APPLICATION OF GPS TECHNIQUE FOR MONITORING OF COPPER BASIN AREA IN POLAND

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Polish Copper Basin is located in South-Western part of Poland, between two towns Lubin and Glogow. The Polish abbreviation for the name of this basin is LGOM. It will be used through the paper. In this area two kinds of influences of mining exploitation on the surface and on the rocks mass there can be distinguished:

- direct influences, caused by displacement of the rocks to the free space created as a result of mining activity
- indirect influences, caused by water escape that, in turn, is a result of draining action of the mines.

For protection of on-ground objects the direct influences are of main significance. On the other

hand, the indirect influences are less important. The latter cause depression of the terrain level which could be dangerous only in a case of considerable unequality of the depressions.

INTRODUCTION

The Since the very beginning of mining activity in this area (ie. since about 1960) investigations and measurements aiming at discover of factors shaping the deformation process have been carrying out there. For determination of the terrain surface movements a precise levelling network of second class was established in the area of LGOM, it was tied to the first-class levelling points. For tasks connected with engineering surveying of the mines as well as for studies of horizontal displacements, a control horizontal point network was also established, in a local reference system of coordinates, called "Pieszkowice".

2. VERTICAL CONTROL NETWORK OF SECOND CLASS IN THE COPPER BASIN AREA

The vertical network covers terrain of area of about 400 km^2. Distances between bench-marks of the network amounts to 1.5-2 km. The first results of measurements from early sixties were devoted to engineering surveying of constructed objects of the basin. The next measurements performed in 1967, 1971, 1975 and further on every 2-3 years discovered that deformations resulting from mining activities took place on the terrain. After the deformations were discovered the time span between successive measurements was shortened to 1-1.5 month.

Detailed analysis of the measurements results from 1971 and later proved that there existed, and what is more, in the degree bigger then it was supposed, the indirect influence of the copper ore deposit exploitation on the terrain surface, caused by the rock mass drainage. The vertical movements which followed the drainage began to extend and cover bigger area, considerably overrunning the area of the direct influences. It caused the necessity of expanding the network. Nowadays, the levelling network covers an area of about 2300 km^2, it consists of 1241 km of levelling poligons, 149 lines and 78 points. Measurement accuracy m_0 of I km of the network amounts to 0.75 to 1.2 mm.

3. HORIZONTAL TRIANGULATION CONTROL NETWORK

The studies of horizontal displacements in the area of LGOM were carried out in the years 1976-88, being repeated every 2-3 year. The studies comprised points of the control classical LGOM network as well as the points belonging to chosen observational lines. The last classical measurements were performed in 1988. The angles of the network were measured with theodolite WILD T-3 ($m\alpha = 5^{CC}$), while the network's sides were measured using electrooptical distance meter (m_d = 5mm +dx10^{-6}). Coordinates of the points belonging to the control network of LGOM were computed in the local system "Pieszkowice". Average value of the mean error for the point positioning does not exceed 20 mm.

On the basis of comparison of the coordinates obtained in 1976 and in 1988, the vertical displacements of selected triangulation points, which were to be used as tying points, were determined. The maximal obtained displacement amounted to 247 mm, and the maximal change of the azimuth was 300^{CC}. Accuracies of these determinations were estimated to be from 8 to 36 mm for the sides, and from 2 to 32^{CC} for angles. On the basis of these results a conclusion of necessity of further measurements in the LGOM area was derived, because of considerable changes of points positions caused by mining activities. An analysis of possible types of further measurements taking into consideration the costs, speed and accuracy was performed and the GPS technique was chosen as an optimal one in the case of these studies.

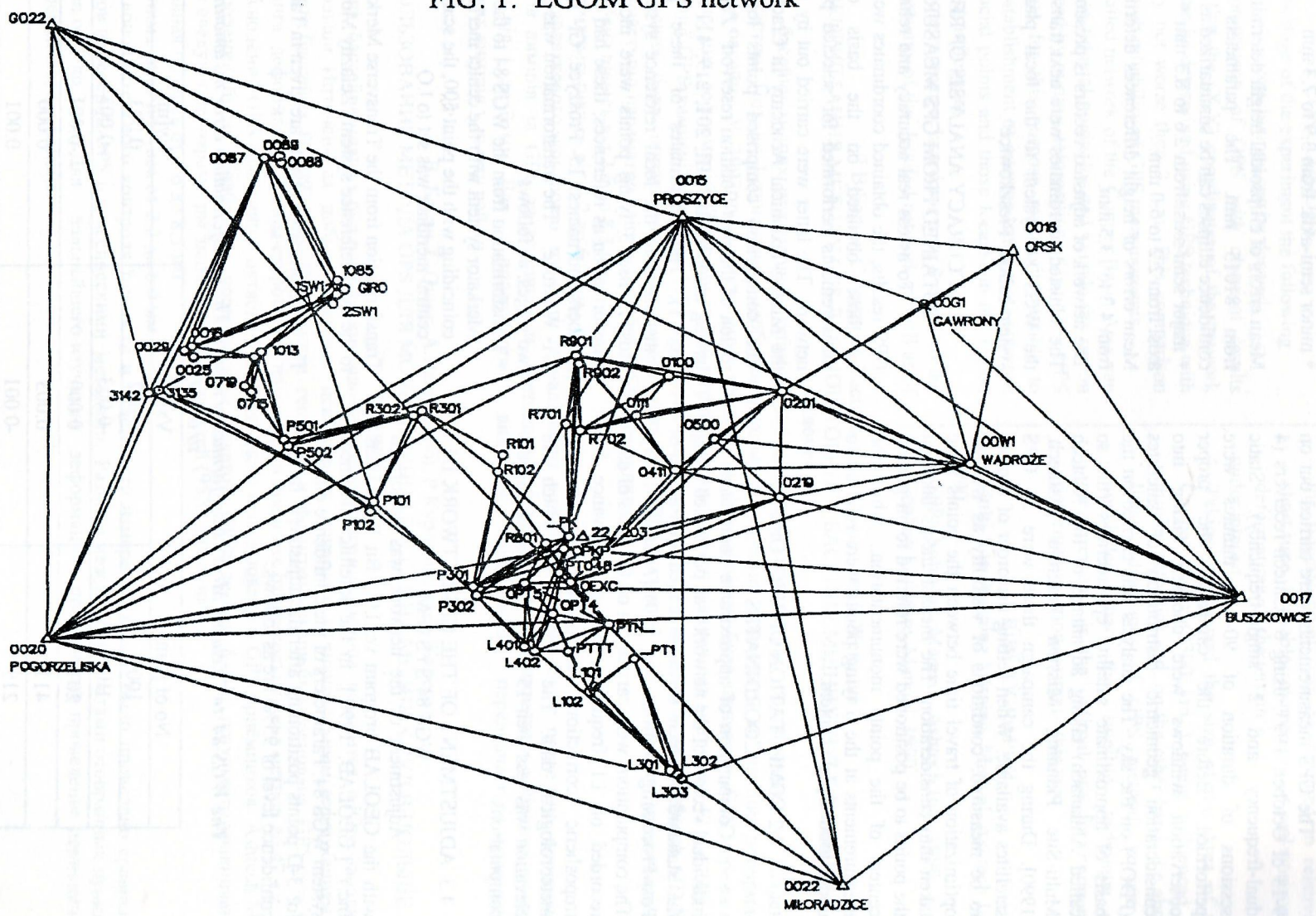
4. 3-D CONTROL NETWORK MEASURED WITH GPS TECHNIQUE

The GPS control network in the Copper Basin area consists of 53 new points. Also 6 existing points of the Polish National Network of the first class have been included to the network, and they were used as tying stations. The GPS network should fulfil the following three tasks:

* orientation transfer to the mines by computation means
* study of displacements on the terrain of mining activities
* study of displacement of safe barrages of post-flotation water reservoirs named "Zelazny Most" ("Iron Bridge") and "Gilow".

In connection with that what has been listed, location of points belonging to the GPS network had to meet these purposes. Near exploatory shafts there were designed and established sets of points serving for orientation transfer underground, the remaining points were designed and established around the post-flotation reservoirs. As reference points there were choosen 6 points of the first-class national triangulation network located outside the region which undergoes the influences resulting from the drainage of the rocks. Sketch of the established points of the GPS network is given in Fig. I.

FIG. 1. LGOM GPS network



4.1. MEASUREMENTS METHODOLOGY

The GPS measurements were carried out on 9-13 of October, 1993, using 6 Ashtech receivers (4 dual-frequency and 2 single-frequency). Static sessions of duration of 90-120 minutes were performed. Before the campaign the proper observation windows were choosen taking into consideration geometric distribution of satellites (PDOP) on the sky. The analysis was carried on the basis of approximate satellite ephemerides (the so called Almanach) taking advantage of the Ashtech Multi-Site Planning Mission Program [Ashtech, 1990]. During the campaign there were 24 GPS satellites available. When setting the order of vectors to be measured, conditions of visibility as well as optimization of travel time between the points were taken into consideration. The measurements taken at the points to be positioned were referred to on-ground centers of the points monumentation.. while the measurements at the 6 tying points were referred to under-ground plate centers.

4.2 COMPUTATION OF VECTOR'S COORDINATES

Computation of approximate coordinates of individual vectors of the network was performed using the standard Ashtech software called GPPS (GPS Post-Processing Software, ver. 5.0) [Ashtech. 1990]. The computations were carried out on the basis of data recorded on LI frequency, making allowance for troposheric corrections computed for standard meteorological data. The satellites for which the elevation was less then 15° were neglcted during the computations.

4 3 ADJUSTMENT OF THE GPS NETWORK IN WGS 84 SYSTEM

Adjustment of the network was performed with the GEOLAB program ver.1.9 (Bit Wise Ideas Inc.) [GEOLAB, 1990], in the satellite reference system WGS 84. Parameters of the confidence ellipses for 3-D points positioning after the adjustment (at the confidence level of 95%) are as follows:

* major semi-axis: from 5.1 to 9.4 mm
* minor semi-axis: from 3.9 to 7.3 mm

Mean errors of ellipsoidal heigth determinations range from 81015 mm. The parameters of relative confidence ellipses can be summarized as follows:
* major semi-axis: from 2.6 to 8.3 mm * minor semi-axis: from 2.2 to 6.0 mm.
Mean errors of height differences determinations are from 4.3 to 13.5 mm.
The network of adjusted vectors is presented in Fig. I. The adjusted coordinates were next transformed from the WGS 84 system to the local plane reference system called "Pieszkowice".

5. ACCURACY ANALYSIS OF RESULTS OBTAINED FROM GPS MEASUREMENTS

To assess real accuracy and reliability of the GPS results, the obtained coordinates were compared to those obtained on the basis of classical measurements performed for selected points of the network. The latter were carried out by a team from the Mining-Technical Academy in Cracow, in 1993. The comparison comprised points located in the region of the post-flotation reservoir "Zelazny Most", having numbers 100, III, 201, 219, 411 and 500 (see Fig. 1). The coordinates of these points were transformed to the local reference system "Zelazny Most". Also 3 tying points were included to the transformation as references, these had the following numbers and names: 15- Proszyce, Gl- Gawrony and Wl- Wadroze. The transformation was performed in two stages, as follows:

* Transformation from the WGS 84 to the Transverse Merkator system with the center meridian coinciding with the point 500, the scale at the central meridian was set to 1.O

Transformation from the Transverse Merkator system to the local reference system "Zelazny Most".

The transformation results are given in Table I.

Table 1.

The WGS 84 to "Zelazny Most" transformation results. The transformation error m_0 amounted to 0.004 m.

No of point	Vx[m]	Vy[m]
100	0.002	0.003
III	-0.003	-0.003
201	0.000	-0.001
411	0.003	0.000
219	-0.001	0.001

6. CONCLUSIONS

At this stage of the experiment the following conclusions can be derived:

1. The comparison of GPS with classical results proved that the (X,Y) coordinates of the network points can be determined using GPS technique with accuracy not worse then 3 mm. This comparison shows high reliability of GPS measurements.
2. The detailed network of the Copper Basin Area can be tied to fiducial points located outside the region influenced by mining deformations. Using the GPS technique for this purpose makes it possible to avoid establishment of intermediate points between the fiducial points and those located in the region of mining influences.
3. The whole campaign lasted for only 3 days, so the measurements of the detailed network as well as of the fiducial points can be repeated in relatively short time. It enables monitoring of real horizontal deformations of the terrain under interest.
4. Taking into regard the size of the Area of the Copper Basin (2300 km) being influenced by mining activities and, on the other hand, the above listed advantages of GPS method, it can be concluded that the satellite technique of measurements is the optimal one for horizontal deformations monitoring in this area.

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ВИКОРИСТАННЯ МЕТОДУ GPS ДЛЯ МОНІТОРИНГУ БАСЕЙНУ МІДНИХ РУД В ПОЛЬЩІ

Резюме

Територія басейну мідних руд площею близько 800 квадратних кілометрів розташована у Південно-Західній частині Польщі. Інтенсивне видобування корисних копалин приводить до значних деформацій на поверхні басейну. У 1993 році Інститутом геодезії та фотограметрії була заснована GPS мережа для моніторингу цих деформацій. Довжини сторін мережі становлять від кількох сот метрів до 42 км. Під час спостережної GPS кампанії у жовтні 1993 року було використано 6 GPS приймачів типу Ashtech MD-XII. Спостереження були опрацьовані програмним пакетом GPPS версій 5.0. В результаті урівноваження отримано наступні параметри еліпсів похибок (95X) для пунктів:

- головна піввісь від 2.6 до 8.3 мм,
- мінімальна піввісь від 2.2 до 6.0 мм.

З метою додаткового контролю точності та надійності вимірів у мережі було проведено порівняння результатів вимірів за GPS та класичними методами. Різниця між координатами вибраних пунктів становила від 1 до 3 мм. Для подальшого вивчення деформацій передбачається проведення періодичних вимірів у цьому районі.

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ИСПОЛЬЗОВАНИЕ МЕТОДА GPS ДЛЯ МОНИТОРИНГА БАССЕЙНА МЕДНЫХ РУД В ПОЛЬШЕ

Резюме

Территория бассейна медных руд площадью около 800 квадратных километров находится в Юго-Западной части Польши. Интенсивная добыча полезных ископаемых приводит к значительным деформациям на поверхности бассейна. В 1993 году Институтом геодезии и фотограмметрии была основана GPS сеть для мониторинга деформаций. Длины сторон сети находятся в пределах от нескольких сот метров до 42 км. Во время наблюдений GPS кампании в октябре 1993 года было использовано 6 GPS приёмников Ashtech MD-XII. Наблюдения были обработаны программным пакетом GPPS версия 5.0. В результате уравнивания получены следующие параметры эллипсов погрешностей (95X) для пунктов:

- главная полуось от 2.6 до 8.3 мм,
- минимальная полуось от 2.2 до 6.0 мм.

С целью дополнительного контроля точности и надежности измерений в сети было проведено сравнение результатов измерений GPS и классическими методами. Разница между координатами отобранных пунктов составляла от 1 до 3 мм. Для дальнейшего изучения деформаций предвидится проведение периодических измерений в этом районе.