PHOTOGRAMMETRIC MEASUREMENT OF DEFORMATIONS OF THE INDUSTRIAL HALLS

Bujakiewicz Aleksandra Ph.D, D.Sc, Eng.
Majde Andrzej Ph.D, D.Sc, Eng.
Prządka Zbigniew M.Sc, Eng.
Institute for Photogrammetry and Cartography,Warsaw Technical University
Institute of Road Construction,
Technical University of Silesia
Poland
Commission V/4

1. Introduction

A number of physical forces acting on the construction of industrial halls necessitate checking their respective geometries. The most important of these forces are:
- weight of snow, dust and of the construction itself,
- load and vibration of the operating machinery,
- thermic changes.

All of the above-mentioned factors might tend to increase as a result of mining exploitation. Parameters determined by the surveyor comprise:
- subsiding of pillars,
- leaning of support pillars and respective changes,
- deviations of roof trusses from standard shape and their deformations,
- width changes in expansion joints, fissures and the like.

Traditional surveying methods for solving the tasks referred to above seem to be the only appropriate ones. Cases however exist when, for instance, with a particular hall being overcrowded with machine units, and consequently with no place in it stable enough to install a theodolite, or no time for traditional measurements to be performed, photogrammetry proves to be indispensable. It is of course impossible for the photogrammetry to measure subsiding of pillars, but other tasks mentioned are capable of being solved. This paper presents remarks concerned with methods that could possibly be used in solving the problem concerned.

2. Roof Trusses Measurement

The varied forces acting on roof trusses tend either to curve or bend them in any direction. This is exemplified by an insignificant lenght compression resulting in considerable buckling of roof trusses /Fig.1/. It is therefore more reea-

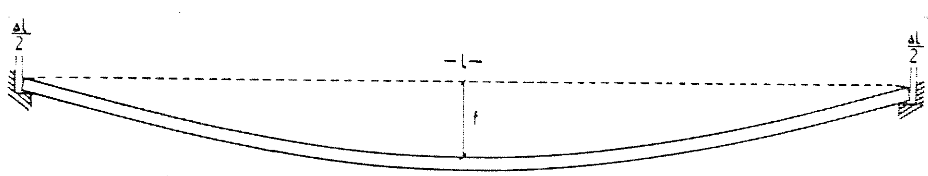

Figure 1

sonable to measure the buckling rather than some scores-times smaller length difference.

2.1. Three-dimensional Measurement
When the type or direction of deformation cannot possibly be envisaged, spatial measurement is required. The best manner in which to execute the photographs is fairly similar to that of aerial photography. A single strip of strictly vertical photographs with an appropriate forward overlap is the most convenient. A wide-angle camera is generally needed for the purpose, because of the width-weight ratio of the hall. The single-model method /analytical or analogous/ is the most convenient one on account of targeted points lacking. Only when a stereoscopic transfer of points is executed, can any of the triangulation methods be used; this is however very difficult to perform in the case of steel constructions. Since on the single model, several roof trusses are measured, the coordinate system is not suited to a particular roof truss. The coordinates of every particular roof truss must therefore be transformed to a reference system determined /defined/ by its support points. The coordinates themselves will then describe the roof truss shape /see Fig.2/ . To determine the shape deviations - the nominal /i.e. designed/ coordinates must be taken into account.

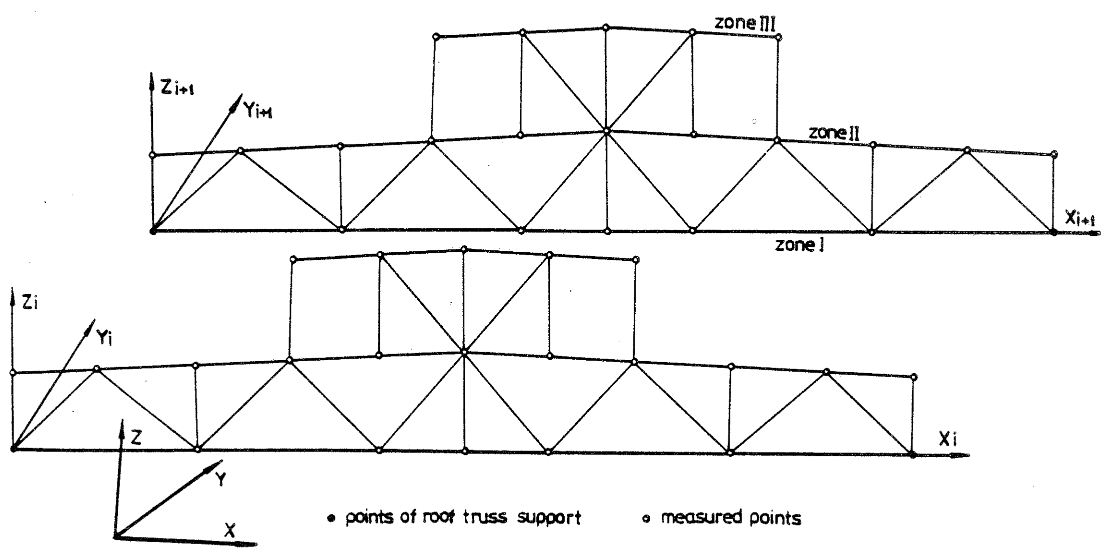

Figure 2

In the case when deformations are required, difference between the results of the initial and present measurement must be taken into account.
The method described has been employed in the measurement of about one hundred roof trusses [4]. These were 15 and 24 metres long. The scale of photographs made with the UMK 10/1318 camera was 1:150 and 1:180, respectively. For model measurem-

ents an A-8 stereoplotter was used. RMS estimated by double measurement of a number of photographs was ±3 ÷ ±4 mm /±20 ÷ 30 um/. Graphical form of results presentation is shown in Fig.3.

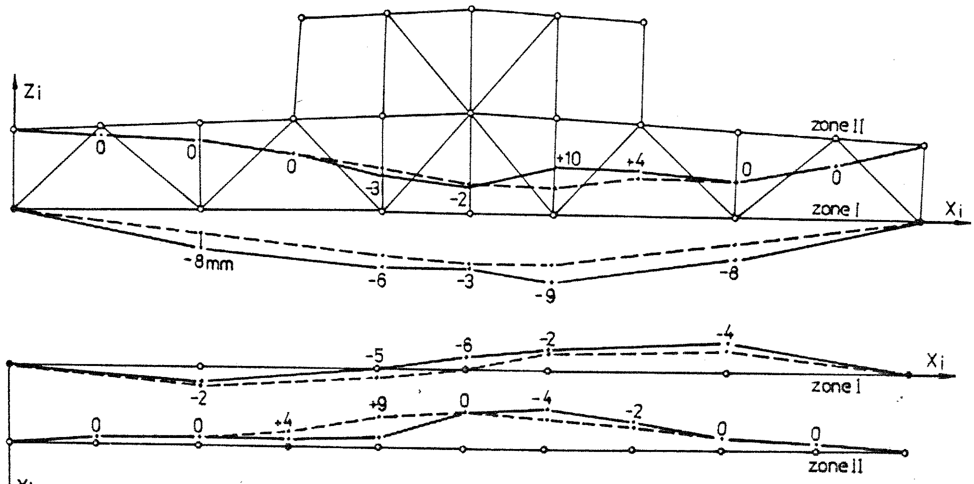

Figure 3

2.2. The vertical deformation of the roof trusses

When the sole deformations expected are vertical, a considerably simpler and more direct procedure can be employed. This applies the time-parallax method on a single photograph. In this case strictly horizontal pictures with the camera's axis placed along the vertical plane of symmetry of the hall, should be made. The camera's station should be situated on an overhead travelling crane. The closer to the x-axis images of the roof trusses are, the less the influence of their actual shape on the results is. As for time-parallax measurement px-movement is preferable, roof truss images should be parallel to the y-axis. Residual deviations from the position mentioned can be eliminated by similarity transformation. The time-parallaxes measured should obviously be multiplied by the scale factor. The image scale of the furthermost roof trusses measured should suit the accuracy required.

3. Measurements of Fissure Propagation

The method discussed can be used for measuring all kinds of fissures, such as expansion joints, wall chinks, slight space between independent construction elements and similar. Since a fissure of very small width is measured, a high accuracy /0.01 ÷ 0.1 mm/ is required in only one direction /perpendicular to the fissure image/.

Since large-scaled photographs /1:1 - 1:10/ are necessary, long-focus nonmetric cameras are to be employed.

The method in question is based on the projective transformation of the single straight line. This line is determined by placing a ruler perpendicular to the fissure direction. When a wall-angle fissure is considered, rulers must be pla-

ced on both adjacent walls.
If the fissure increases or decreases in width along the wall, a single time-stereogram will suffice, but when the direction of fissure variation is unknown, space-time stereograms, with their base perpendicular to the fissure direction, must be taken /see Fig.4/. Time-parallaxes must be measured by px, and

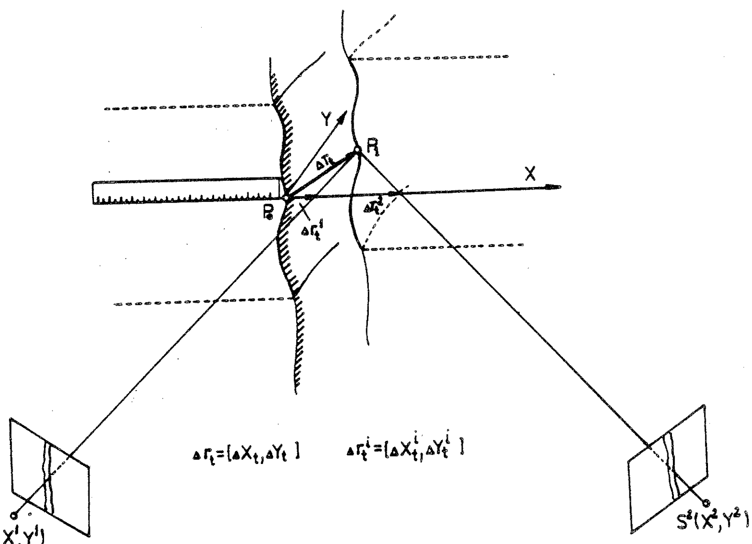

Figure 4

if the number of width measurements is more than one, the pictures must be reoriented. When the fissure increases in width along the wall, the procedure performed is as follows :

- the coordinates and time parallax px of at least four reference points /of ruler/ and both sideedges of the chink must be recorded,
- the x coordinates of the present picture were superposed onto the reference picture, and subsequently both of them were superposed onto the ruler,
- the substraction of present from reference x-coordinates of the point opposite to the rulers side of the fissure represents the actual increase in the fissures width. When the direction of width increase is unknown, the whole of the foregoing procedure must also be executed. With the natural values of the components of time-parallaxes along the ruler /or rulers, for wall-angle fissure/ known, their real values consequent on plane intersection /see Fig.4/ can be calculated.

The formula for the wall fissure is:

$$\Delta Y_t = \frac{Y^1 Y^2 (\Delta X^2_t - \Delta X^1_t)}{X^1 Y^2 - X^2 Y^1} \qquad (1)$$

$$\Delta X_t = \frac{X^1 Y^2 \Delta X^2_t - X^2 Y^1 \Delta X^1_t}{X^1 Y^2 - X^2 Y^1} = \Delta X^1_t + \frac{X^1}{Y^1} \Delta Y_t$$

and that for the wall-angle fissure:

$$\Delta Y_t = -\frac{Y^1\left(Y^2 \Delta X_t^1 + X^2 \Delta Y_t^2\right)}{X^1 Y^2 - X^2 Y^1} \qquad (2)$$

$$\Delta X_t = -\frac{X^2 Y^1 \Delta X_t^1 - X^1 X^2 \Delta Y_t^2}{X^1 Y^2 - X^2 Y^1} = \frac{X^1}{Y^1} \Delta Y_t + \Delta X_t^1$$

respectively. All of the denotations used are shown in Fig.4. All the exterior orientation elements needed should be measured during the making of the photographs.
The method presented is an approximate one. It should be equivalent to a precise one for a fissure width not existing in the reference picture. If the width of the fissure, however, is assumed to be sufficiently small, and the camera stations are kept stable during all of the measurements, the errors in question will be insignificant. A full explanation of the method described can be found in [3] .

4. Measurement of the Inclination Changes of Support Pillars
The problem referred to above occurred when we were requested to measure pillars situated in so overcrowded an industrial hall that the only convenient place for camera station to be installed was the operator's box of the overhead travelling crane. The only possible reference marks for the measurement were plumb-lines suspended from ceiling along the pillarś row. Such a control permits independent levelling of any single picture or in the case when the correct procedure is available, for all the pictures as a network. Pictures should of course be taken in such a manner that every pillar be imaged on at least three or four photographs. With all the reference and present photographs oriented in this manner, differences between the corresponding points of pillars can be calculated. When the network procedure is employed, even considerable station-time changes may be taken into account.
The consequent accuracy depends on the scale of the photographs, the number of images of pillar and intersection angles. In the experiment performed, RMS errors ±1 ÷ 3 mm for a 1:300 image scale.

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