THE APPLICABILITY OF CLOSE-RANGE PHOTOGRAMMETRY IN STRUCTURAL MODEL TESTINGS

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ABSTRACT

Photogrammetry, specially close-range photogrammetry, is used outside the topographic mapping in the fields of engineering and scientific disciplines as an indirect measuring method. Construction engineering, one of the application areas of the close-range photogrammetric methods offers many possibilities for use of different photogrammetric methods. An optimized use of photogrammetric methods with regard to the requirements of accuracy, time, cost and type of output will increase the use of photogrammetric methods in this area. From this study, which tests three photogrammetric restitution techniques (analog, analog-analytical and analytical methods) in two different structural tests, one can conclude that analog method can only be used when minor deformations are not in question. Analog-analytical and analytical methods give the same results and their use depends mostly to the existing equipment, personel and soft-ware.

INTRODUCTION

Photogrammetry is the science of determining geometric and other properties of objects by measurements and observations on the photographs of those objects. The most frequent use of photogrammetry is the field of map production. Nowadays photogrammetric techniques are being used increasingly in the field of industrial metrology as an alternative to traditional measuring techniques |2|.

Application of photogrammetry in building construction, civil engineering, mining and in other industrial branches at the phases of research, planning, manufacture, testing, monitoring, repair and reconstruction are the scopes of industrial photogrammetry.

The aim of the this study is to test these photogrammetric restitution techniques which are connected with building constructions and to determine the precisions applicable for the solution of specific problems by comparing these methods |5|. While the time parameter is studied to the some extent.

In contrast to Hottier |4| who discusses the obtainable accuracy of close-range analytical restitutions, we study here the differences in the results between the analog, analytical and semi-analytical restitutions. The data which we used is obtained from the photogrammetric photographs during the shell and girder tests in the Structure Laboratory at the Technical University of Istanbul.

Data Acquisition and Reduction

During both of the tests a Wild C40 stereometric camera was used. Before taking photographs, a minimum number of pass points (in both tests 4) are established in order not to spend much time for geodetic measurements |3|. For the analog restitution the obtained photographs are placed on the Wild A40 autograph. The plotting scales are 1/20 and 1/5. For the analog-analytical restitution, the three dimensional model co-ordinates which are obtained from the Wild A40 autograph, are transformed to the object co-ordinate system using the following formulae.

$$D.s.x_i - \Delta X - X_i = 0 = F(y)$$

For the analytical restitutions the bundle program, which permits the handling of interior orientation elements differently for each photograph as a parameter, is used. As the correlation between the photographic distance and the principle distance of the camera is high the co-ordinates of the perspective center are taken as observations |1|.

TEST 1 : Shell Test

The data which are obtained from the test of a shell under different loads is the first application .

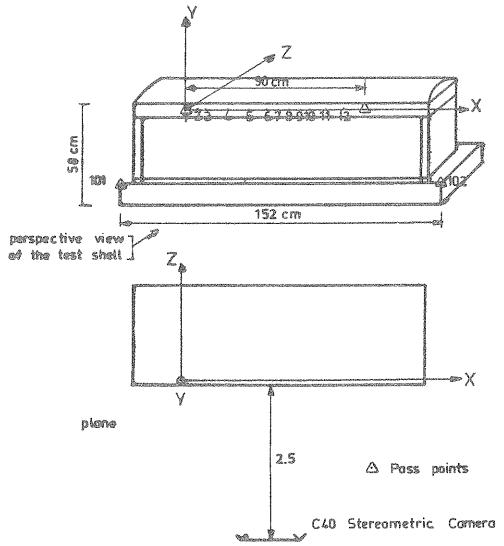

Figure 1 : Situation of the stereometric camera, control points and the test shell.

The dimensions of the test shell, location of the pass points and the camera situation are shown in figure 1. The photographs which are taken at different loadings are placed on Wild A40 Autograph in order to obtain graphical plottings of the shell.

Later on, the stereo pairs which are taken at different loading steps of the shell are placed on Wild A40 Autograph and the obtained model co-ordinates of the shell points are transformed to the object co-ordinates system according to Formulae 1.

For two choosen loading steps the calculated co-ordinate differences from these object co-ordinates gives us the displacements of these points. A typical example of the application can be seen in FIG. 2.

The image co-ordinates obtained from the A9 Autograph, which is used as a comporator are handled with a bundle program. Similar to the above the calculated differences of the shell point co-ordinates are calculated.

TEST 2 : Girder Test

For the second application of these three methods, during a test of a reinforced girder under different loadings, photographs are taken with a stereometric camera.

The dimensions of the test girder, location of the pass points and the camera situation is shown in FIG.3. In this figure the crosses represent the girder points, which are marked on the surface of the girder in order to obtain the behaviour of the girder under different loads.

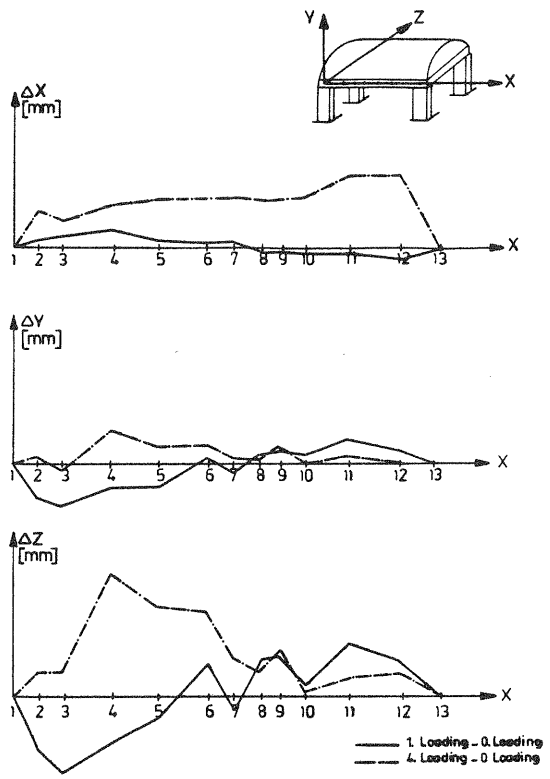

Figure 2 : The calculated displacements at the shell points (1,2,...13) from the analog - analytical restitution.

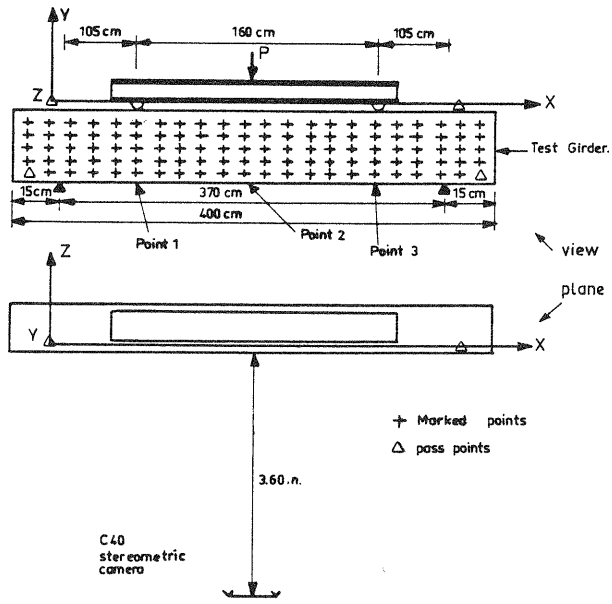

Figure 3 : Situation of the streometric camera, control points and the test girder.

In order to compare the three photogrammetric methods with a direct measuring technique, three deformation comparators are located under the girder. The readings of these comparators are done at every loading step simultaneously with the photo takings. Similar to the shell test the stereopairs or single photographs are restituted on Wild A40 and A9 Autographs.

The crack locations, their development during the test and their width are plotted at a scale of 1/5. A typical example at the plottings is given in FIG. 4.

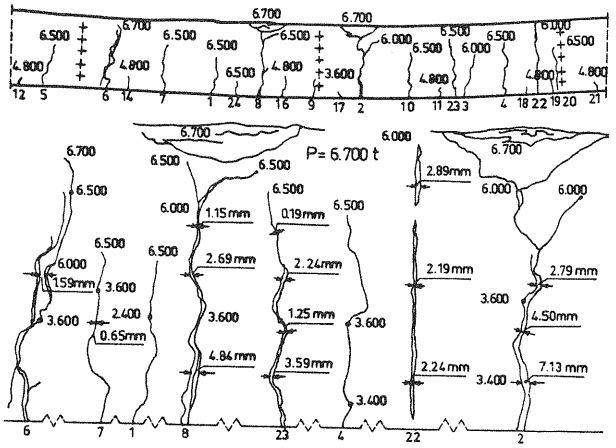

Figure 4 : The behaviours of the girder under a load of P 6.7 t. the positions and width of cracks (A reduced copy from 1/5 original plotting).

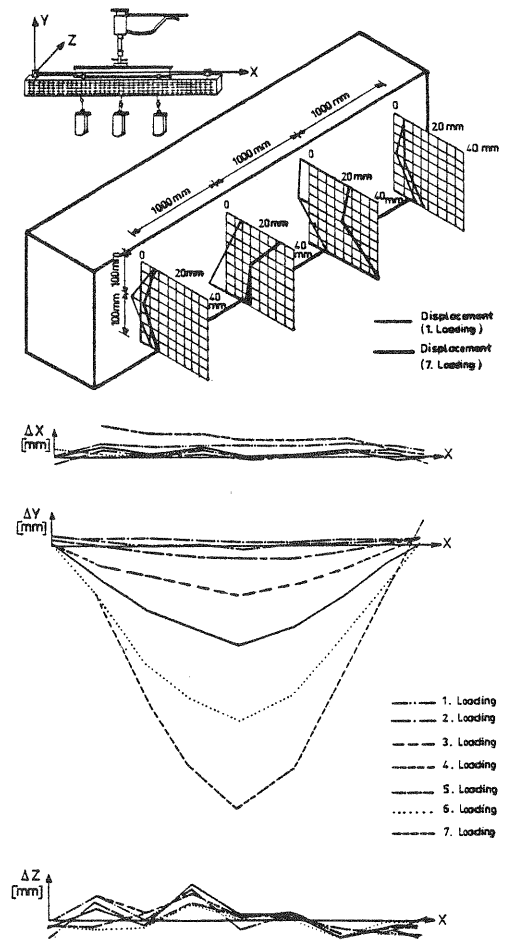

Figure 5 : Graphical representations of the displacement of girder points (analog-analytical method) in three directions and a cross-sectioned displacement of the girder from the data obtained by the bundle method.

The model and image co-ordinates which are taken from the stereo pairs or single photograph restitutions on the A9 autograph are handled accordingly with the transformation and the bundle computer programs.

Similar to the shell test the computed displacements of the girder points are represented at FIG.5. It shows the result of the transformation program (analog-analytical method). The bundle method gives the same results. Further details of their plottings can be seen in |5|.

The Comparison of the Results

It hasn't been possible to obtain displacement values through graphical restitutions done at a scale of 1/5 in the shell test. However, in the girder test, the graphical restitutions (see, figure 4) make it possible to obtain the deformations with the graphical method for each step of loading (especially after 3.rd loading). The deformation values obtained from the graphical restitutions show a relative difference of 0.3 mm according to analog-analytical method and a relative difference of 0.6 mm according to the analytical method. These results are in the direction of Y where deformation is high, and no deformation can been detected in the directions of X and Z axes where minor deformations occur.

Crack measurements (topography and width of the crack), an important information in the field of constructive engineering, can be obtained by analog methods.

The relative differences of the displacements obtained by means of the three methods in two tests an be seen in Table (1).

Table 1 : Relative Difference Between Three Photogrammetric Methods.

SHELL TEST	ANALOG METHOD	ANALOG-ANALYTICAL METHOD	ANALYTICAL METHOD
ANALOG METHOD	-	-	-
ANALOG-ANALYTICAL METHOD	-	-	1,92 mm
ANALYTICAL METHOD	-	1,92 mm	-

GIRDER TEST	ANALOG METHOD	ANALOG-ANALYTICAL METHOD	ANALYTICAL METHOD
ANALOG METHOD	-	0,30 mm	0,63 mm
ANALOG-ANALYTICAL METHOD	0,30 mm	-	0,49 mm
ANALYTICAL METHOD	0,63 mm	0,49 mm	-

In Figure 6, displacement of equivalent points obtained from the photogrammetric method (analog-analytical method) and by means of deformation comparator are drawn in relation to the load P applied to the girder.

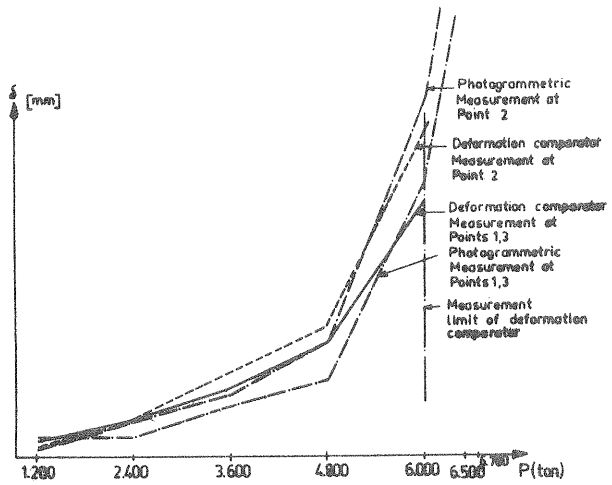

Figure 6 : The comparison of displacements (analog-analytical method) obtained by means of photogrammetric and direct measuring techniques (deformation comparator measurements)

Table 2 shows the time spent of the three photogrametic methods.

Table 2 : The Comparison of Photogrammetric Restitution Methods in Regard to Time

	TAKİNG OF PHOTO-GRAPHS + DEVELOPİNG (Minute)	İNNER AND OUTER ORİEN-TATİON (Minute)	RESTİ-TUTİON (Minute)	READİNG OF CO-ORDİ-NATES (Minute)	COMPUTER TİME (Minute)	TOTAL TİME (Minute)
ANALOG METHOD	30	10	20	-	-	60
ANALOG-ANALYTİCAL METHOD	30	10	-	15	60	115
ANALYTİCAL METHOD	30	3	-	15	60	108

The reason why the computer time is 60 minutes in the analog-analytical and in the analytical method is that the used recording unit doesn't magnetic tape recorder or a automatic card punch machine, making have a it possible to give the measured values directly to the computer. When there is such an equipment, the computer time can be reduced to a period of about 14 minutes and the total of periods will become 69 and 62 minutes, respectively.

CONCLUSION

While the aim of the birth of photogrammetry is to obtain the topographic structure of the earth, this aim now includes new and various fields of application. Most application fields of photogrammetry, that are not topographic, concern the field of close range photogrammetry. Each of the various application fields have specific conditions, and the demands at the end of the measurement processes differ from each other. Therefore, when precision, productivity and economy factors of the photogrammetric restitution methods are taken into consideration, it is necessary

to determine which of the methods can be carried out.

In this study, three photogrammetric methods are used in the problems of the deformation measurements concerning the girder and shell tests. By comparing these methods and processing the data obtained from the photographs taken during the two tests carried out in the Photogrammetry Laboratory of the Technical University of Istanbul we have reached to these conclusions:

- The results obtained with the analog method are not useful when minor deformations are in question (see shell test). The reason of this is the difficulty of making measurements on graphic restitutions. In addition to this, on graphic restitutions, the deformations can only be measured in two directions.

- With the analog-analytical or the analytical method, it is possible to determine the deformations in three directions.

- In the graphical restitutions it is possible to determine the state of the cracks for every loading step and to measure their width.

- In this study, the use of Wild A9 autograph instead of a comparator has reduced the precision of measurements. Use of a comparator will increase specially the precision obtained from the analytical method.

- Photogrammetric methods produce results more precisely in comparison to the deformation comparator measurements, the photogrammetric method makes it possible to determine the deformations in each of the three directions and at all the points on the object.

- With the deformation comparator it is only possible to measure the displacement in one direction at a certain point up to the measuring limit of the used comparator.

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