Buletinul Ştiinţific al Universităţii "POLITEHNICA" din Timişoara

Seria HIDROTEHNICA
TRANSACTIONS on HYDROTECHNICS

Tom 55(69), Fascicola 1, 2010

A method for point stability verification in a closed level traverse

Doandeş Victor*

Abstract:The correct interpretation of a displacement is a direct function of knowing the precision with which it was determined. Therefore, the measurements taken on the points that constitute the level traverse (with unequal distance between stations) must ensure the determination of each traverse point's level position, the medium squared error, and the verification of points' stability in the traverse between different survey stages.
Keywords: topography, level traverse, errors

1. The problem

Most building projects are engineered and built to last for many years. Deviations from the original projected parameters can happen after a structure's construction has ended, as well as during its operational use. Some of these deviations are known beforehand and are taken into account in the structure's design, but others are unforeseeable, especially quantitatively speaking. These deviations can greatly impact the functionality of the structure.

Thus, some high structures, dams, bridges, embankments, silos can suffer from geometrical shape skewing (deformations), as well as spatial displacements such as settling, shifting, or tilting. These can happen due to the structure's own weight, due to water pressure, or many other known or unknown factors.

It is important to keep track of vertical displacements of certain structures in order to ensure their safety. In most cases, this is accomplished by means of geometrical leveling between reference points and object points (settle marks) with the instrument placed midway between each two points.

To this end, a special network is built on two different kinds of measurement points, specifically: marking points (object points) on the structure itself, undergoing the same displacements as the structure; and fixed control points (reference points) located in a more stable area, outside the structure's influence and which are used as benchmarks to determine the relative positions of the object points, such that absolute displacements can be determined.

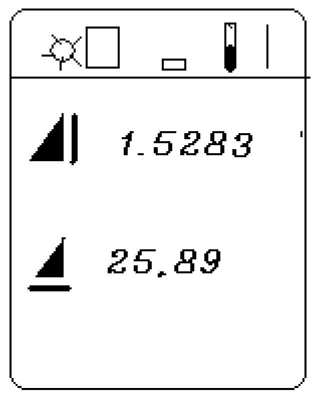

Fig. 1

In most cases, when previous topographic altitude or elevation measurements are not known, the fixed control points can be part of a closed level traverse. The correct interpretation of a displacement is a direct function of knowing the precision with which it was determined.

Therefore, measurements taken against the fixed reference points in the closed level traverse must ensure the correct determination of each point's level position, its mean square error, as well as verification of each point's stability between various measurement stages.

When dealing with closed level traverses with different weight factors for various distances between stations, measurements can be devised in such a way as to ensure constant staff reading precision at points *i* and *i+1* (backsight and foresight) within the same level. Field measurements will be taken using the (midway) geometrical leveling method, with approximately equal lengths of sight (20 to 50 meters), and with precision instruments (NI-007 + invar staves) or more recently with SPRINTER 100M electronic level with bar-coded staff, which can also display

[1]Faculty of Hydrotechnical Engineering Timisoara, CHIF Department, George Enescu Str. No. 1/A, 300022 Timisoara, E-mail: victordoandes@yahoo.com

the length of sight. Figure 1 shows the SPRINTER 100M display set to precision mode, with four decimal places.

2. Error correction

As shown in figure 2, we will take staff backsight readings “INAPOI”, (a_i) and foresight readings “INAINTE”, (b_i). These readings will be taken at the collimation axis.

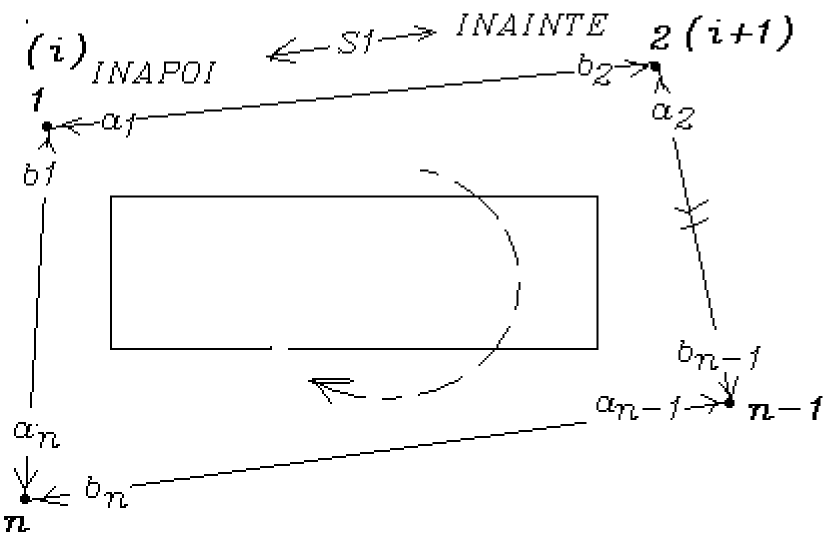

Fig.2

Notations used in equations:

Oi = instrument horizon;

v_{ai} and v_{bi} = accidental errors which affect staff readings;

p_i = weight factor for the distance between two station points;

H_i = elevation of traverse points;

H_1 = starting RL at the site Datum.

The equations for error detection and correction can be written as:

$$O1=H_1+a_1+v_{a1}=H_2+b_2+v_{b2}$$
$$O2=H_2+a_2+v_{a2}=H_3+b_3+v_{b3} \qquad (1)$$
$$\vdots$$
$$Oi=H_i+a_i+v_{ai}=H_{i+1}+b_{i+1}+v_{bi+1}$$

Using the formulas in (1) we can now expand the error calculation equations to account for the p_i weight factor:

$$v_{a1}=O1-(H_1+a_1);\ v_{b2}=O1-(H_2+b_2)...(p_1)$$
$$v_{a2}=O2-(H_2+a_2);\ v_{b3}+O2-(H_3+b_3)...(p_2)$$
$$\vdots$$
$$(2)$$
$$v_{an}=On-(H_n+a_n);\ v_{bn}=On-(H_1+b_1)\dots(p_n)$$

Since the starting RL at the sight Datum H_1 is not affected by measurement errors, the system of equations (2) represents a system of *2n* equations with *2.n-1* unknown variables (Oi and H_i).

We apply the least squares method and obtain:

$$2.O1-H_2-(H_1+a_1+b_2)= 0$$
$$2.O2-H_2-(H_3+a_2+b_3)= 0$$
$$\vdots \qquad (3)$$
$$2.On-Hn_2-(H_1+a_n+b_1)= 0$$
$$-p_1.O1-p_2.O2+(p_1+p_2).H_2= -p_2.a_2-p_1.b_2$$
$$-p_2.O2-p_3.O3+(p_2+p_3).H_3= -p_3.a_3-p_2.b_3$$
$$\vdots$$
$$-p_n.On_{-1}-p_n.On+(p_{n-1}+p_n).H_n= -p_n.a_n-p_{n-1}.b_n$$

We obtain the following from the first n equations:

$$O1=0,5\ (H_1+H_2+a_1+b_2)$$
$$O2=0,5\ (H_2+H_3+a_2+b_3)$$
$$\vdots \qquad (4)$$
$$On=0,5\ (H_n+H1_2+a_n+b_1)$$

We use (4) to substitute the Oi unknown variables in the last (n-1) equations from (3), and obtain a new equation system represented as:

$$N.H=L \qquad (5)$$

Resolving this new system of equations gives us values for absolute elevations H_i, represented as:

$$H=N^{-1}.L \qquad (6)$$

[1]Faculty of Hydrotechnical Engineering Timisoara, CHIF Department, George Enescu Str. No. 1/A, 300022 Timisoara, E-mail: victordoandes@yahoo.com

We apply the notation $S_i = \sum_{i=1}^{n} \frac{1}{pi}$, (7) make the appropriate substitutions and obtain:

$$H_2 = H_1 + (a_1 - b_1) - \frac{S_1}{S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right)$$

$$\vdots \qquad (8)$$

$$H_n = (a_1 - b_2) + (a_2 - b_2) + \ldots + (a_{n-1} - b_n) - \frac{S_{n-1}}{S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right)$$

Using the H_i values from (8) and Oi values from (3), the formulas in (2) become:

$$v_{a1} = -\frac{S_1}{2S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right); \quad b_2 = \frac{S_1}{2S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right)$$

$$v_{a2} = -\frac{S_2 - S_1}{2S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right); \quad b_3 = \frac{S_2 - S_1}{2S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right)$$

$$\vdots \qquad (9)$$

$$v_{an} = -\frac{S_n - S_{n-1}}{2S_n}\left(\sum_1^n a_i - \sum_1^n b_i; \quad b_1 = \frac{S_n - S_{n-1}}{2S_n}\left(\sum_1^n a_i - \sum_1^n b_i\right)\right.$$

3. Root mean square error (RMSE)

We start from the mean square error of a staff reading;

$$m_0 = \sqrt{\sum_1^n (v_{ai}{}^2 + v_{bi}{}^2)} = \frac{e_H}{\sqrt{2n}} \qquad (10)$$

from this we obtain the weighted RMSE:

$$m_0 = \sqrt{\sum_1^n p_i (v_{ai}{}^2 + v_{bi^2})} = \sqrt{\frac{e_H{}^2}{2S_n}} = \frac{e_H}{\sqrt{2S_n}} \qquad (11)$$

where: $e_H = \sum_1^n a_i - \sum_1^n b_i$

The final RMSE on the elevation of a traverse point after adjustment will be:

$$m_{Hi} = m_0 \sqrt{Q_{ii}} = m_0 \sqrt{\frac{S_n - S_{n-1}}{S_n} S_{i-1}} = \frac{e_H}{S_n} \sqrt{\frac{(S_n - S_{i-1}).S_{i-1}}{2}} \qquad (12)$$

4. Conclusions

The initial RL at the site Datum influences the adjustment amount alone, the relative position of the traverse points remaining unaffected by it.

In order to verify the traverse points' stability between two different measurement stages, one can use the elevations from a previous stage's points as ancillary elevations.

The stability of the points can therefore be determined by comparing the values of elevation corrections, equal values denoting stability.

5. Bibliography

[1]V.Doandeş, Topografie aplicată, ed.Politehnica, Timişoara, 2000
[2]D.Guţescu, V.Doandeş, Măsurarea tasărilor la un rezervor de gaze lichefiate, Timişoara, 1986

[1]Faculty of Hydrotechnical Engineering Timisoara, CHIF Department, George Enescu Str. No. 1/A, 300022 Timisoara, E-mail: victordoandes@yahoo.com