REVIEWING THE VERTICAL OF A METALLIC CONSTRUCTION THROUGH GEOMETRIC LEVELLING

Cornel Arsene[1]
[1]*Faculty of Constructions, Technical University Cluj-Napoca, 72 Observatorului Street, Cluj-Napoca, Romania; *Corresponding author: cornelarsene@yahoo.com*

Abstract. Checking the verticality of constructions must be carried out both during its execution and during its entire exploitation process. There are a number of methods for determining the tilting of the buildings, but for the use of a great majority of these methods, a sufficient amount of space is needed around the structure for the observations to be made. This paper presents a method for determining the slope of metal structures located in a limited space, surrounded by other constructions.

Keywords: review of the vertical, metallic constructions, working method.

INTRODUCTION

During the construction period, and in particular of the vertically-predominant arranged constructions, it is necessary to check the condition of its verticality; this operation does not end with the completion of the construction but must be continued throughout its operation.

Among the methods used to determine the vertical deviation of the constructions we mention (Nistor, 1993):

- the vertical projection of the vision axis of the theodolite;
- measuring small zenith-distances between two points set at the base of the construction;
- measuring horizontal angles by using two or more baseline points;
- measuring horizontal and vertical angles through one baseline point;
- determining the coordinates;
- determining the subsidence of the foundation.

For the first five of the presented methods, the observations being made with the theodolite or the total station, the situation at the site must allow the instrument to be located at a point / points located at a certain distance from the construction, even when using a 90˚ orientated eyepiece.

MATERIAL AND METHOD

The tool used to determine the tilting of the structure must be consistent with the purpose of the job.

When the field situation allows the application of the working methods to which the observations are made with the theodolite or the total station, the instrumental error established (Ortelecan, Pop, 2005) shall be taken into consideration with the relation:

$$s_i = \pm\sqrt{s_1^2 + s_2^2 + s_3^2 + s_4^2 + s_5^2} \quad (1)$$

where:

s_1 - the collimation error;

s_2 - the tilting error of the instrument's main axis;

s_3 - the tilting error of the instrument's secondary axis;

s_4 - the error for the division of the horizontally graded circle and the reading device of the instrument;

s_5 - the extra-centric error of the alidade of the instrument,

also for: the centering error of the instrument in the station point (s_e), the centering error of the targeted signal (s_r), the actual measuring error (s_m), the error caused by the existing conditions (s_{ce}), so as at the end the direction measured will be determined with the error:

$$s_d = \pm\sqrt{s_e^2 + s_r^2 + s_i^2 + s_m^2 + s_{ce}^2} \qquad (2)$$

When the calculation of the tilt of the construction is based on the observations made with a leveling tool, when the space around the structure is restricted, the reading on the leveling staff is affected by the determined average square error (Nistor, 1993) with the relation:

$$s_c = \pm\sqrt{s_{or}^2 + s_p^2 + s_t^2 + s_f^2 + s_d^2 + s_l^2 + s_i^2} \qquad (3)$$

in which:

s_{or} - the error for horizontal targeting the axis of the instrument;

s_p - the vision error on the leveling staff;

s_t - the reading error on the micrometer of the instrument;

s_f - the error caused by the tracing precision of the cross-link wires of the instrument;

s_d - the error caused by the division precision of the leveling staff;

s_l - the counter-perpendicularity error of the foot of the leveling staff on its longitudinal axis;

s_i - the reading error on the tilted leveling staff.

A situation where the only applicable method for determining the tilt of the construction is the one based on the leveling observations and is represented with the case of several metal towers for communication, with a height of H = 52m, located in crowded areas where the distance between the tower and the neighboring constructions is reduced.

The towers are made of modules, the first is 12m high and the ones following are 10m high. In a horizontal section, the tower has an equilateral triangular shape with the base side length l_b = 6m and the upper one l_s = 3m.

Each of the three legs is fastened with bolts to individual foundations by means of a metal plate on which the marks for which the observations are made are also fixed in place.

For the calculation of the tilt of the construction, a system of horizontal axes is arranged so that one is parallel to one side of the triangle and the other one is perpendicular to the first. The origin of the axis system represented by the center of the horizontal section at the base, and the vertical axis coincides with the symmetry axis of the structure.

Fig. 1 presents the horizontal section at the base and the top of the tower, respectively, and the arrangement of the axis system on a horizontal plan.

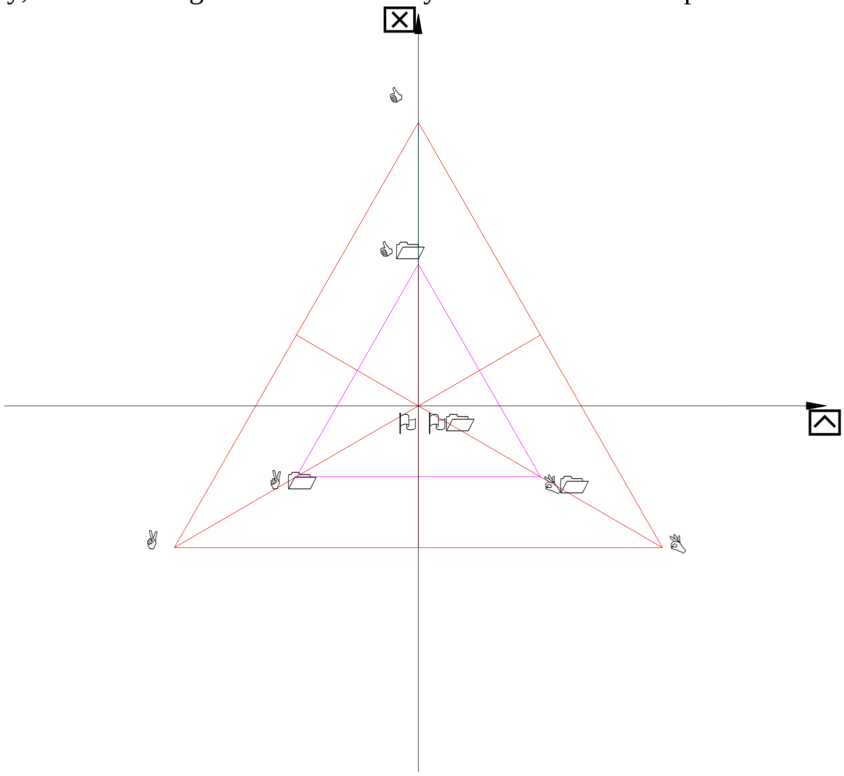

Fig. 1

RESULTS AND DISCUSSION

After installing all the modules, the vertical position of each metal plate was adjusted by means of which the feet of the tower were fixed to the foundations so that they were all brought to the same horizontal plan (the marks placed on the metal plates had the same elevation). The observations for elevation determination were made with a KoNi 007 leveling tool.

At a time interval of one month after the tower was assembled, leveling observations were made on the marks placed onto the metal plates, as two of the three individual foundations (foundations for foot A and foot C respectively) suffered subsidence.

Table 1 shows the values of the elevations for the marks at assembly time and after a one-month interval and the level differences of the marks upon installation, respectively after one month.

Table 1

Observation cycle	Marks elevations			Level differences		
	H_A [m]	H_B [m]	H_C [m]	Δh_{AB} [mm]	Δh_{AC} [mm]	Δh_{BC} [mm]
0 - initially	252.400	252.400	252.400	0.0	0.0	0.0
I - after one month	252.399	252.400	252.398	+1.0	-1.0	-2.0

The determined values show that by the unequal compaction of the individual foundations, the AB side of the base section underwent a tilt of $\alpha_{AB} = 1^c 6^{cc}.1$ corresponding to the 1mm compaction of the foot foundation A relative to the foot foundation B, the AC side underwent a tilt of $\alpha_{AC} = 1^c 6^{cc}.1$ corresponding to the 1 mm foundation of the foot foundation C with respect to the foundation of the foot A, and the BC side has gone through a tilt of $\alpha_{BC} = 2^c 12^{cc}.2$ corresponding to the 2mm subsidence of the foundation of the foot C in relation to the foundation of the foot B. These tilts have affected the construction as a whole.

To determine the tilt of the structure, the displacements in space of the end points of the symmetry axis of the tower O and O1 will be determined.

For the center of the base section O displacements are given by the relations:

$$dh_{Oy} = \Delta y_{O,B} \bullet tg\alpha_y = 3 \bullet tg(-1^c 6^{cc}.1) = -0.0005m$$
$$dh_{Ox} = \Delta x_{AB,O} \bullet tg\alpha_x = 1.7321 \bullet tg(-1^c 83^{cc}.8) = -0.0005m$$
$$dy_O = \Delta h_{Oy} \bullet tg\alpha_y = -0.0005 \bullet tg(-1^c 6^{cc}.1) = 0.83 \bullet 10^{-7} m \qquad (4)$$
$$dx_O = \Delta h_{Ox} \bullet tg\alpha_x = -0.0005 \bullet tg(1^c 83^{cc}.8) = -1.44 \bullet 10^{-7} m$$
$$dh_O = -\sqrt{dh_{Ox}^2 + dh_{Oy}^2} = -\sqrt{(-0.0005)^2 + (-0.0005)^2} = -0.000707m$$

For the center of the superior section O1 we have the displacements:

$$dh_{O1y} = \Delta y_{O1,B} \bullet tg\alpha_y = 3 \bullet tg(-1^c 6^{cc}.1) = -0.0005m$$
$$dh_{O1x} = \Delta y_{AB,O1} \bullet tg\alpha_x = 1.7321 \bullet tg(-1^c 83^{cc}.8) = -0.0005m$$
$$dy_{O1} = \Delta H_{O,O1} \bullet tg\alpha_y = 52 \bullet tg(-1^c 6^{cc}.1) = -0.0087m \qquad (5)$$
$$dx_{O1} = \Delta H_{O,O1} \bullet tg\alpha_x = 52 \bullet tg(1^c 83^{cc}.8) = 0.01501m$$
$$dh_{O1} = -\sqrt{dh_{O1x}^2 + dh_{O1y}^2} = -\sqrt{(-0.0005)^2 + (-0.0005)^2} = -0.000707m$$

The determination of the linear and angular size of the tower's tilt and its orientation in relation to the considered coordinate system is achieved with the relations:

$$dl_{O'O1'} = \sqrt{dx_{OO1}^2 + dy_{OO1}^2} = \sqrt{(0.015010144\ )^2 + (-0.008700083\ )^2} = 0.0173492\ m$$
$$d\alpha_{O'O1'} = arctg\frac{dl_{OO1}}{\Delta H_{OO1}} = arctg\frac{0.0173492}{52} = \frac{dl_{OO1}}{\Delta H_{OO1}} \bullet \rho^{cc} = \frac{0.0173492}{52} \bullet 636620 = 2^c 12^{cc} \qquad (6)$$
$$\theta_{O'O1'} = arctg\frac{dy_{OO1}}{dx_{OO1}} = \frac{-0.008700083}{0.015010144} \Rightarrow \theta_{O'O1'} = 366^g 55^c 87^{cc}$$

CONCLUSIONS

Determining the vertical deviation of the buildings makes it possible to determine the nature of the movements, the causes that lead to them and to lead to the adoption of solutions that ensure the stability of the construction and its safe operation.

To work in the field of terrestrial measurements, depending on the fieldwork conditions and the precision with which the work is to be carried out, involves the choice of the working method and the tools used following a careful analysis.

The presented working method ensures the precision required to determine the tilt of a building under the conditions of limited work space by the existence of other constructions in the area in which it is located.

REFERENCES

7. Arsene C., I. Morar, 1992, Montarea şi verificarea unor turnuri de comunicaţii, Contract C 50-512/1992
8. Nistor Ghe., 1993, Geodezie aplicată la studiul construcţiilor, Editura GH. ASACHI, Iaşi, ISBN 973-95650-6-9
9. Ortelecan M., N. Pop, 2005, Metode topografice de urmărire a comportării construcţiilor şi terenurilor înconjurătoare, Editura AcademicPres, Cluj-Napoca, ISBN 973-7950-99-2