PHOTOGRAMMETRIC MEASUREMENTS OF DEFORMATIONS
DETERMINATION DES DEFORMATIONS AU MOYEN DE LA PHOTOGRAMMETRIE
PHOTOGRAMMETRISCHE DEFORMATIONSUNTERSUCHUNGEN

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ISPRS Kommission V

ABSTRACT

A method of deformation measurements of engineering structures by analytical terrestrial photogrammetry has been developed. There are distributed additional control points outside the structure. Survey control is reduced but the accuracy is achieved.

RESUME

Une méthode de détermination des déformations au moyen de la photogrammétrie terrestre analytique est élaborée. Des points complémentaires de contrôle se placent hors du bâtiment. Les mesurages géodésique de contrôle sont réduit mais la précision est assurée.

ZUSAMMENFASSUNG


KEY WORDS: Analytical, Close range, Photogrammetry, Terrestrial.

1. INTRODUCTION

The photogrammetric methods are very useful for the needs of measurement of engineering structures. These methods have got a lot of priorities compared to geodetic methods:
- productivity and economy;
- mobility and universality;
- accessibility and safety;
- the photograph is a document of the structure the moment it is taken at and it can serve as a reference.

Furthermore, there is a possibility of a direct transmission of data, obtained with the help of photogrammetric instruments into the memory of the computer where they can be either stored or analytically processed (Bujakiewicz, Preuss, 1983).

There are many well-known scientific research works which prove these priorities, therefore they are not discussed here.

The changes of the structure both in the process of building as well as in its life-time are examined by observations of a fixed number of points and determination their displacements. These displacements can be determined by several methods and the differences between the co-ordinates are used here.

There are several ways to photograph but the normal way is preferred, i.e. the axes of the cameras are perpendicular to the photographic base.

2. THEORY

It is known that corrections \( \Delta Y \) in the determined distances \( Y \), done by the photogrammetric examinations give rise to corrections in the others co-ordinates, i.e.

\[
\Delta X_1 = \frac{x_1}{f} \Delta Y_1
\]

\[
\Delta Z_1 = \frac{z_1}{f} \Delta Y_1
\]  

where \( x_1 \) and \( z_1 \) are image co-ordinates.

The corrections \( \Delta Y \) can be determined as follows (Miloshev, 1983). According to one of the standard schemes the places of the control points (SP) are fixed on the examined structure (Fig.1, pp.A, B, S, D, E).

![Fig. 1](image-url)

Out of the structure, in range which is perpendicular to the axis \( Y \), subsidiary control points (SCP), (Fig.1, points I, II, III) are traced. Each of these points is opposite the respective CP (for example: p.I is opposite p.A and p.D; p.II is opposite p.B; p.III is opposite p.C and p.E).
The distances $Y_i$ of each one of the SCP are measured as follows: first by means of an instrument (telemeter is the best alternative) and secondly - photogrammetrically. The differences between the double determined distances is $\Delta Y_i$, where $n$ is the number of SCP (in this case $j = 1 + III$).

These differences give rise to corrections in the distances of the CP which can be determined with sufficient accuracy using the proportional dependence between the distances and the horizontal parallax, i.e.

$$\Delta Y_i = \frac{p_{ij}}{p_{11}} \Delta Y_j$$

(2)

where $p_{ij}$ is the horizontal parallax of the respective SCP; $p_{11}$ is the horizontal parallax of the CP.

The formulas (2) are used to determine corrections (1).

After the photogrammetric determination, the special photogrammetric co-ordinates $X_i^i$, $Y_i^i$, $Z_i^i$ of the CP are corrected with the help of (1) and (2), i.e.

$$X_i = X_i^i + \Delta X_i;$$

$$Y_i = Y_i^i + \Delta Y_i;$$

$$Z_i = Z_i^i + \Delta Z_i.$$  

(3)

The transformational image co-ordinates $X_t$, $Y_t$, $Z_t$ are determined using (3). The differences between them and the measured image co-ordinates are

$$\Delta x = x_0 + a_0 x_t + a_1 x_t x + a_2 x_t z + a_3 z + a_4 x;$$

$$\Delta z = c_0 + c_1 z_t x + c_2 z_t z + c_3 x + c_4 z.$$  

(4)

The formulas (4) are figured out by means of the principle of least squares and result in the coefficients "a" and "c".

The same formulas (4) are used also to receive the corrections of the image co-ordinates of the examined points (EP), (Fig.1, points 1, 2, 3, ...).

The iterative method is applied. For the first approximation the measured values of $x$ and $z$ are used. The iterations continue until the following conditions are observed:

$$|\Delta X_{n+1} - \Delta X_n| < \varepsilon X;$$

$$|\Delta Z_{n+1} - \Delta Z_n| < \varepsilon Z,$$

(5)

where $\varepsilon X$ and $\varepsilon Z$ are apriori values; "n" is the number of the "EP" and "k" is the number of the iterations.

The image transformational co-ordinates are received using the calculated corrections and through them - the special photogrammetric transformational co-ordinates of the EP. These co-ordinates can serve to calculate the geodetic co-ordinates or the relative displacements as it is very often done:

$$\Delta X_n = X_n^i - X_0^i;$$

$$\Delta Y_n = Y_n^i - Y_0^i;$$

$$\Delta Z_n = Z_n^i - Z_0^i,$$

(6)

where $X_0^i$, $Y_0^i$, $Z_0^i$ are the special photogrammetric transformational co-ordinates of the EP at the zero cycle; $X_n^i$, $Y_n^i$, $Z_n^i$ are similar co-ordinates at the deformational cycle "$j$" ("j" depends on the function of the structure and on its size and shape); "n" is the number of EP.

3. PRACTICAL RESULTS.

The deformations of a reinforced reservoir (size 28/14/5 m), which is supported by 45 pillars, are examined. Photographic parameters: $f = 194.82$ mm (Photo 19/1318, Carl Zeiss); $B = 13.020$ m; $Y = 62.000$ m.

Nineteen EP are observed in two cycles: a zero (an empty reservoir) and a deformational cycle (a full reservoir). Geodetic measurements are used to get the displacements: range (using the theodolite Theo 010A, Carl Zeiss) and levelling (using the level Ni 007, Carl Zeiss).

The photogrammetric displacements are compared to the latter, which are accepted as most probable.

In each cycle three photographs are taken and they are measured with the help of Stekometer, Carl Zeiss. Each of the points is measured three times. In calculations a computer is used and software respectively. The final results are given in Table 1.

TABLE 1

<table>
<thead>
<tr>
<th>EP</th>
<th>$\Delta X_{ph}$</th>
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There $\Delta X_{ph}$, $\Delta Y_{ph}$, $\Delta Z_{ph}$ are photogrammetric displacements; $\Delta X_{g}$, $\Delta Y_{g}$, $\Delta Z_{g}$ are geodetic displacements; $\varepsilon X$, $\varepsilon Z$ are true errors of the photogrammetric displacements. The results of the examination of only one of the walls are shown, i.e. of the wall with the biggest displacements.

The displacements of the EP are illustrated graphically in Fig.2.

Using the true errors the standard errors of the displacements are calculated:

$$m_{\Delta X} = \sqrt{\frac{\sum \varepsilon X^2}{n}};$$

$$m_{\Delta Y} = \sqrt{\frac{\sum \varepsilon Y^2}{n}};$$

$$m_{\Delta Z} = \sqrt{\frac{\sum \varepsilon Z^2}{n}},$$

where $n$ is the number of the EP.
The relative accuracy are calculated too:

\[
\frac{m_{\Delta z}}{y} = \pm \sqrt{\frac{\sum \varepsilon_z^2}{n}} = \pm \sqrt{\frac{589}{19}} = \pm 5.6 \text{mm}.
\]

4. CONCLUSIONS

The optimum photographic conditions, i.e. the length of photographic base line must be equal to the width of structure and the value of the base/distance ratio ranges from 1:1 to 1:2.5 (Miloshev, 1983) are not kept because of the ground conditions. Nevertheless the final results are satisfactory.

The optimum photographic conditions and the most suitable camera will ensure undoubtedly better results.

REFERENCES


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