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PRECISION OF GEODESY VERSUS PHOTOGRAMMETRY IN BUILDING CONTROL

ABSTRACT

Photogrammetric control can in many cases replace geodetic control in building production. This is specially the case for checking positions of larger groups of points, or where the access to the points are less good.

The paper describes a check measurement of a reinforced concrete floor, size 7 by 40 m, with 216 steel-cylinders cast into the floor. The cylinders should have a positional accuracy of ± 1 mm. Initially a geodetic control was carried out with a precision of 0.3 - 0.4 mm. Then a photogrammetric survey was carried out, planned like an ordinary 3-strip aerial triangulation with a flying height of 10 m. The photographs had 60% longitudinal and 83% lateral overlap. They were measured in mono on a Wild Stk stereocomparator connected on-line to a mini-computer which performed certain checks of the measurements. Different adjustment methods, with a varying number of given point coordinates, were tested. In the paper these results are compared with the initial geodetic control measurements. The economy of the different methods are also presented.

1. BACKGROUND

In connection with the construction of a floor, aimed to carry out tension tests, at The Swedish Official Standards Laboratory Organization in Borås, the National Swedish Institute for Building Research (SIB) was requested to carry out the check measurements of the floor. A large number of steel cylinders have been inserted into the cast floor. A tension testing machine with anchor plates will be mounted in these cylinders.

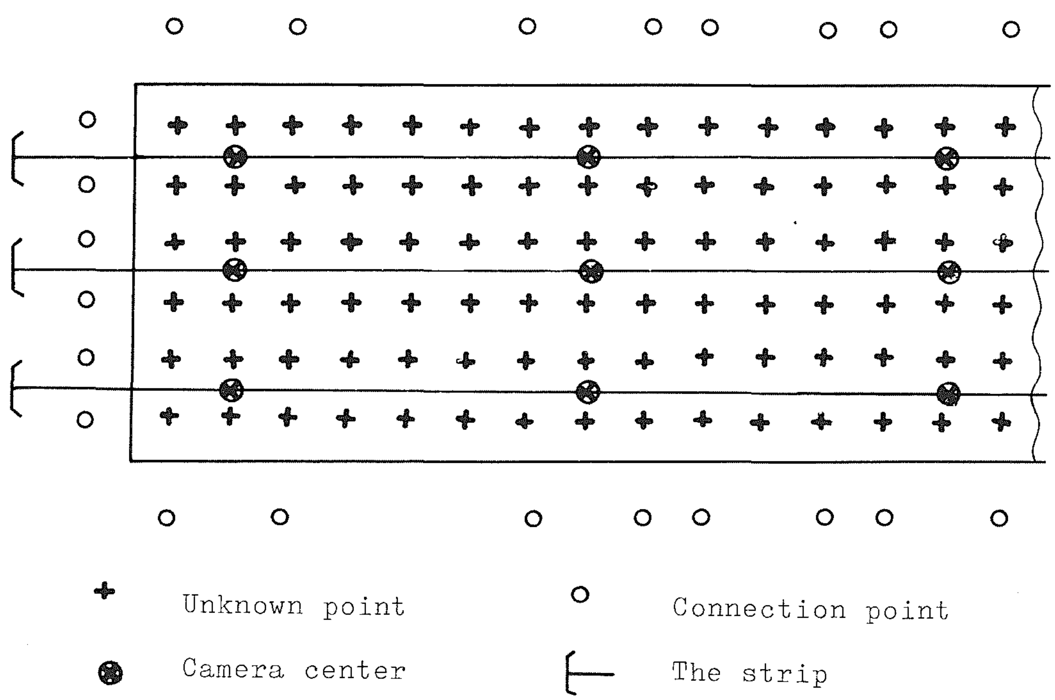
2. DESCRIPTION

The dimension of the floor is 41 by 7 m and has a thickness of 700 mm. In the heavily reinforced floor 216 cylinders have been placed. See figure 1. The cylinders have two different diameters of which the larger ones are cone-shaped. The positions of the cylinders are determined by their center lines. The distances between center lines of the cylinders are 1 m and the tolerance specified is ± 1 mm between adjacent cylinders. The tolerance for the difference in level is the same, that means ± 1 mm between adjacent points.

The large hall in which the floor is situated was at the time for the check measurement clean from equipment which could disturb the measurement. Over the floor is a 15 m heigh travelling crane situated. In the hall the light was very good and the temperature was constant.

FIGURE 1

Plan over the floor



3. PLANNING

When SIB was requested to do the check measurement it was decided that the measurements should be carried out with geodetical methods. As the conditions for photogrammetrical measurements were good it was also decided, as a comparing study, to do the check measurements with photogrammetric methods.

4. GEODETICAL MEASUREMENTS

4.1 In plane

For the positioning in plane a system of parallel lines was marked along the floor. The distances between the lines were 1 000 mm. In each line special center targets were placed in the cylinders. The lateral deviations from these lines were determined with the aid of a theodolite equipped with a parallel plate micrometer, by means of which the sight line could be moved laterally. The distances along the floor were checked by steel tapes. Before the measurement the tapes were calibrated on each meter at a length test base with the aid of an interferometer. All measurements were made twice.

4.2 In level

The level of the points were determined by precision levelling from two stations.

4.3 Results

The standard deviation of the measurement in plane and level was estimated to 0.3 mm.

5. PHOTOGRAMMETRY

5.1 General

The planning of the photogrammetrical study was first discussed with Prof K Tolegård at the Royal Institute of Technology in Stockholm, Department of Photogrammetry. It was decided that two different computer programs should be used for the calculation. As the two programs were based on bundle adjustment the measurements had to be done in a comparator.

5.2 Planning

The camera used was a Zeiss TMK with a focal distance of 60 mm and provided with glass plates, with the size 6 by 9 cm. The accuracy of the measurement with the Wild Stk-1 stereocomparator was supposed to be 2 μm. With a precision demand of approximately 0.5 mm in the ground system this gives a distance to the camera of 10 m and a base of 6 m. As the floor is long and narrow three strips with 80% lateral and 60% longitudinal overlaps were selected. To tighten up the connections between the photos several connection points were placed around the floor. As reference points selected points from the geodetical measurements were used.

5.3 Photography

A platform for the camera and the operators was mounted in the crane on a level of 10 m. To locate each photo station, nadir points were marked on the floor. The crane was then moved into position for each exposure.

5.4 Comparator measurements

The measurement of the points was done monoscopically on a Wild Stk-1 stereo comparator. The position of the cylinders were determined with four measurements along the circumference. A circle was then fitted to these four points by at least wquares procedure. This was done in a mini-computer connected on-line to the comparator. In such a way, the measurements could be checked and repeated, in case the fit was not acceptable. This procedure was chosen because it was felt that the precision of the measurement would be better compared to that of a single measurement of a target. It was also the most practical way, because there were not enough targets available to mark the holes.

5.5 Bundle adjustment

The adjustment of the photo co-ordinates was performed with two different bundle adjustment systems. The first system is installed at the Royal Institute of Technology, Department of Photogrammetry. It is based on the bundle adjustment system described by Anton Schenk (in Schenk 1972 a and b.) At the department it is converted to IBM OS-360 operating system running on an Amdahl 470 V/7 computer. This conversion has been done by Civ.Eng Rune Larsson. The adjustment procedure start with fiducial transformation, strip triangulation and preliminary polynomial block adjustment. The refined photo co-ordinates and the preliminary ground co-ordinates then enter the final bundle adjustment program. Error equations based on the collinearity equations are computed. The normal equations are then calculated and reduced to contain elements only from the orientation parameters of the photo stations. They are solved directly by a band equation system solving routine, and the solution is used to improve the orientation of the photos. Corrections for the ground point co-ordinates are also computed and added to these. The entire process is iterated until the corrections for orientation elements are sufficiently small. In this case was used the value 2.5 mgon as the greatest angular correction permitted in the last iteration. In our adjustments a final solution was achieved with only two iterations. The biggest correction in the final iteration was never greater than 0.5 mgon.

This bundle adjustment system is designed for aerial triangulation. It will allow a maximum of 49 points per photograph and no more than 9 photos of each point. In the case, in question, the first restriction was serious, since some photos contained no less than 150 points. To get around this problem the observations had to be divided into three groups, all with a common set of control points. The regular distribution of points and the numbering system allowed to do this with a simple program, which separated the original photo co-ordinates into three groups automatically. When the adjustment was carried out for each group, the resulting co-ordinate files were merged together and displayed.

The other bundle adjustment system is presented in a thesis given by Jörg Albertz 1966. The error equations have been modified according to a work of Karl Rinner 1957. The residuals are thus calculated as space vectors instead of vectors in the photo planes. Practical tests has shown that the convergence of the iterative solution has improved as a result of this.

To solve the normal equations, block successive over-relaxation (BSOR) is used. What is performed in each interation step is firstly space intersections of all photos from the control points and approximations of the other points. The calculated orientation parameters are then used for resection of new positions for the ground points. The iteration is interrupted when all differences between successive orientation data are less than a specified tolerance. This tolerance was chosen to match that of the first adjustment system.

This adjustment system is implemented on a Prime 400 computer at the Swedish National Board of Survey by Civ.Eng Claes-Ulf Thorsell. Because of the virtual memory allocation of this computer, the size of the internal data arrays can be chosen freely. However, because of time and cost limitations, all points could not be used in the adjustment. The rest of the points were respected from the final orientation of the photos, obtained from the adjustment.

6. RESULT AND CONCLUSIONS

In the photogrammetric evaluation three different sets of control points were used. All control points are known in the coordinates taken from the geodetic measurement. The control configurations are shown in figure 2 and 3 on page 8 and 9. They are based on 5, 3 and 2 control chains placed across the strips in regular intervals. Each chain have three points except for the version with two drains, where there are only one point in each corner of the block. Thus were avaiable three control versions with 15, 9 and 4 reference points. All three versions were used with two bundle adjustment systems. To check the results, all points were compared to their positions determined by the geodetical method, which means that all points are checkpoints. Root-mean-square differences were computed from these comparisons and are shown in table.

TABLE 1

Comparison between geodetic and photogrammetric point determination

RMS values of differencies in 206 points

Control version	Direct-solving adjustment			BSOR adjustment		
points	dx_{RMS}	dy_{RMS}	dz_{RMS} (mm)	dx_{RMS}	dy_{RMS}	dz_{RMS} (mm)
15	0.8	0.6	1.6	0.8	0.9	3.7
9	0.8	0.7	2.3	0.9	1.0	5.0
4	1.4	0.8	3.7	1.3	1.0	8.0

The general accuracy is what could be expected from experience. The accuracy in height depends mainly on the control distribution, but there is also a significant difference between the two adjustment programs. This is partly explained by the fact that only about 125 points were used in the adjustment with the BSOR program. This has not, however, affected the planimetric accuracy significantly and in this study this is of prime importance. The decrease in planimetric accuracy, when a less number of reference points were used, is not very dramatic. This implies that one has found optimum accuracy and that more reference points will not improve the result significantly.

The planimetric stability of the block when only four reference points were used, are due to two things. First, the systematic errors are small or do not accumulate the strip. The calibration of the TMK used was performed at the Department of Photogrammetry in 1964 so the results show the excellent stability of this camera. The second fact which contributes to the good accuracy is that all points are either targeted or defined with multiple settings on a circumference defining the point. The good geometric quality of the bundles is also demonstrated by the small RMS differences between the co-ordinates from the preliminary polynomial adjustment and the geodetical co-ordinates, namely 0.9, 0.9 and 2.8 mm i x, y and z respectively.

7. ECONOMY

TABLE 2

Economic comparison between geodetical and photogrammetrical methods

Methods	Persons	Days
1. Geodetical method		
Preparation (planning, calibration)	3	1
Measurement	3	4
Calculation	2	2
	Sum	19
2. Photogrammetric method		
Preparation	1	3
Measuring of geodetical points	3	0.5
Photography	3	1
Comparator measurement	1	6
Calculation	1	3.5
	Sum	17

From the table above we see that the total time for each method is comparable. However, the time on site is much less for the photogrammetric method. In this case one must also have access to photogrammetric equipment and a bundle adjustment system.

The intention with this study was to find out whether a photogrammetric method could give sufficient accuracy for this sort of check measurements. If so, the photogrammetric method can be used for repeated measurements of the floor in order to monitor deformations even when the floor is occupied by different equipment.

FIGURE 2

Control direct-solving version adjustment

Referens points

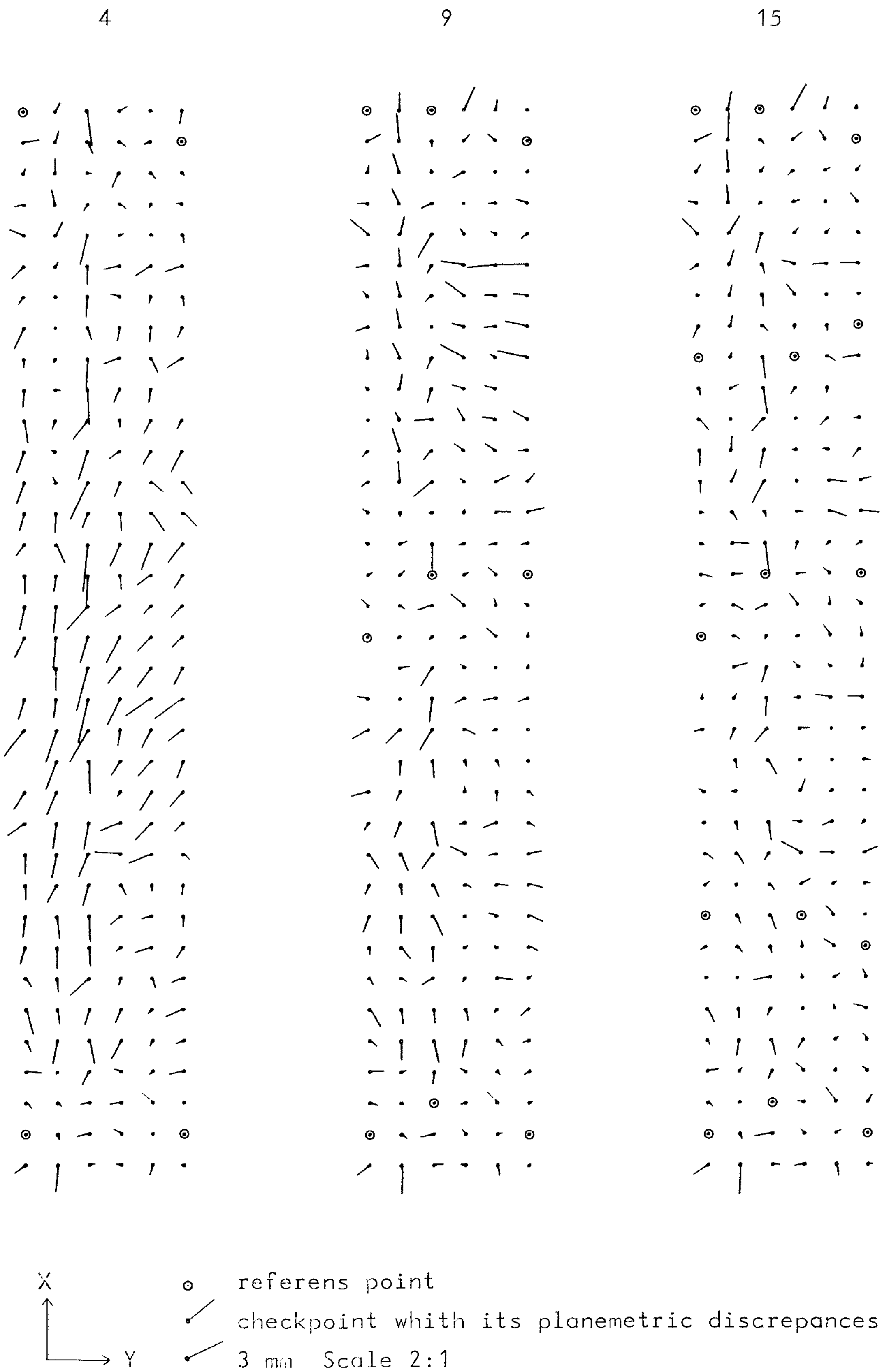
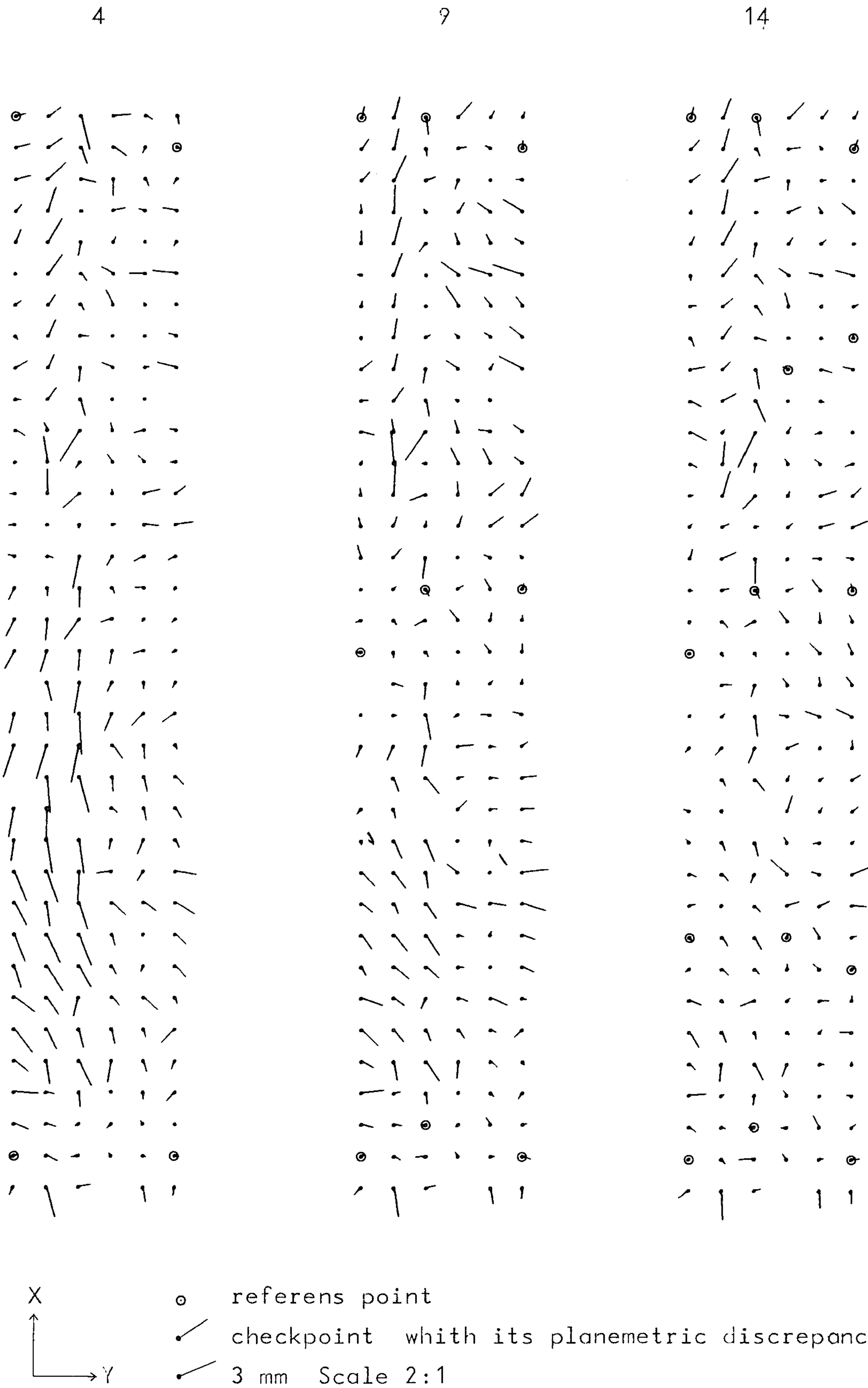


FIGURE 3

Control block successive over-relaxation adjustment(BSOR)

Referens points



o referens point

checkpoint whith its planemetric discrepances

3 mm Scale 2:1

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