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SURVEYING OF OLD UNDERGROUND MINING WORKS USING INNOVATIVE MEASUREMENT TECHNIQUES

POMIARY GEODEZYJNE W OPUSZCZONYCH WYROBISKACH GÓRNICZYCH Z WYKORZYSTANIEM NOWOCZESNYCH TECHNIK POMIAROWYCH

The article describes mine survey works during opening old St. Anthony of Padua water adit in Horní Město (Czech Republic) to make it accessible to visitors. The works cover the connecting survey and orientation measurement, traverse measurement of the first opened part, setting-out projection of the end of opened part to the surface to make shaft from the surface, new connecting survey and orientation measurement by shaft and traverse measurement of the rest of water adit. Non-standard aids and techniques were used during surveying. One of the tools is a suspended prism holder developed at Institute of geodesy and mine surveying, VSB – Technical university of Ostrava, registered as a utility patent.

Keywords: Old Underground Mining, Innovative Measurement Techniques, Utility patent

W artykule przedstawiono pomiary geodezyjne prowadzone podczas prac w starej sztolni wodnej św. Antoniego Padewskiego w miejscowości Horni Mesto (Czechy) w ramach projektu udostępniania jej dla turystów. Prace obejmowały wykonanie pomiarów geodezyjnych: pomiarów nawiązania, pomiarów orientacji oraz badania poligonowe w pierwszej otwartej części sztolni, sporządzania rzutów granic części otwartej w celu przygotowania do poprowadzenia szybu z powierzchni, a także badania nawiązania, pomiary orientacji i badania poligonowe pozostałej części sztolni. W trakcie pomiarów wykorzystano niestandardowe i innowacyjne narzędzia i techniki. Jedno z tych narzędzi, podwieszany uchwyt pryzmatu, opracowane zostało w Instytucie Geodezji Górniczej VSB na Uniwersytecie w Ostrawie i zarejestrowane jako wzór użytkowy.

Słowa kluczowe: opuszczone wyrobiska górnicze, nowoczesne techniki pomiarowe, wzór użytkowy

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1. Introduction

The works on making the St. Anthony of Padua Adit in Horní Město accessible to visitors are part of the public contract entitled "Rehabilitation and Resocialisation of the Land Affected by Mining Activities in Horní Město – Restoration of the Town Centre after Mining Activities – Ensuring the Safety of Old Chambers", which is performed by GEMEC – UNION a.s. The company opened an old water adit through an inclined drift, and cleaned and secured the parts that had caved in. The old adit is approx. 600 m long. The new inclined adit reached the water adit at the stationing at 180 m; at the time when the surveying works were performed, a section until the stationing at 475 m had been made accessible (Fig. 1).

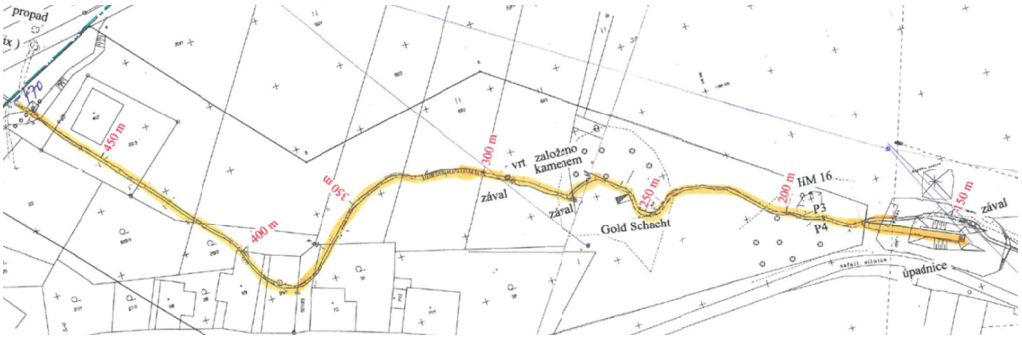

Fig. 1. Drawing from the documentation provided (historical survey used)

In view of the length of the recovery works already completed, the connecting survey and orientation measurement had to be carried out in accordance with Section 4.1.3 in (Regulation, 1992). Another reason for performing the measurement was the need to set out the axes of the shaft on the surface to ensure that, when excavated, the shaft reaches the adit. The shaft will serve both as a haulage and upcast shaft.

Difficult conditions underground, where the width of the shaft ranges between 0.5 to 1 m and the height from 1.2 to 3 m, required that the measurements be adapted as much as possible to take into account the possibilities of the underground environment for the sake of achieving the maximum possible accuracy of the surveying results. This was also the reason why we used a suspension for the insertion of a prism, which was originally developed for mechanical point projection by a plummet. It was presented on ISM congress in 2013 and is described in (Černota et al., 2014) – see Fig. 2.

2. Connection to the valid reference system

Two points of the basic underground horizontal control, stabilised with a plastic-cap steel boundary mark, and one point as checking orientation stabilised by a shot-fired arrow pin on the verge of the II/370 asphalt road were set up for the purposes of the connection to the reference system. Point 4001 was situated before the opening of the adit by which the old underground mining work had been made accessible (Fig. 3).

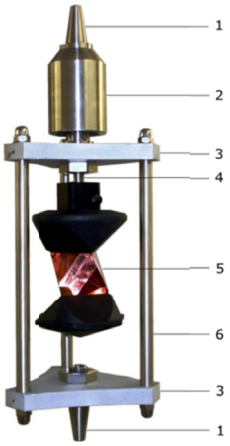

Fig. 2. Suspended holder for coaxial insertion of a prism.
Legend: 1 – Screw for central fastening of a steel wire, 2 – Casing with bearings allowing the orientation of the suspension, 3 – Supporting plates, 4 – Pivot for the attachment of the surveying prism, 5 – Omnidirectional surveying prism, 6 – Connecting bars

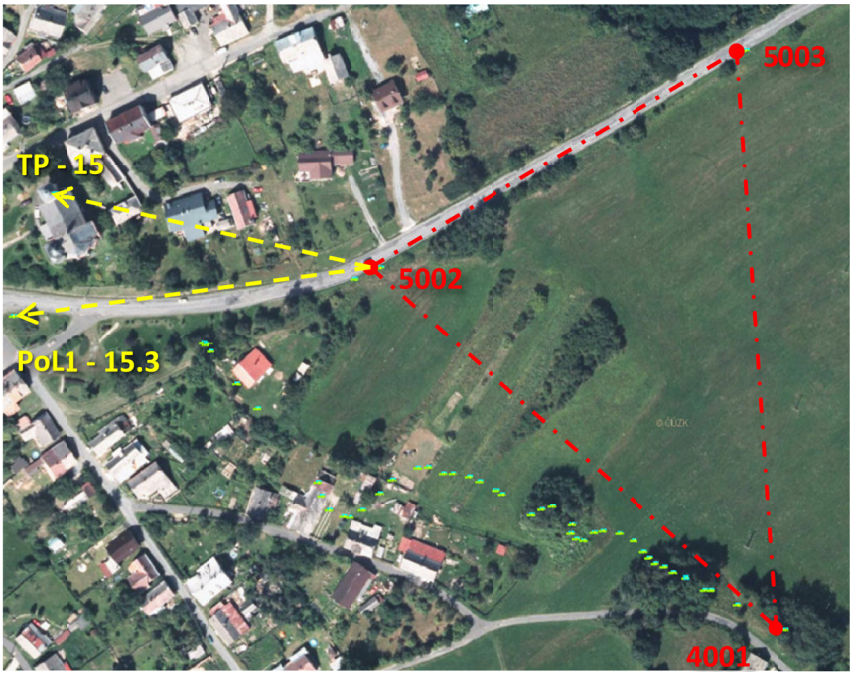

Fig. 3. Basic underground horizontal control points on the surface

The measurement was conducted on 13 March 2013 using Leica System 1200 – an ATX1230 GG Antenna on a tripod with a RX 1250XC controller. A fast static survey method with an ob-

servation time of 15-17 minutes was employed. Vectors were calculated in relation to the CSUM (Šumperk) permanent reference station included in the CZEPOS network. The coordinates were converted into the S-JTSK system by means of the local transformation key (Fig. 4) using the points determined in the ETRS89 and S-JTSK systems, whose coordinates were obtained from the DATAZ service available on the website of the Czech Office for Surveying, Mapping and Cadastre (ČÚZK). The coordinates were calculated using the LEICA Geo Office 7.0 software, other calculations were made using the SW Groma v. 9.0 software.

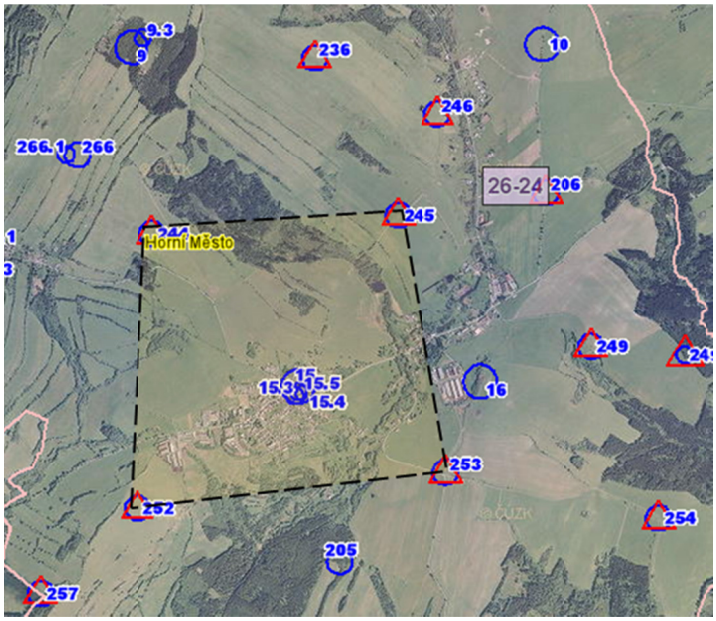

Fig. 4. Configuration of the transformation key points

The accuracy of the coordinates was verified by means of a checking survey of the position of the determined points and by means of checking surveys TP (Trigonometric Point) no. 15 and PoL1 (Point of Lock) no. 15.3 (Triangulation Sheet 2624).

3. Adit survey

When performing the survey, a standard tripod system could not be used, or, more precisely, it would only be possible with great difficulties. The confined space does not allow free movement around the tripods and makes it difficult to just hand over the surveying devices between the surveyors, which would be necessary if the tripod system were used. Another complication consisted in the wood planks installed on the adit floor, which facilitate movement and material haulage in the shaft with incessantly running water but which do not permit (but for certain exceptions) positioning the tripod on the base surface. It was therefore necessary to use various protrusions and, in some cases, to cut pockets for the tripod legs in the shaft walls (Fig. 5).

Fig. 5. Example of tripod legs installed in pockets cut in the adit wall

The tripod was used only for the surveying instrument; for taking backsights and foresights; suspensions were used for inserting a surveying prism (Fig. 2). The suspensions were fastened at the points on the adit ceiling like plummets. This solution permits to set any height of the target prism as may be necessary to ensure signal visibility depending on the particular conditions (Fig. 6). The height of the prism is measured easily from the given point to the beginning of the prism suspension and then the value of the distance to the prism centre is added, which is constant for the particular prism used. Leica GPH1P precise reflector prism was used during the survey.

Fig. 6. Height setting to ensure visibility

4. Accuracy analysis

The accuracy was tested by verifying the difference of the coordinates at the end of the traverse determined by two measurements against the maximum permitted value defined in 0 The measurement met the criteria for accuracy.

The allowable deviation between the terminal point positions of the open traverse as determined by two independent measurements is computed in accordance with the Regulation using the following formula:

$$D_{x,y} = \pm\sqrt{D_I^2 + D_{II}^2} \tag{1}$$

where D_I and D_{II} are allowable deviations of the terminal point of the individual traverses.

As the measurements were conducted on the same points, the allowable deviation of the two traverses will be the same, and therefore the following formula applies:

$$D_{x,y} = \pm D\sqrt{2} \tag{2}$$

D will be calculated on the basis of the following formula:

$$D = \pm\sqrt{k_1 L + k_2 [RR]} \tag{3}$$

where: k_1, k_2 are the coefficients based on the required accuracy, L is the sum of the lengths of the traverse sides, $[RR]$ is the sum of the squares of direct distances between the individual points and the terminal point.

The following coefficients apply to the accurate measurement category: $k_1 = 2$; $k_2 = 0.008$. In the traverse concerned, $D_{x,y} = 0.139$ m. The achieved deviation was 0.108 m.

4. Connecting survey by shaft

In the next stage, the end of the adit was staked out on the surface. The company responsible for making the underground accessible had dug a shaft (depth ~42 m). The caving fall, which prevented from accessing further parts of the adit, was removed (Fig. 7).

The surveying continued with connecting surveys and orientation measurements making use of the shaft. On the shaft bottom a measuring point, where the tripod was positioned, was stabilized. The transport grip, which prevents surveying upright, was removed from the instrument. The telescope was set for the zenith angle 0^g and making use of a laser beam a perpendicular line was projected on a board placed above the shaft mouth. At the same time, the distance to determine the depth was measured repeatedly (Fig. 8).

The image of the point on the surface was obtained using an optical plummet (FPM Holding GmbH, FG-OLZ) in four quadrants as a mean of 4 projections on an auxiliary board above the shaft mouth. This way, the usability of the laser beam to project the position on another horizon was verified. The terminal point was surveyed from the points of the dot field on the surface and its coordinates were used to calculate the original polygonal traverse (Fig. 9).

Fig. 7. View of the shaft

Fig. 8. Total station on the shaft bottom with zenith measure

Having recalculated the free polygonal traverse to one-side and two-side traverses, the deviations were:

Deviation in the terminal point position: 0.122 m,
Deviation in the terminal point of traverse: 0.104 m (transverse) / 0.064 m (longitudinal),
Deviation in height: 0.064 m.

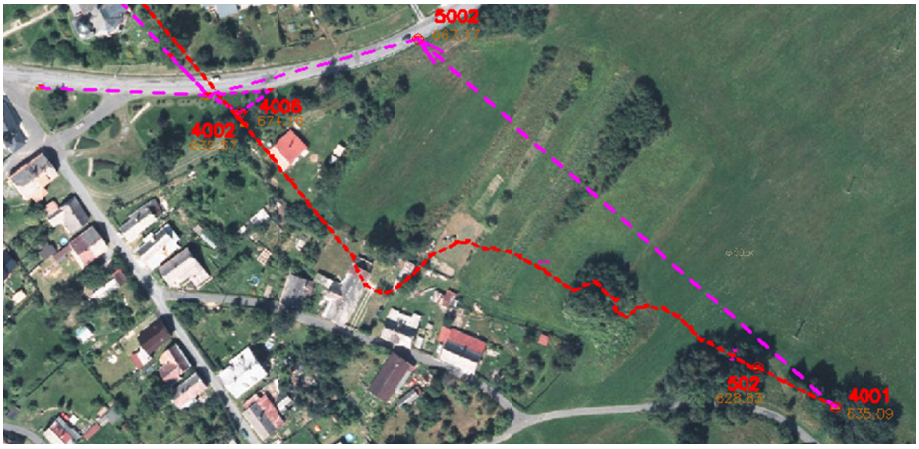

Fig. 9. Connecting traverse to a point from the surface

Parameters of the polygonal traverse:
Number of points: 40,
Length of traverse: 338 m.

To survey the remaining part of the adit the same procedure as in the first part is used, and the survey is connected to the end of the recalculated polygonal traverse. The length of the remaining part of the adit is 195 m. The resulting coordinates are calculated as an arithmetic mean of two independent measurements of the traverse.

5. Conclusion

Connecting surveys form the basis of all mine-surveying activities and must be therefore conducted with maximum accuracy and care. For this reason, the most appropriate surveying techniques and technologies should be applied in the connecting survey.

The purpose of the present study was to test a part of our utility patent for measuring in old underground mining works without enough free space. A suspension prism hung as a plummet is able to achieve precise results. It is obvious from the deviations calculated after the connecting measurement by shaft.

It can be considered as a new measurement technique to be used underground at it achieves the accuracy imposed by Regulation.

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