CONSIDERATIONS REGARDING THE DETERMINATION OF CHIMNEY TILT BY GEODETIC METHODS

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Abstract. This paper refers to the use of geodetic methods required to determine the inclination of chimneys related to some thermal power stations or of thermal micro-power stations. To determine the inclination of chimneys at a certain time, it will be determined the coordinates of the chimney's shaft by geodetic methods at the top and bottom part of it.

Keywords: chimney, geodetic methods, chimney tilting.

INTRODUCTION

In the scientific literature (Cristescu, 1978; Ortelecan, 1999; Pop and Ortelecan, 2005) are known topographical methods for determining the inclination at a certain time of chimneys or the increase of their tilt. Topographic methods for determining the inclination of chimneys or of high towers inclination consist of determining the angular tilting and then of determining linear tilting of two points situated perpendicularly to the study objective.

Since chimneys have a circular shape, to get direction to the chimney's shaft, it will be targeted from the station points the diameters of the chimney by bringing the reticular vertical wire tangent to it, at the top and bottom.

The average values of readings at the top and bottom part will give directions towards the shaft at both ends of the chimney.

The difference between the directions to the shaft at both extremities (bottom and top) will give the tilt angle at a certain time, and to obtain the linear inclination it will be calculated the product between the angled inclination and the distance to the axis of the chimney at the bottom. The sum of the measured distance to the chimney and its radius is the distance from the station point to the axis of the chimney. The angular and linear tilt of the chimney can be determined in a similar way, from a station point located perpendicular to the objective. The tilting of the chimney will be obtained from the two linear tilts according to the parallelogram rule.

The geodetic method for determining the inclination of the studied objective consists of the determination of the axis coordinates of the objective (in the upper and lower part) by the method of multiple intersections from a network consisting of at least three points placed near the chimney. The coordinates of the network can be determined in national or local system.

MATERIAL AND METHOD

The objective taken into study refers to a chimney of a brick factory in Cluj-Napoca. The chimney has a height of 100 m.

In the area of interest were determined, in a local system, the coordinates (Table 1) of three station points (Figure 1), which were chosen so it exists visibility between the points and the objective taken into (at top and bottom).

Table 1 – Station points coordinates

Point	X	Y
P1	585561.407	498500.000
P2	585600.000	498538.578
P3	585628.446	498470.415

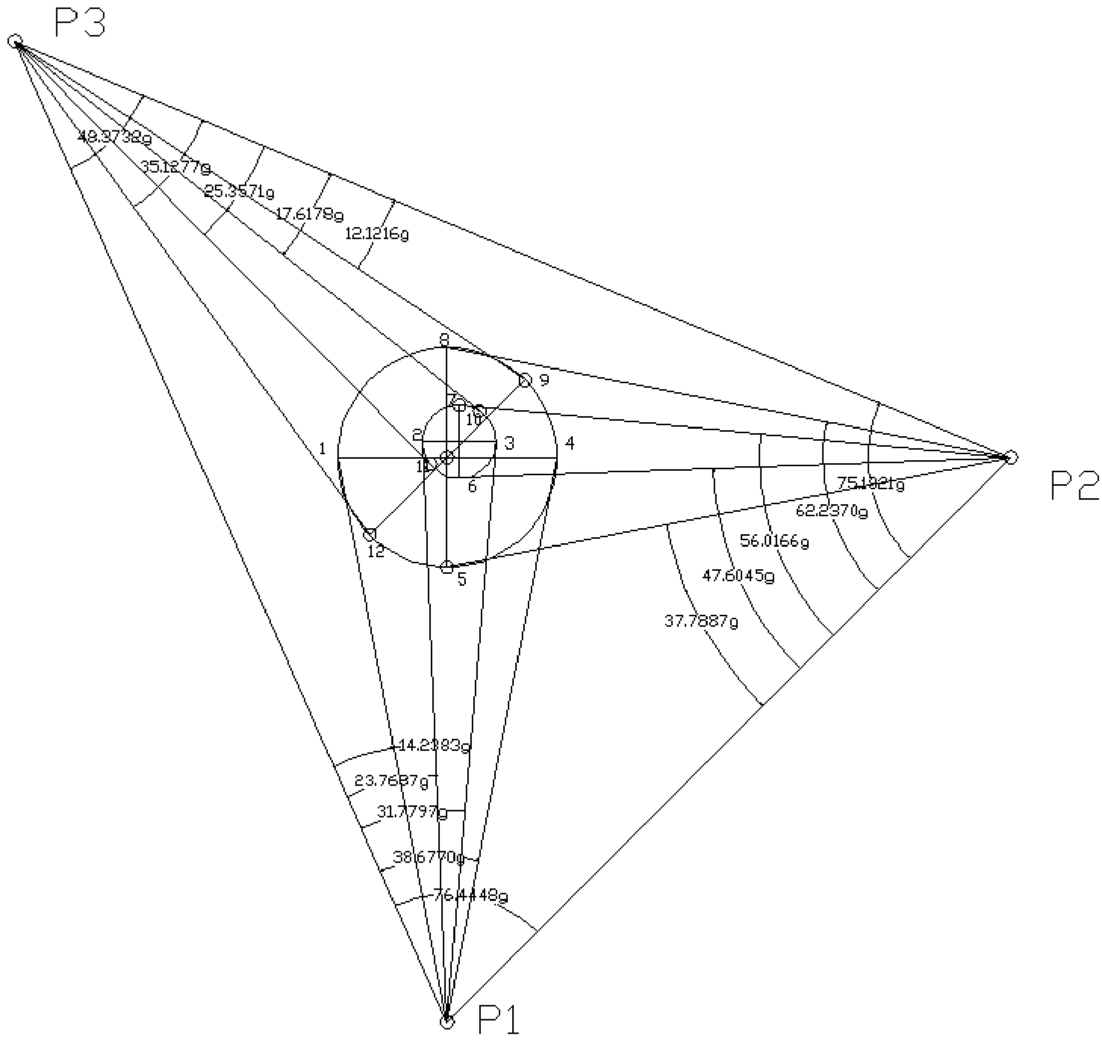

Fig.1. Visas sketch from the station points

From the three station points were made azimuthal and distance observations between the station points and the chimney (Figure 1).

If the distances from the station points to the objective taken into study are 2-3 times lower than the height of the building, then to target the upper part, will be used ocular with prism.

The values of the azimuthal directions of the three station points are shown in figures 1 and 2, and the directions to the shaft are calculated using the equation:

$$r_2 = \frac{c_1 + c_4}{2} = 26.4577$$
$$r_3 = \frac{c_3 + c_4}{2} = 35.2284$$
$$r_6 = \frac{c_5+c_8}{2} = 50.0129 \quad (1)$$
$$r_7 = \frac{c_6 + c_7}{2} = 51.8106$$
$$r_{10} = \frac{c_{10} + c_{11}}{2} = 21.4875$$
$$r_{11} = \frac{c_9 + c_{12}}{2} = 48.3732$$

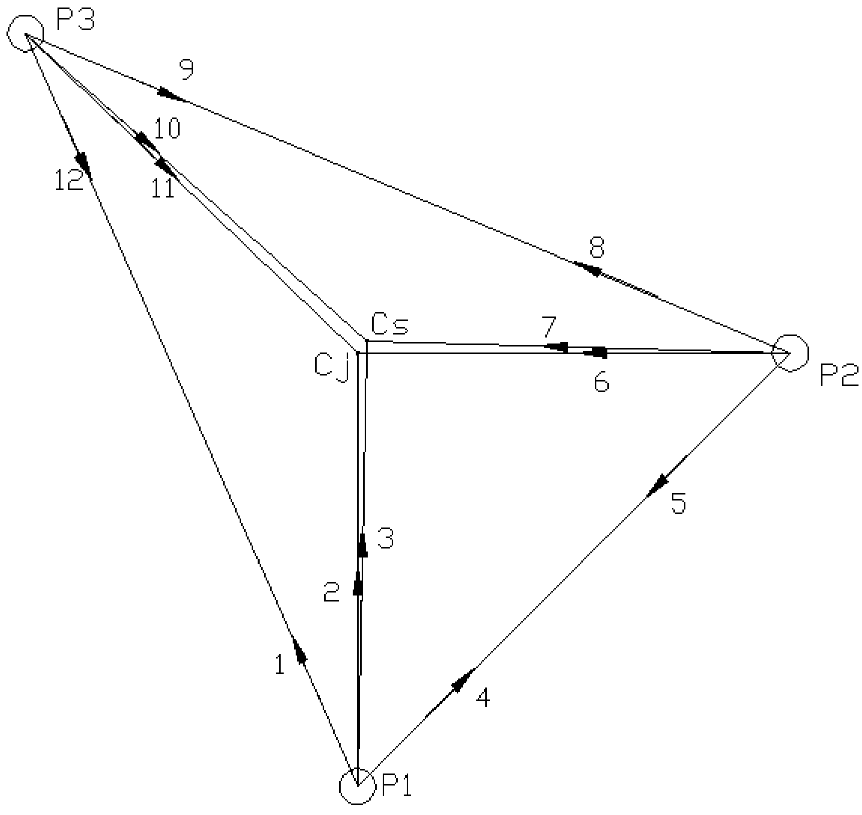

Fig. 2. Forward multiple intersection

In a first step will calculate the shaft's coordinates at the upper and lower part of the objective taken into study, using the forward intersection.

$$X_{C_j} = \frac{Y_{P2} - Y_{P1} + X_{P1} \times tg\theta_{P1-Cj} - X_{P2} \times tg\theta_{P2-Cj}}{tg\theta_{P1-Cj} - tg\theta_{P2-Cj}}$$

$$Y_{C_j} = Y_{P1} + (X_{Cj} - X_{P1})tg\theta_{P1-Cj} = Y_{P2} + (X_{Cj} - X_{P2})tg\theta_{P2-Cj} \quad (2)$$

$$X_{C_s} = \frac{Y_{P3} - Y_{P2} + X_{P2} \times tg\theta_{P2-Cs} - X_{P3} \times tg\theta_{P3-Cs}}{tg\theta_{P2-Cs} - tg\theta_{P3-Cs}}$$

$$Y_{C_s} = Y_{P2} + (X_{Cs} - X_{P2})tg\theta_{P2-Cs} = Y_{P3} + (X_{Cs} - X_{P3})tg\theta_{P3-Cs} \quad (3)$$

The most probable values of the coordinates at the upper part (Cs) and the lower part (Cj) of the shaft are calculated using the equation:

$$\begin{aligned}(X_{Cs}) &= X_{Cs} + dx_{Cs}\\ (Y_{Cs}) &= Y_{Cs} + dy_{Cs}\\ (X_{Cj}) &= X_{Cj} + dx_{Cj}\\ (Y_{Cj}) &= Y_{Cj} + dy_{Cj}\end{aligned} \quad (4)$$

where:
(X_{Cs}), (Y_{Cs}), (X_{Cj}), (Y_{Cj}) – the most probable values of the shaft's coordinates;
X_{Cs}, Y_{Cs}, X_{Cj}, Y_{Cj} – provisional values of the shaft's coordinates;
dx_{cs}, dy_{cs}, dx_{cj}, dy_{cj} – corrections to the provisional coordinates.
To calculate the corrections will write a system of equations of corrections whose form is found in the literature of specialty (Ghiţău, 1983; Ortelecan, 2006).
In matrix solving, the correction equations system, for the case taken into study (Figure 2), takes the form:

$$AX + l = V \quad (5)$$

where: A – direction coefficients matrix;
X – unknown elements matrix;
l – free terms matrix;
V – corrections matrix.
By solving the system using the inverse matrix are obtained the values of the corrections, which have the following form:

$$X = -(A^T PA)^{-1} A^T Pl \quad (6)$$

where:

$$A_{(9,4)} = \begin{pmatrix} a1 & b1 & c1 & d1 \\ a2 & b2 & c2 & d2 \\ \dots & \dots & \dots & \dots \\ a9 & b9 & c9 & d9 \end{pmatrix}$$

$$A^T_{(4,9)} = \begin{pmatrix} a1 & a1 \cdots & a9 \\ b1 & b2 \cdots & b9 \\ c1 & c2 \cdots & c9 \\ d1 & d2 \cdots & d9 \end{pmatrix}$$

$$P_{(9,9)} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{pmatrix}$$

$$X_{(4,1)} = \begin{pmatrix} dx_{Cj} \\ dy_{Cj} \\ dx_{Cs} \\ dy_{cs} \end{pmatrix}$$

$$l_{(9,1)} = \begin{pmatrix} l1 \\ l2 \\ \dots \\ l9 \end{pmatrix}$$

$$V_{(9,1)} = \begin{pmatrix} v1 \\ v2 \\ \dots \\ v9 \end{pmatrix}$$

The linear inclination of the chimney is calculated using the equation:

$$\Delta D = \sqrt{(X_{Cs} - X_{Cj})^2 (Y_{Cs} - Y_{Cj})^2} \quad (7)$$

$$Q = \arctan \frac{\Delta Y}{\Delta X} \quad (8)$$

The inclination angle (γ) of the chimney will be equal with:

$$\gamma = arctan \frac{Q}{h} \quad (9)$$

RESULTS AND DISCUSSIONS

After writing the equations of corrections and applying the rules of equivalent 1 and 3 of Schreiber was obtained a system of nine equations with four unknowns, the matrix coefficients has the following form:

$$A = \begin{pmatrix} 2.5223E-05 & 164.9552883 & 0 & 0 \\ 0 & 0 & -3.373116428 & 160.4501259 \\ 1.26115E-05 & 82.47764416 & -1.686558214 & 80.22506296 \\ 165.0219174 & -4.95223E-05 & 0 & 0 \\ 0 & 0 & 168.5327735 & 4.760277843 \\ 82.51095872 & -2.47611E-05 & 84.26638675 & 2.380138922 \\ 0 & 0 & -115.6148321 & -104.0669924 \\ -111.812426 & -107.5100219 & 0 & 0 \\ -55.906213 & -53.75501093 & -57.80741607 & -52.03349621 \end{pmatrix}$$

The matrix of free terms has the following form:

$$l = \begin{pmatrix} 54.0 \\ -162.2 \\ 0.0 \\ -0.2 \\ -0.2 \\ 0.0 \\ -106.3 \\ 318.6 \\ 0.0 \end{pmatrix}$$

The values of the coordinates corrections are given by the matrix X:

$$X = \begin{pmatrix} -0.92 \\ -0.90 \\ 0.34 \\ -1.07 \end{pmatrix}$$

Since the direction coefficients were divided by 100, the corrections values are expressed in centimeters.

The corrections of the measured elements are expressed by the matrix V^T:

$$V^T = (-202.2 \quad -10.9 \quad -160.6 \quad -151.7 \quad 52.3 \quad -49.9 \quad 178.5 \quad -119.1 \quad 135.9)$$

The most probable values of the coordinates are:

$$(X_{Cs}) = X_{Cs} + dx_{Cs} = 585599.991$$
$$(Y_{Cs}) = Y_{Cs} + dy_{Cs} = 498499.991$$
$$(X_{Cj}) = X_{Cj} + dx_{Cj} = 585601.070$$
$$(Y_{Cj}) = Y_{Cj} + dy_{Cj} = 498500.820$$

The standard deviation (S_0) is equal with:

$$S_0 = \sqrt{\frac{V^T P V}{n-k}} = 114.9$$
$$m_{dx_{Cj}} = \pm S_0 \sqrt{Q_{11}} = 0.74$$
$$m_{dy_{Cj}} = \pm S_0 \sqrt{Q_{22}} = 0.75$$
$$m_{dx_{Cs}} = \pm S_0 \sqrt{Q_{33}} = 0.73$$

$$m_{dy_{Cs}} = \pm S_0\sqrt{Q_{44}} = 0.78$$

The value of the chimney's inclination angle is:

$$\gamma = 0.8672$$

CONCLUSIONS

The accuracy for evaluating the chimney's inclination using geodesic determination methods is superior to conventional methods. For the implementation of the proposed method it is necessary to have visibility between network points and the top and bottom of the chimney. When aiming at increasing the inclination of the objective taken into study, the coordinates obtained from the basic measurement and the current measurements will allow to increase the inclination in time due to the uneven compaction of the foundation.

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