2009) concerning analysis of rock mass surface deformation in one of protection pillars in Walbrzych. The new modernised GPS and precise levelling network was measured for the first time in September 2009.

2. DESCRIPTION OF THE RESEARCH AREA

The former Walbrzych Underground Hard Coal Mines are located within the administrative borders of the Walbrzych District (*Poviat*) in the Dolnoslaskie Voivodeship (SW Poland). The mines have been closed in succession between 1993 and 1998 (Piatek and Piatek, 2002). Mining activity had taken place in four mining grounds: "Bialy Kamien" established for the "Thorez" mine, "Kuznice" for the "Victoria" mine and "Gaj and Podgorze" for the "Walbrzych" one. Location of the mining grounds in Poland and the GEOSUD research network (Chapter 3.2) has been shown in Figure 1. The decision to end coal mining has been caused by very difficult geological and mining conditions, which made the operation hazardous and unprofitable.

2.1. GEOLOGY

Coal deposits of the Walbrzych Coal Basin are associated with the Upper Carboniferous deposits. Four coal-bearing geological complexes have been identified: Walbrzych, Bialy Kamien, Zacler and Glinik formations. Altogether 80 coal seams have been documented, among these 30 in the Walbrzych layers and 48 in the Zacler ones. There are two main coal basins, the larger Sobiecin and the smaller Gorce synclines separated by the Chelmiec magma intrusion (laccolite). The whole area is divided by numerous

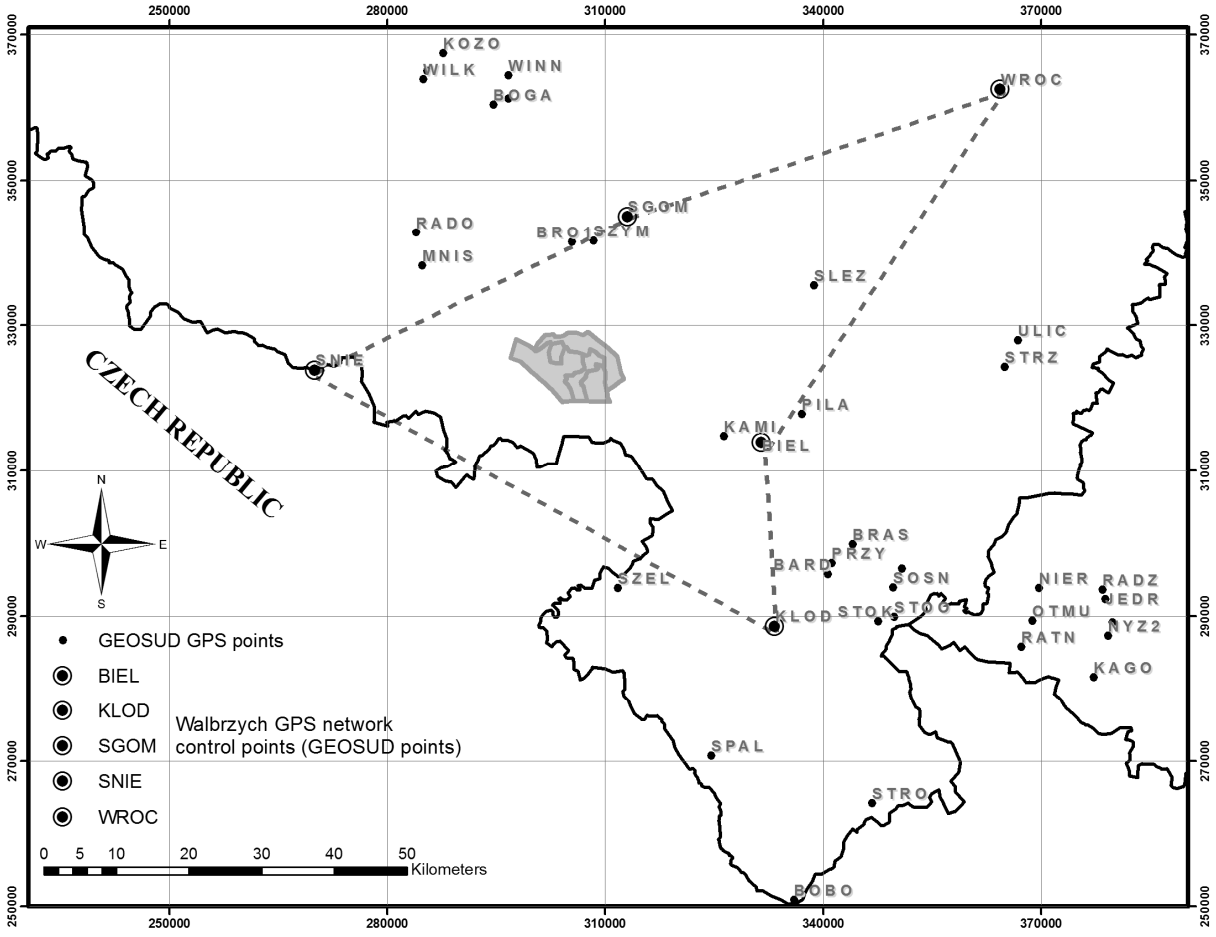

Fig. 1 Location of former Walbrzych coal mining grounds and the GEOSUD research network points.

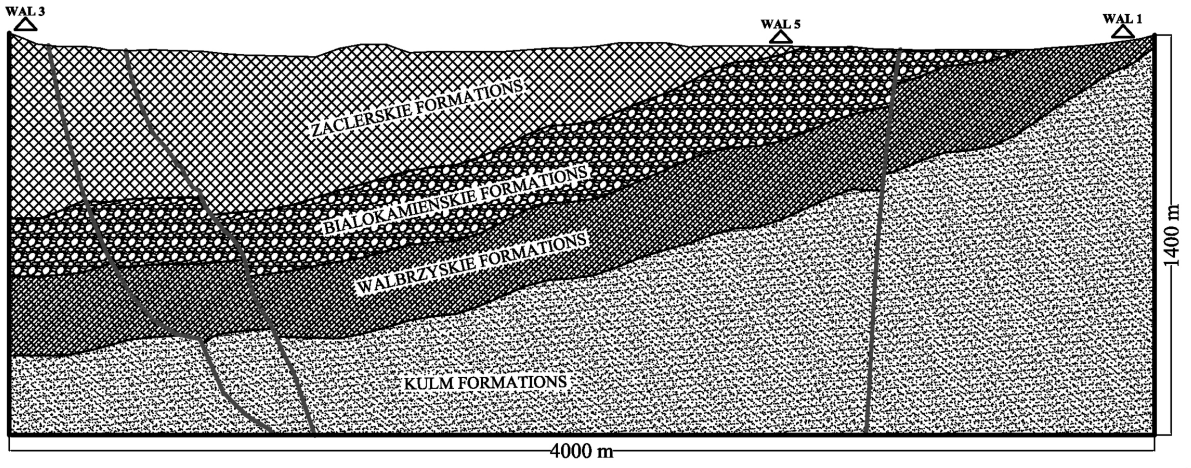

Fig. 2 Cross-section through the Walbrzych coal basin.

tectonic faults extending generally from NW towards SE but many further transformed by intrusions. Dip of coal seams ranges from 30 to 60 degrees in the southern part of the Sobiecin syncline and 30 to even 90 degrees in the Gorce syncline (Kominowski, 2000).

Generalised cross-section through the Walbrzych basin showing main geological units, location of faults and GPS points is presented in Figure 2. The cross-section has been produced from a 3D numerical model developed basing on geological and mining documentations.

2.2. MINING

Mining systems used in Walbrzych mines changed over time. In the 20th Century longwall mining system with wooden roof support was used. Exploited voids (gobs) were fully filled. Several coal layers (panels) were mined at the same time. During the 1970'ties Walbrzych mines used longwall and caving mining system with steel roof support (chocks). Inside protective pillars (e.g. for shafts) full pneumatic fill was used for gently inclined coal layers, whereas steeply inclined ones were mined with longwall system, full dry fill and wooden roof support(Piatek and Piatek, 2002).

Underground mining caused large scale deformations on the surface. Between 1993 and 1998 all the mines have been closed. The decision to end coal mining has been caused by very difficult geological and mining conditions, which made the operation hazardous and unprofitable.

3. RESEARCH NETWORK

The purpose of the proposed network is to detect possible rock mass surface movements including potential activity near main tectonic faults after the end of mining activity. Therefore a combined satellite GPS observations and Total Station measurements approach has been considered. Combination of measurement techniques is a standard approach in studies of surface deformation caused by natural, as well as man made factors (Cacoń, 2001; Pielok, 2002). The aim of the proposed network is to detect active and stabilised parts of the research area.

The following (chapter 3.1.) network design criteria have been taken into account.

3.1. NETWORK DESIGN CRITERIA

When designing a network for geodetic measurements of rock mass surface deformation it is essential to take into consideration that the quality of measurements is affected by two sets of co-dependent factors, namely spatial and temporal factors. The first group includes accurate locations and stability of reference and controlled points, fixed reference system and accuracy of measurements. The second one includes starting time of measurements, interval and period of measurements, and processing time of results (Cacoń, 2001). The most important spatial factors are location and stability of points. Temporal factors are related to the character of the observed phenomena. Thus taking these factors into consideration the design of a proposed control-measurement network should meet the following criteria (Pielok, 2002):

- Location of network points has to correspond to geology and tectonics and rock mass conditions,
- Construction of points has to take into account ground conditions,
- Reference points have to be located outside the expected area of mining influence,
- Location of network points has to correspond with mining operation plans.

3.2. RESEARCH NETWORK LAYOUT AND CONSTRUCTION

The following design assumptions have been made: network consists initially of 7 satellite GPS observation points and connected levelling lines with the target number of 20 GPS points (13 to be constructed at a later stage), selected satellite GPS points from the GEOSUD regional geodynamic network are used as reference points, additional ASG-EUPOS geodetic network points can be used. As a starting point, in the initial stages of the project, satellite GPS network concept presented in (Cacoń and Blachowski, 2006) has been used.

The locations of satellite GPS network points have been chosen with the aid of GIS analyses and take into account: geology, former mining production levels, calculated subsidence for the period of mining activity (Kowalski, 2000), rock mass surface conditions and surface development (Blachowski, 2008). In addition ground conditions and satellite signal reception conditions have been taken into account.

It has been assumed that the planned levelling lines use geodetic network existing in the area i.e.: benchmarks making up 2nd class height network, benchmarks used for control measurements at the time of mining works operations, benchmarks of the 3rd class height network in Walbrzych.

With the aim to observe activity of the rock mass surface 12 additional benchmarks have been constructed in the levelling lines. These have been arranged in pairs located on both sides of each of the selected tectonic faults (Fig. 3). These near-fault benchmarks are to provide data on activity of the main local tectonic zones in the Walbrzych Basin.

The proposed levelling network links all of the 7 satellite GPS observation points (Fig. 3).

The network has been constructed in two stages in July and August of 2009. Construction of the GPS points is based on the design developed by (Cacoń and Kontny, 1994). The points are made of concrete reinforced with 10 mm diameter steel bars and placed

Fig. 3 Location of the new satellite GPS and levelling networks against ortophoto of former mining ground in Walbrzych.

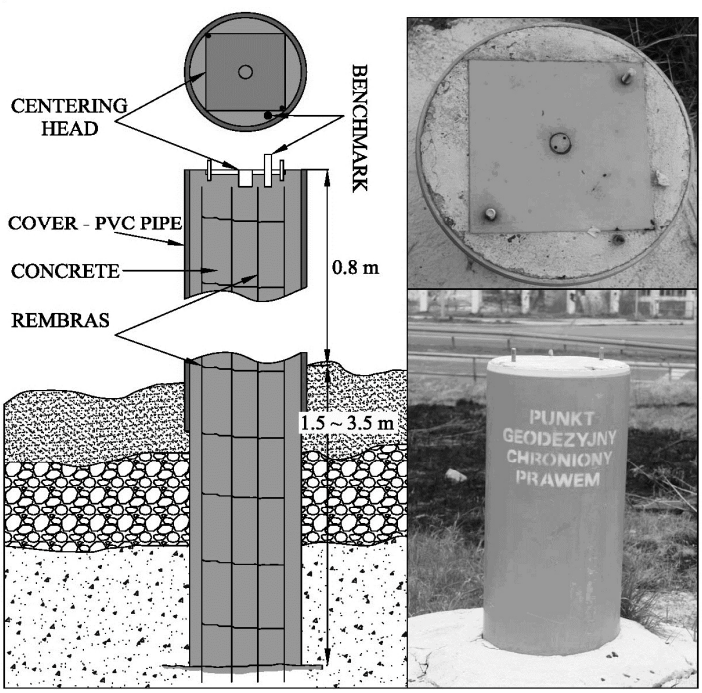

Fig. 4 Construction of GPS observation point. Cross-section (left), actual point (right).

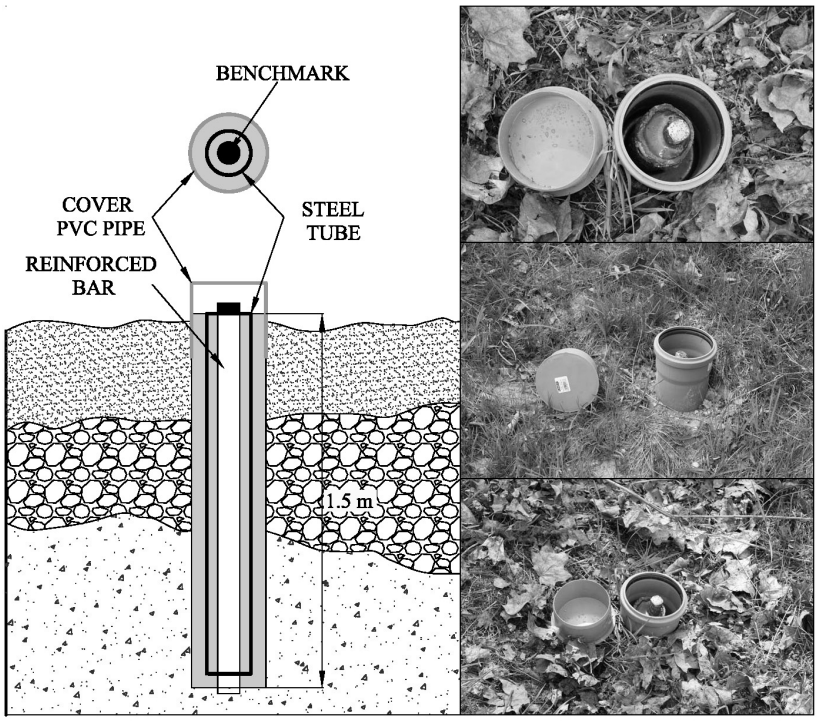

Fig. 5 Construction of benchmark in the near-fault zone. Cross-section (left), Actual benchmark (right).

in the ground, below ground freezing level, to a depth of 1.2 to 3.5 m depending on the individual location. The points reach 0.8 to 1.0 m above the ground and are protected with PCV pipe 0.4 m in diameter. The head is equipped with benchmark and metal plate for forced centring of GPS antenna (Fig. 4).

Construction of benchmarks located in the near-fault zones is presented in Figure 5.

Each point consists of reinforced steel rod 1.5 m long concreted in a steel pipe of 60 mm diameter and 1.3 m length. In addition a cover made of PCV pipe with a lid has been made. The pipe is 100 mm in diameter and 0.25 m in length.

4. MEASUREMENT CAMPAIGN

In September 2009 the first measurement of satellite GPS network was carried out. The measurement campaign consisted of two 10hour static observations on each of the 7 satellite GPS points. Five additional, reference points have been simultaneously measured: WROC (Wroclaw), SGOM (Strzegom), BIEL (Bielawa), KLOD (Klodzko) and SNIE (Sniezka). The following GPS receivers have been used: Ashtech ZXtreme, Ashtech Z-12 and Trimble 4700.

The accuracy of calculated coordinates of observation points in the first campaign is [dx, dy] $\geq \pm 2$ mm at P=95 % confidence level. This indicates that surface movements at the ±2 mm level can be detected at 95 % confidence level in future measurement epochs.

The levelling lines were measured in October 2009. Altogether 23 km of levelling lines were measured using Topcon DL-101C precise digital level and invar rod. The calculated loop closure errors were within ±2 mm with the maximum allowed value for 2^{nd} class levelling network being ±4.8 mm.

5. CONCLUSIONS

In the paper the new research GPS and precise levelling network has been characterised and its importance for future monitoring the state of rock mass surface on former mining grounds in Walbrzych explained. The network consists of 7 GPS observation points linked to selected points of regional geodynamic research network and 12 new ground benchmarks and levelling lines. Location of all the points has been correlated among other things with tectonic faults, areas of former underground activity and spatial development.

The results of measurements carried out in September 2009 will form base for analyses of future measurement campaigns. The accuracies obtained for both precise levelling and satellite GPS measurements suggest that both horizontal and vertical surface movement exceeding of the ±2 mm magnitude can be detected.

The next joint satellite GPS and precise levelling measurement campaign is planned for July 2010. In addition extension of the research network on the whole area of former Walbrzych Coal Basin is planned.

ACKNOWLEDGMENTS

This work has been financed from the Ministry of Science and Higher Education 2009-2010 funds as a research project *Analysis of rock mass surface changes after the end of mining in a selected part of the former Walbrzych Basin* (N N524 465436).

REFERENCES

Blachowski, J.: 2008, Geographical information system of the Walbrzych Underground Coal Mines a way to improve effectiveness and accuracy of mining grounds deformation studies. Scientific Papers of the Wroclaw University of Technology, No 34, Mining and Geology X, Wroclaw, 17–27, (in Polish).

Blachowski, J., Cacoń, S. and Milczarek, W.: 2009, Analysis of post-mining ground deformations caused by underground coal extraction in complicated geological conditions Acta Geodyn. Geomater., 6, No. 3 (155), 351–357.

Cacoń, S. and Kontny, B.: 1994, Measurement and monitoring system for lithosphere deformations of natural and engineering objects in the Sudety Mountains, Proceed of the 1st Turkish Int. Symp. On Deformations, Istanbul, 5-9 September, 97–104.

Cacoń, S.: 2001, The problem of reliability of deformation measurements of engineering objects and rock mass. Wroclaw University of Technology Scientific Papers, 2001. No. 73. 40:85–96, (in Polish).

Cacoń, S. and Blachowski, J.: 2006, Monitoring of ground surface changes following the end of mining with satellite GPS technique, International Global Navigation Satellite Systems Society Symposium, Surfers Paradise, Australia, 17 – 21 July 2006, @http://www.ignss.org/conf2006/review/CACON,%20Stefan%20(24).pdf.

Kominowski, K.: 2000, Geology and hydrogeology, In: Kowalski A. (Ed.), 2000: Mining and surface protection. Experiences from the Walbrzych, Mines, Central Mining Institute, Katowice, (in Polish).

Kowalski, A.: 2000, Mining and surface protection. Experiences from the Walbrzych, Mines, Central Mining Institute, Katowice, (in Polish).

Piątek, E. and Piątek, Z.: 2002, Summary of coal mining history in Lower Silesia from 1434 to 2000, Szczawno Zdrój, @ http://www.boehm-chronik.com/bergbau/gorn1434–2000.pdf.

Pielok, J.: 2002, Studies of ground and rock mass deformations caused by mining. AGH-UST Publishers, Cracow, (in Polish).