Revista Minelor – Mining Revue
ISSN-L 1220-2053 / ISSN 2247-8590
vol. 27, issue 1 / 2021, pp. 66-69

INCREASING THE ACCURACY OF THE ORIENTATION OF UNDERGROUND TOPOGRAPHIC WORKS

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DOI: 10.2478/minrv-2021-0009

Keywords: *topo-geodetic measurements, topographic network, geodetic network*

Abstract: *Geodetic and topographic works determine the necessary information base and of major importance in the design and management of underground construction works (mining, hydrotechnics, roads, etc.). The efficiency and safety of these investments with special financial implications depend on their quality. In this context, the geodetic orientation of the underground topographic works was the main and permanent subject of study and analysis on which this scientific paper refers.*

1. Introduction

Underground topographic works are related to a reference system defined on the surface in a system of representation or projection, adopted at national or local level (cylindrical, stereographic).

The underground materialization of the surface reference system is achieved by topographic operations of topographic transmission on underground works: horizontal, inclined or vertical.

The topographic element of the materialization is the orientation for which purpose different methods were used.

The methods used are numerous and complex in the topographic transmission of the orientation on a vertical underground work. For this situation, specific analysis are required, with the related constructions [1].

2. The junction of topographic elements

If on the surface the reference system is defined by pointsA, B located in the free area of the vertical work (fig.1) they are transmitted underground by their verticals through the points A, B [2].

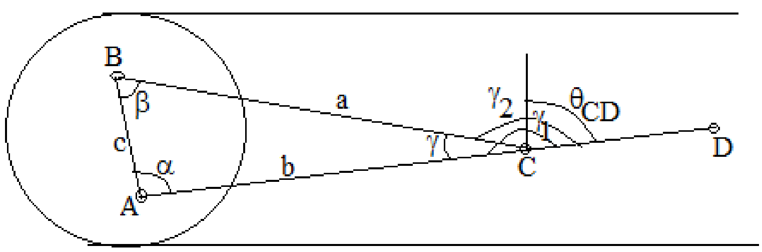

Fig.1

Underground topographic works relate to orientation θ_{CD} of the direction CD frequently obtained by the method of the connecting triangle (ABC).

Distances are measured in the connecting triangle a, b, c and γ (through γ_1 and γ_2). It is known to be determined:

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- The angles α and β with relationships:

$$\sin\alpha = \frac{a}{c}\sin\gamma \qquad \sin\beta = \frac{b}{c}\sin\gamma \tag{1}$$

- Orientation θ_{CD} with relationships:

$$\theta_{CD} = \theta_{AB} + \alpha + \gamma_1 \pm 200 = \theta_{AB} - \beta + \gamma_2 \pm 2\cdot 200 \tag{2}$$

It is observed that the error with which the guidance is obtainedθ_{CD} it is determined by the errors with which the distances are measured a, b, c and with which the angles are determined α, β and γ.

But:

$$ln\sin\alpha = ln\, a - ln\, c + ln\sin\gamma \tag{3}$$

By differentiation they are obtained:

$$ctg\alpha\, d\alpha = \frac{da}{a} - \frac{dc}{c} + \frac{d\gamma}{tg\gamma} \tag{4}$$

and:

$$m_\alpha = tg\alpha\sqrt{\left(\frac{m_a}{a}\right)^2 + \left(\frac{m_c}{c}\right)^2 + \left(\frac{m_\gamma}{tg\gamma}\right)^2} \tag{5}$$

analogous:

$$m_\beta = tg\beta\sqrt{\left(\frac{m_b}{b}\right)^2 + \left(\frac{m_c}{c}\right)^2 + \left(\frac{m_\gamma}{tg\gamma}\right)^2} \tag{6}$$

Errors m_α and m_β are minimal for:

$$\alpha \to 200 \qquad \beta \to 0$$ (fig. 2a)

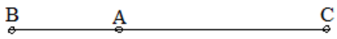

Fig. 2a

or:

$$\alpha \to 0 \qquad \beta \to 200$$ (fig. 2b)

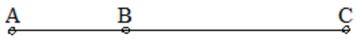

Fig. 2b

This is the case of a triangle with the surface $S \cong 0$ (with angle γ very small). The minimum conditions presented cannot be technically met in all situations and as a result errors must be taken into account. m_a, m_b, m_c, m_γ. These errors are obtained using the theory of direct measurements of the same accuracy, if we consider the quantities $(a,\ b,\ c,\ \gamma)$ independent [3].

However, these quantities are dependent (conditioned) by the existing relations in the triangle.

For probable values (a), (b), (c), (γ) it can be written:

$$\frac{(a)}{\sin\alpha} = \frac{(b)}{\sin\beta} = \frac{(c)}{\sin(\gamma)} \tag{7}$$

The number of conditions is given by the excess of measurements [4]. 4 sizes are measured and 2 sizes are required. Consequently, two conditions result. They are:

$$(a)\sin(\gamma) = (c)\sin\alpha \qquad (b)\sin(\gamma) = (c)\sin\beta \tag{8}$$

According to the theory of conditional measurements, proceed as follows:

$$ln(a) + ln\sin(\gamma) = ln(c) + ln\sin\alpha \qquad ln(b) + ln\sin(\gamma) = ln(c) + ln\sin\beta \tag{9}$$

Through series development results:

$$\frac{da}{a} - \frac{dc}{c} + ctg\gamma\ d\gamma + \omega_1 = 0$$

$$\frac{db}{b} - \frac{dc}{c} + ctg\gamma\ d\gamma + \omega_2 = 0 \qquad (10)$$

where:

$$\omega_1 = \frac{\varphi"}{M} log \frac{a}{c} \frac{\sin\gamma}{\sin\alpha}$$

$$\omega_2 = \frac{\varphi"}{M} log \frac{b}{c} \frac{\sin\gamma}{\sin\beta} \qquad (11)$$

M – factor of transformation of natural logarithms into decimal logarithms

To specify:
- The angles α and β it is calculated according to the sides a, b, c measured.
- The angle γ it is calculated according to the angels $\gamma_1,\ \gamma_2$ measured.

Increases are considered to be errors and result in the system of equations of error, written as:

$$\frac{\rho}{a} v_a - \frac{\rho}{c} v_c + \frac{v_\gamma^"}{tg\gamma} + \omega_1 = 0$$

$$\frac{\rho}{b} v_b - \frac{\rho}{c} v_c + \frac{v_\gamma^"}{tg\gamma} + \omega_2 = 0 \qquad (12)$$

From the system of normal equations, table 1 is formed:

Table 1

Correction	**1/p**	**Correction coefficients**	
		a	**b**
v_a	$a/2$	$\frac{\rho}{a}$	0
v_b	$b/2$	0	$\frac{\rho}{b}$
v_c	$c/2$	$-\frac{\rho}{c}$	$-\frac{\rho}{c}$
v_γ	1	$ctg\gamma$	$ctg\gamma$

The weights are:

$$p_S = \left(\frac{m_0}{m_S}\right) = \left(\frac{1}{\sqrt{S}}\right)^2 = \frac{1}{S} \qquad (13)$$

or:

$$p_S = \frac{2}{S} \qquad (14)$$

$$p_\gamma = \left(\frac{m_0}{m_\gamma}\right)^2 = \left(\frac{2"}{2"\sqrt{2}}\right)^2 = \frac{1}{2} \qquad p_\gamma = 1 \qquad (15)$$

Literally the system of normal equations has the form:

$$\left[\frac{a'a'}{p}\right] K_1 + \left[\frac{a'b'}{p}\right] K_2 + \omega_1 = 0$$

$$\left[\frac{a'b'}{p}\right] K_1 + \left[\frac{b'b'}{p}\right] K_2 + \omega_2 = 0 \qquad (16)$$

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By solving the system, the values of the correlates are obtained K_1, K_2, with which the values of the corrections with the relations are obtained:

$$v_a = \frac{\rho}{p_a \cdot a'} K_1 \quad (17)$$

$$v_b = \frac{\rho}{p_b \cdot b'} K_2 \quad (18)$$

$$v_c = -\frac{\rho}{p_c \cdot c'} (K_1 - K_2) \quad (19)$$

$$v_\gamma = (K_1 - K_2) ctg\gamma \quad (20)$$

a', b', c' according to mm the sides of the weights are considered in m.

The values of the determined corrections are added algebraically to the measured quantities obtaining the probable values with which the angles are calculated α and β [5].

3. Conclusions

Compared to the known methods, the processing of the measured quantities in order to obtain their probable values ensures the orientation of the topographic base in conditions of high precision, with special consequences regarding the accomplishment of the underground construction works.

The additional volume of calculation that is required does not constitute a disadvantage compared to the requirements of making investments with special financial implications.

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