THERMAL OBSERVATIONS IN GEODETIC LINEAR NETWORKS FOR ENGINEERING CONSTRUCTIONS MEASUREMENTS

Edward Kujawski, Jacek Sztubecki
University of Technology and Agriculture
Bydgoszcz, Poland

Abstract

In the paper, it is proposed to take into regard temperature observations determining length changes of constructional elements of the measured structure in the case of losing linear observations in the established geodetic control network.

Introduction

Linear networks are established as one possible form of geodetic control serving for monitoring of displacements and deformations of engineering construction elements. Results of these measurements depend, between others, on the temperature. The influence is twofold – for the sake of used devices (tapes, telemeters) as well as on account of the materials the construction itself is made of. This factor, often ignored in carried studies, causes significant changes of results, often exceeding the deformations of constructional elements themselves. Therefore, it is a duty of those carrying the observations, to determine the temperature conditions influencing the scale of units of used device as well as deformations of the construction being monitored. Thermal effects are, besides applied forces from loads or weights, basic factors causing deformations of the engineering constructions. In this paper it was assumed that the thermal changes of lengths of the elements made of a certain material, determined on the basis of measured temperature, can be accepted as equivalent observation with direct measurement of this length change of the studied constructional element. In this aspect it will be a "thermal observation" of the same rank as "linear observation" performed in the established geodetic control network.

Changes in example control network

During carrying out multiple, periodic check measurements of the same object, it often happens that the geodetic control network established on the object is not fully accessible for the next measurement. Such a situation causes that the control network settled in the primary first measurement changes its shape, and, what is connected with that, also the set of observation equations is not longer valid. Updating the shape of the network and adapting the set of observation equations into the new situation requires not only additional time devoted to the task, but also it can cause significant changes of determined positions of the monitored points.

An example confirming the above considerations is given in Fig. 1. It was assumed in this network that the side connecting points 12, 13 is a steel bar of coefficient of thermal expansion α=0.000013 m/1^0 C.

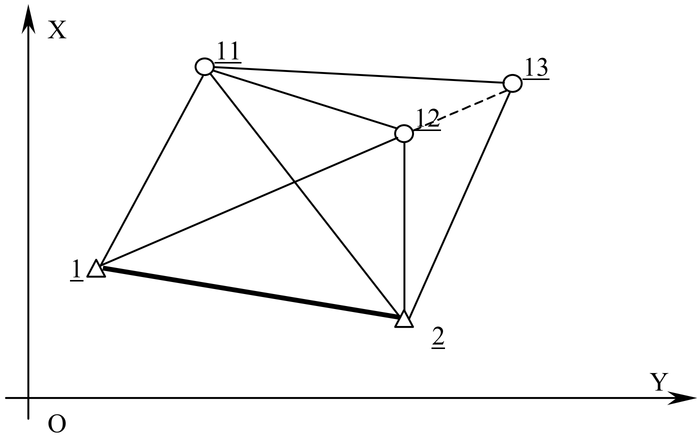

Fig. 1. Example control network

To estimate effect of thermal phenomenon in this network, co-ordinates of the points were admitted as given in Table 1 and on this basis the sides of the network were computed (Table 2). The obtained values are referred to as the “zero” measurement of the network on the construction, at temperature t_0.

Co-ordinate / No	X	Y
1	**22.000**	**17.000**
2	**11.000**	**37.000**
11	38.000	38.000
12	52.000	29.000
13	50.000	47.000

Table 1. List of assumed co-ordinates.

Distances [m]			
D_{1-11}	32.3110	D_{2-13}	40.2616
D_{1-12}	26.4008	D_{11-12}	16.6433
D_{2-11}	41.7732	D_{11-13}	18.1108
D_{2-12}	27.0185	D_{12-13}	15.000

Table 2. List of linear measures admitted to adjustment of the network

Two series of simulation adjustments were performed, taking advantage of the parametric method, under the following assumptions:

The series I
- Change of temperature amounted to $\Delta t = +20\ ^0$ C (the length of $d_{12\text{-}13}$ increased according to the law of thermal expansion),
- The normal distribution of the observation errors within $\pm$ 1.5 mm at the side measurements was admitted.

The series II
- Change of temperature amounted to $\Delta t = +20\ ^0$,
- Change of the network shape in comparison to the full network given in Fig. 1 was introduced through rejecting the side $d_{12\text{-}13}$,
- The normal distribution of the observation errors within $\pm$ 1.5 mm at the sides measurements was admitted.

Displacements were determined on the basis of results of both the networks results. Their values are given in Table 3.

Displacements	Series I		Series II	
No	dX[mm]	dY[mm]	dX[mm]	dY[mm]
11	-0.10	+1.55	+0.03	-0.09
12	-0.87	-0.24	-0.05	-0.09
13	+0.60	+2.21	-0.10	+0,04

Table 3. Maximum values of determined displacements obtained from adjustment of the full network and without observation of the side $d_{12\text{-}13}$.

Analyzing the results listed in Table 3 it can be concluded that the change of temperature and resulting elongation of the side $d_{12\text{-}13}$ (the series I) causes change of determined co-ordinates of the points which is not the case when this length is rejected from the adjustment. This effect resulting from change of measuring scheme and requiring additional considerations during interpretation of the performed measurements, can be partially removed through replacement of the linear observation with the thermal one.

Material bar length from thermal observation

Usually, the points of geodetic control network established for displacement and deformation studies of a certain engineering construction are arranged in such a way that it is possible to indicate respective pairs of points which are located on the edges of continuous homogenous constructional element. In particular, it can be a bar with two points on its edges established, named A and B here. Let us assume that 3D co-ordinates of the points in the primary measurement were obtained as $A(X_{A-Tp}, Y_{A-Tp}, Z_{A-Tp})$ and $B(X_{B-Tp}, Y_{B-Tp}, Z_{B-Tp})$ respectively. The temperature of the construction, measured at this moment amounted to Tp (do not confuse it with the temperature influencing result of length measurement). In the secondary measurement, the temperature of the bar of interest, amounted to Tw and the co-ordinates of the points A and B were determined as $A(X_{A-Tw}, Y_{A-Tw}, Z_{A-Tw})$ and $B(X_{B-Tw}, Y_{B-Tw}, Z_{B-Tw})$. At the same time it should be emphasized that visual observations of the bar did not discover any scratches on it, thus the bar did not lose its continuity (homogeneity).

Under these assumptions, according to the law of thermal extension, the bar should change its length between the primary and secondary measurements as follows:

$$D_{Tw} = D_{Tp} + dD_{dT} = D_{Tp} + dT \bullet D_{Tp} \bullet \alpha \qquad (1)$$

where:

D_{Tw} – length of the bar at the temperature occurring during the secondary measurement,

D_{Tp} – length of the bar at the temperature occurring during the primary measurement,

dD_{dT} – length increment caused by the change of temperature,

dT – temperature increment between the primary and secondary measurements,

D_{Tp} – primary length of the bar,

α – coefficient of thermal expansion of the material the bar is made of.

Assuming that:

- there is not a possibility to perform repeated linear observation of a certain element of the geodetic control network in the secondary measurement,
- the above non-possible observation would determine length of a continuous, rigid constructional element,
- we have at our disposal temperature state values of this element in the primary and secondary measurements,

after stating, on the basis of visual observation, that:

- the element did not undergo any change of continuity visualized by occurring scratches,
- it did not undergo any buckling visualized by a deflection in any of its planes,

it is proposed to introduce the additional "linear observation" to the list of performed observations in the secondary measurements, determined on the basis of the relation (1) i.e.:

$$D_{Tw} = D_{Tp} + dT \bullet D_{Tp} \bullet \alpha$$

Such an observation will be called a “thermal linear observation”, and its result will be treated equally with normally performed observations of lengths.

The presented algorithm will enable, for successive control measurements, to solve this same set of observation equations, in which only the free terms will be changed and they will be determined from successively performed linear and thermal observations.

References

Kujawski E., 1984, Modification of the Precise Leveling Method for the Needs of the Bridge Construction Studies (in Polish), Bydgoszcz, ISSN 0208-6379

Kujawski E., 1996, Investigation of deformation and displacement of engineering construction, Seminar of General Directorate of Public Roads, Warsaw 1996.