DEFORMATION MONITORING BY MEANS OF MONOSCOPIC PHOTOGRAPHY

by Prof. Badekas and Dr. A.Georgopoulos
Laboratory of Photogrammetry
National Technical University of Athens
Commission V

1. Introduction

A 1:1 model of a reinforced concrete cross-shaped beam
join (Fig. 1) was to be tested under stress by the Reinforced
Concrete Laboratory of NTUA. The object had been constructed in
situ and set up in such a way that it could be loaded
consecutively by alternating pairs of forces of varying
magnitude. Each sequence of loading and deloading constituted a
cycle. The objective of the study was to determine the
behaviour of the test object after the implementation of the
loads. Special strain gauges were employed in order to monitor
the displacements of particular pre-selected points and every
time the distances between the pre-marked points were measured
(Fig. 2). What the Civil Engineers were not able to determine
were the absolute displacements of these points with reference
as well to the initial unloaded position as to the preceding
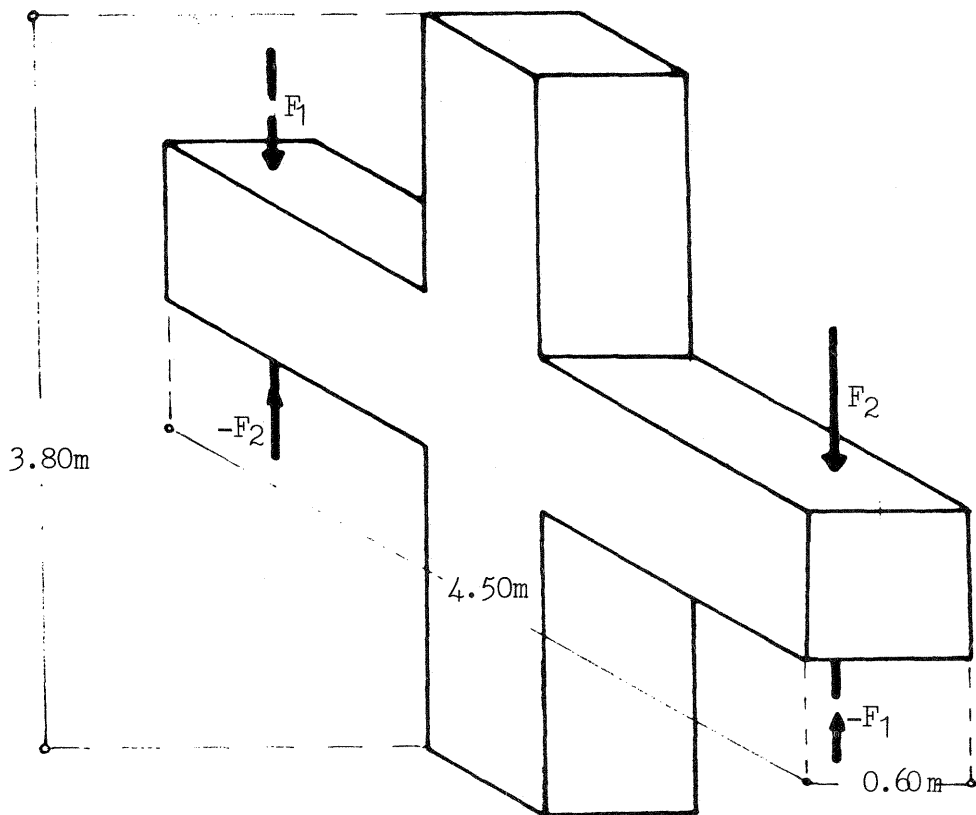loading cycle.

Fig. 1 The test object

A fast and simple photogrammetric procedure was to be chosen in order to determine these displacements within an accuracy of 1-2 mm. As these displacements were forced by the setup of the experiment to be confined to the front plane of the object a monoscopic procedure was employed.

2. The Photogrammetric Procedure

In order to establish a reference system for all photogrammetric data, a plane frame was hung independantly just in front, and parallel to the test object in such a way that it remained uninfluenced during the loading cycles (Fig. 2). The frame was rhomboidal in shape, bearing 8 targetted points (control points). The distances between all these 'control points' were measured directly on the set up frame with sub-millimetre accuracy. These were the only geodetic measurements carried out for this project.
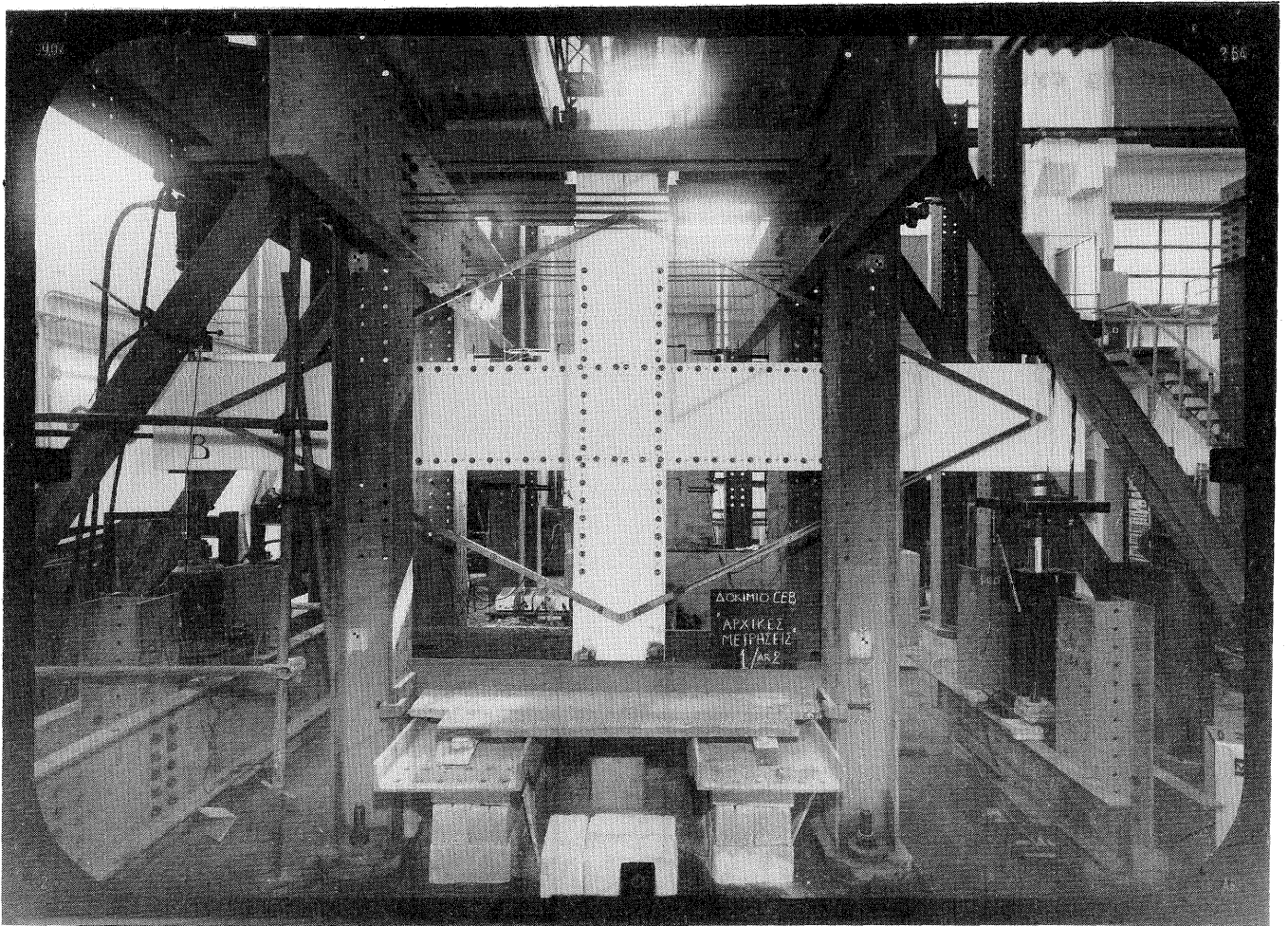

Fig. 2 Plate #1, zero loading

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A ZEISS JENA UMK 1318/100 metric phototheodolite was employed for the photography from a distance of approximately 4.0 m, thus giving a 1:40 scale. Glass plates were used to reassure maximum flatness of the negative. With the help of the horizontal circle of the UMK, parallelity of the negative and the test object, as well as the frame was achieved. Thus scale variations within the same photograph were minimised. The tripod and the orientating part of the UMK remained undisturbed during the whole experiment. Photographs were taken after every loading cycle. Seven plates were taken in all, including the first one, which was taken before any load implementation in order to serve as the basic reference (Fig. 2).

A Stereoplanigraph C8, used as a monocomparator (Exinta-velonis et al.), was employed to measure co-ordinates on the plates. The points observed on each plate were:

a. The 4 fiducial marks
b. The 8 'control points' on the reference frame
c. 18 of the pre-marked points on the test object, distributed evenly on the front surface
d. 4 points marked on the steel beams supporting the object, in order to monitor eventual displacements on them as well.

Each point was observed three times and the measurements were directly stored in an HP-9845S desktop computer.

3. Data Processing

The data was transfered to an ALTOS 586 of the Laboratory of Photogrammetry, which is working under a XENIX environment. All the computer programmes developed for this application were written in Microsoft FORTRAN 77, v.4.0.

Firstly mean values of the observations were calculated and the standard deviation was determined at 12 μm. The mean values were referred to a cartesian co-ordinate system defined by its x-axis being the 1-5 line on the frame (Fig. 3) and point 1 being the origin. Using the measured distances on the frame the mean value for the scale of each plate was determined. The study of the scale factors of the plates indicated that at least plates #2, #3 and #4 were taken with a phi rotation.
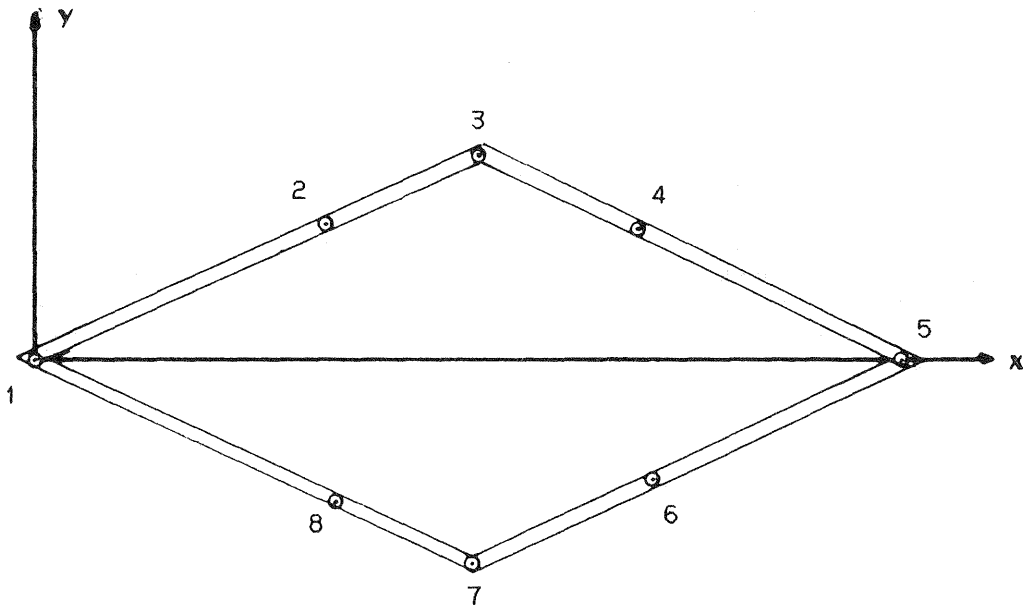
Fig. 3 The control and the reference system

Projective transformation of all frame point observations onto the first plate was chosen to be the best solution. Several deterministic models were tested and implemented. The one chosen included a scale factor, two translations and two differential rotations. The criterion for choosing this model was the a posteriori σ_0 of its fit, which was 0.305 mm.

$$
\begin{bmatrix} x \\ y \\ c \end{bmatrix} = K \begin{bmatrix} 1 & 0 & -\Delta\varphi \\ 0 & 1 & \Delta\omega \\ \Delta\varphi & -\Delta\omega & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ C \end{bmatrix} + \begin{bmatrix} \Delta X \\ \Delta Y \\ 0 \end{bmatrix}
$$

Based on the fact that the control points on the frame remained undisturbed for all plates, the parameters for the transformation of each plate to the first one were determined. Using the same transformation the observed co-ordinates of the points on the test object were also transformed to the first image. Thus point co-ordinates in the same reference system and in the same scale were produced. A simple subtraction of the co-ordinates of a point on the different plates would produce its absolute displacement.

In Figs. 4 and 5 the displacements are plotted. In the first one (Fig. 4) the displacements between plates #1 (zero loading) and #2 are plotted, while in the second one (Fig. 5) those between plates #1 and #7.

4. Conclusion

By applying this photogrammetric procedure, the de-formations have been determined, both in magnitude and

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LABORATORY OF PHOTOGRAMMETRY

POINT DISPLACEMENTS
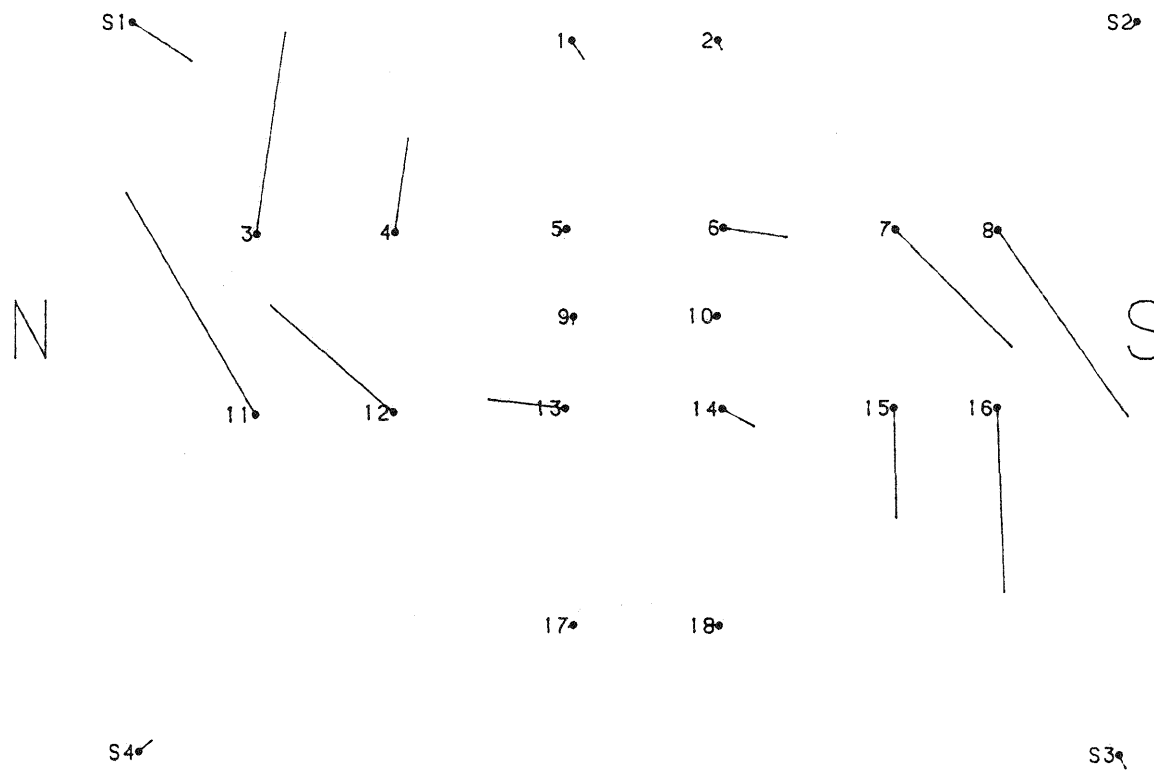ON TEST OBJECT UNDER STRESS

Fig. 4

5
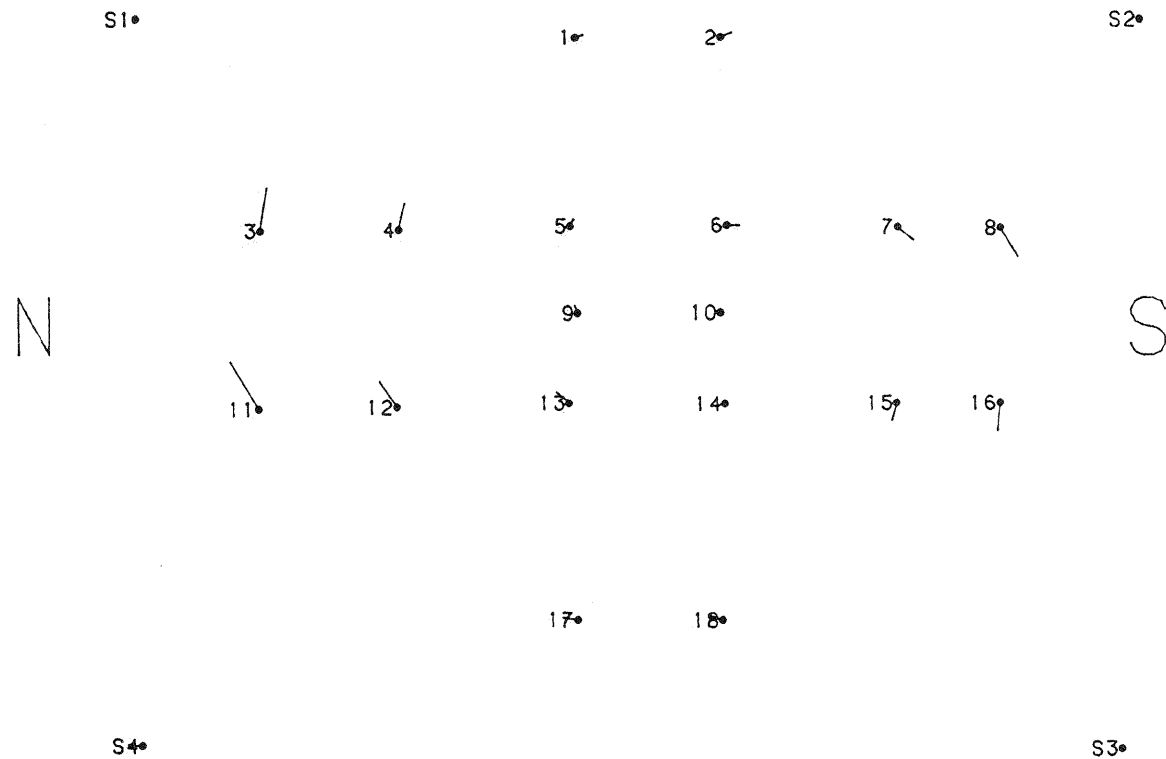
LOADING CYCLE #2

   N   +0.8 MY
   S   -0.8 MY

SCALE
10 MM

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POINT DISPLACEMENTS
ON TEST OBJECT UNDER STRESS

TOTAL DISPLACEMENT

PLATE 1 - PLATE 7

SCALE
10 MM

Fig. 5

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direction. The accuracy of the determined deformation is of the order of 0.5 mm, which, combined with the information provided by the strain gauges was considered more than adequate for the test.

It has been shown that simple photogrammetric procedures may well contribute to deformation monitoring with an acceptable accuracy.

Reference

1. Exintavelonis, J., Patas, J., Badekas, J., 1981. Image co-ordinate measurement on a Stereoplanigraph C8. Photo-grammetria 36(1981), pp. 101-109.