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 achived.

RESUME

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

ZUSAMMENFASSUNG

Eine Methode für Deformationsuntersuchungen wird durch analytische Terrestrischphotogrammetrie dargestellt. Zusätzliche Kontrollpunkten werden außerhalb dem Gebäude stellen. Geodatischen Kontrollmesungen werden abgenehmen aber die Genauigkeit wird erreicht.

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 sciuntific reserch works which prove these priorities, therefore they are not discused here.

The changes of the structure both in the process of building as well as in its life-time are examinated by observations of a fixed number of points and determination their displacements. These displacements can be determinated 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 ΔY_i in the determined distances Y_i done by the photogrammetric examinations give rise to corrections in the others co-ordinates, i.e.

$$\Delta X_i = \frac{x_i}{f} \Delta Y_i$$
$$\Delta Z_i = \frac{z_i}{f} \Delta Y_i \qquad (1)$$

where x_i and z_i are image co-ordinates.

The corrections ΔY_i can be determined as follows (Miloshev, 1983). According to one of the standard schemes the rlaces of the **control points** (SP) are fixed on the examinated structure (Fig.1,pp.A, B, S, D, E).

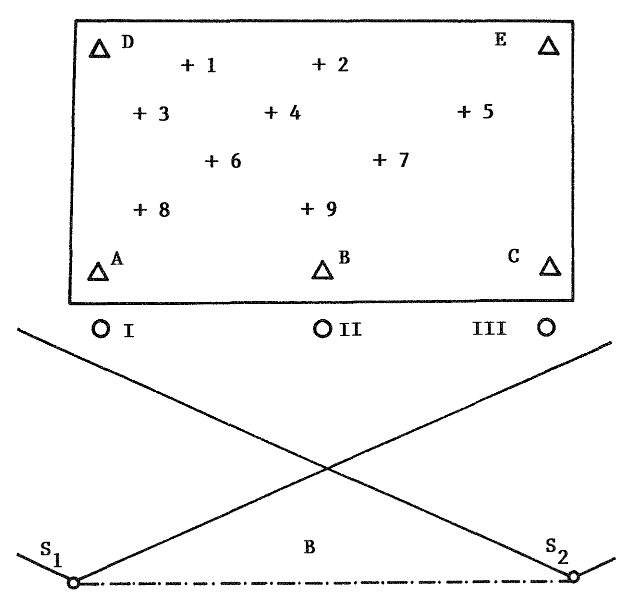

Fig. 1

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_j 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 ΔY_j, where "j" is the number of SCP (in this case $j = I \div III$).

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 paparallax, i.e.

$$\Delta Y_i = \frac{p_j}{p_i} \Delta Y_j \tag{2}$$

where p_j is the horizontal parallax of the respective SCP; p_i is the horizontal parallax of the CP.

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

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

$$\begin{aligned} X_i &= X_i' + \Delta X_i \; ; \\ Y_i &= Y_i' + \Delta Y_i \; ; \\ Z_i &= Z_i' + \Delta Z_i \; . \end{aligned} \tag{3}$$

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

$$\begin{aligned} \Delta x &= a_o + a_1 x_t x + a_2 x_t z + a_3 z + a_4 x \; ; \\ \Delta z &= c_o + c_1 z_t x + c_2 z_t z + c_3 x + c_4 z \; . \end{aligned} \tag{4}$$

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 **examinated points** (EP), (Fig.1, points 1, 2, 3, ...). The iterative method is applied. For the first approximation the measured values of x_t and z_t are used. The iterations continue until the following conditions are observed:

$$\begin{aligned} \left| \Delta x_n^{k+1} - \Delta x_n^k \right| &\leqq \mu_x \; ; \\ \left| \Delta z_n^{k+1} - \Delta z_n^k \right| &\leqq \mu_z \; , \end{aligned} \tag{5}$$

where μ_x and μ_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 spacial 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:

$$\begin{aligned} \Delta X_n &= X_n^i - X_n^o \; ; \\ \Delta Y_n &= Y_n^i - Y_n^o \; ; \\ \Delta Z_n &= Z_n^i - Z_n^o \; , \end{aligned} \tag{6}$$

where X_n^o, Y_n^o, Z_n^o are the spacial 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 "i"("i" 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 examinated. Photographic parameters: f = 194.82 mm (Photheo 19/1318, Carl Zeiss); B = 13.020 m; Y = 62.000 m.

Nineteen EP are observed in two cycles: a zero (an emrty reservoir) and a deformational cycle (a full reservoir). Geodetis 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 accept 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

№ EP	ΔX_{ph} mm	ΔX_g mm	ε_X mm	ΔY_{ph} mm	ΔY_g mm	ε_Y mm	ΔZ_{ph} mm	ΔZ_g mm	ε_Z mm
1	15	6	9	-34	-25	-9	- 9	-3	-6
2	18	12	6	-37	-28	-9	-13	-4	-9
3	13	8	5	-29	-20	-9	-13	-4	-9
4	8	5	3	-14	- 9	-5	- 7	-3	-4
5	- 6	- 1	-5	-20	-14	-6	-10	-4	-6
6	14	8	6	-16	-11	-5	- 9	-4	-5
7	- 7	- 3	-4	-19	-11	-8	-11	-4	-7
8	- 9	- 1	-8	-12	- 6	-6	- 8	-3	-5
9	- 7	- 2	-5	- 9	- 5	-4	-10	-4	-6
10	4	2	2	- 6	- 2	-4	- 7	-4	-3
11	6	2	4	- 5	- 1	-4	-10	-4	-6
12	6	3	3	- 5	- 2	-3	-10	-4	-6
13	5	2	3	- 3	5	-8	- 5	-3	-2
14	7	2	5	- 3	3	-6	- 5	-3	-2
15	6	3	3	- 3	- 5	2	- 6	-3	-3
16	- 2	6	-8	- 3	- 6	3	- 7	-4	-3
17	6	1	5	- 5	- 2	-3	-10	-4	-6
18	7	1	6	- 3	0	-3	- 9	-3	-6
19	7	1	6	- 3	0	-3	- 8	-3	-5

There ΔX_{ph}, ΔY_{ph}, ΔZ_{ph} are photogrammetric displacements; ΔX_g, ΔY_g, ΔZ_g are geodetic displacements; ε_X, ε_Y, ε_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:

$$m_{\Delta X} = \pm \sqrt{\frac{\sum \varepsilon_X^2}{n}} = \pm \sqrt{\frac{550}{19}} = \pm 5.4 \text{ mm},$$

$$m_{\Delta Y} = \pm \sqrt{\frac{\sum \varepsilon_Y^2}{n}} = \pm \sqrt{\frac{626}{19}} = \pm 5.7 \text{ mm},$$

$$m_{\Delta Z} = \pm \sqrt{\frac{\sum \varepsilon_Z^2}{n}} = \pm \sqrt{\frac{589}{19}} = \pm 5.6 \text{ mm.}$$

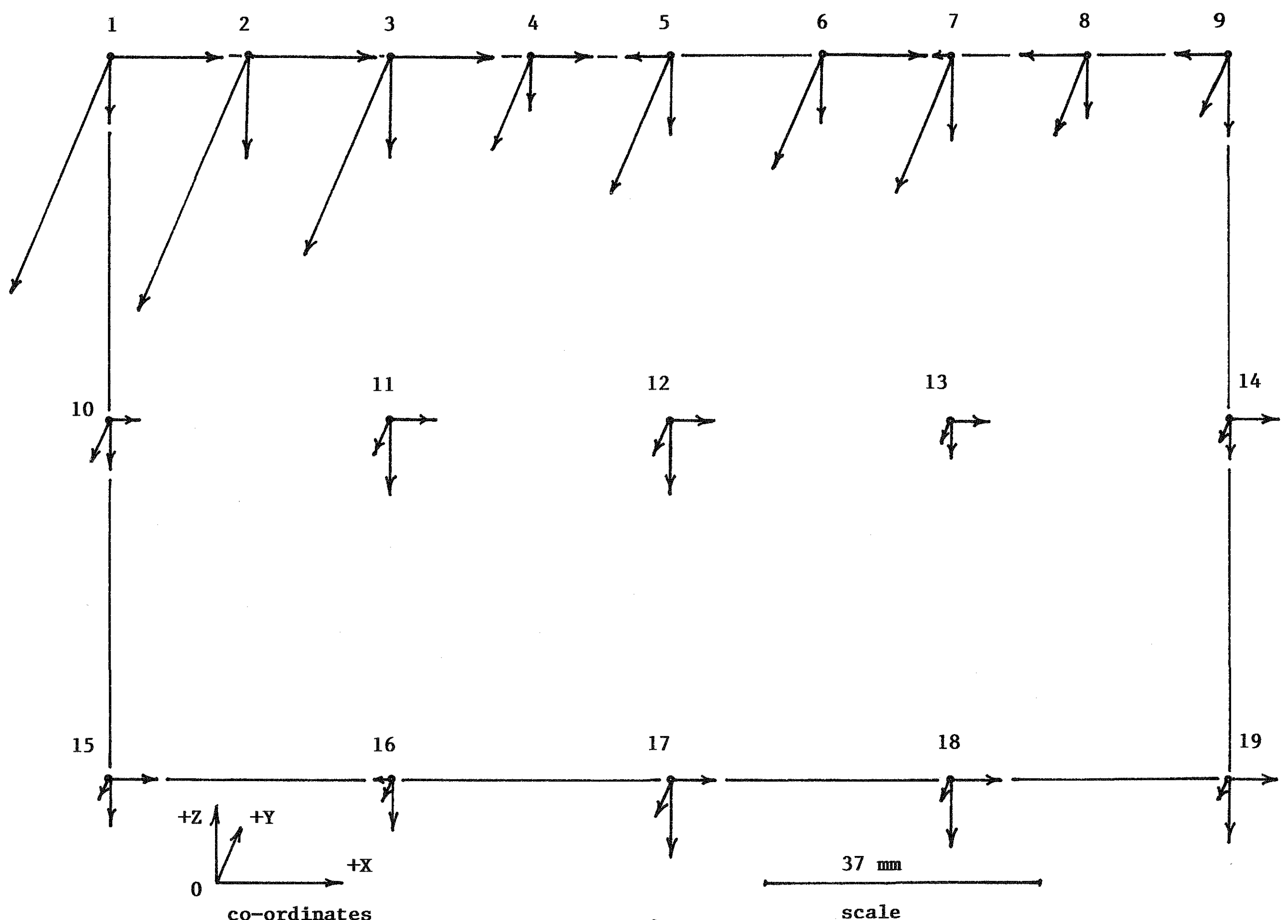

Fig.2

The relative accuracy are calculated too:

$m_{\Delta X}$ / Y = 1 / 11500 ,

$m_{\Delta Y}$ / Y = 1 / 10900 ,

$m_{\Delta Z}$ / Y = 1 / 11070 .

4. CONCLUSIONS

The optimum photographic sonditions, 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.

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