THE PHOTOGRAMMETRIC SYRVEY OF AN ARCHAEOLOGICAL SITE (CNOSSOS-CRETE) FOCUS ON SPECIAL PROBLEM

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ABSTRACT

For the detail survey of the Minoan Palace in Cnossos at a scale of 1:20,mainly photogrammetric techniques were employed.This paper gives a brief outline of the works carried out for providing the control and photography,which was mostly non-metric.Terrestrial photogrammetry was employed for the elevations and sections through the monument and low-altitude (up to 7.50m) photography was used to record planimetric details of semi- destroyed walls and paved floorings.The photographic material was processed mostly by a rectification method.

Innumerable special problems were encountered.They include establishing the incredible amount of control for an object as complicated and as vast (30.000 m²) as Cnossos,overcoming adverse lighting conditions,indexing and rectifying the thousands of photographs that were taken,elevating the camera(s) to desired heights both for horizontal and vertical photography and interpreting and plotting at such a large scale.Finally the solutions adopted and the decisions taken are presented,discussed and assessed for their cost effectiveness and time consumption.

1. INTRODUCTION

The arhaeological site of Cnossos in Crete covers today an area of 30.000 m². It includes the partially reconstructed multi-storey palaces that belong to the famous Cretan civilization that flourished on the island during the Bronze Age (2500-1500 B.C.).

Numerous small and large rooms and appartmens , storerooms workshops,staircases and corridors all in labyrinthical combinations forming the legendry buildings , give an idea to the 20th century visitor of their past grandeur and splandour. At the same time , however , they present a highly intriguing problem to the 20th century land surveyor-photogrammetrist as well.

By the end of 1983 the Archaeological Service of the Ministry of Culture and Sciences made a contract with a Joint-Venture of three Greek private Survey Firms for the detailed survey of the Minoan Palace in Cnossos. The main aim of the contract was the production of a highly detailed survey , which would later enable and facilitate decisive interventions on the part of the restoration engineers and archaeologists , in order to restore and rescue the monument from the rapid wear due to a number of reasons , such as soil creep , bad weather conditions and changes and thousands of visitors. Hence a detailed survey in a scale of 1:20 was required. The whole project would comprise:

a. The completion of the 1:100 plans and sections compiled by the British Archaeological School in Athens under the supervision of S. Hood , the only existing survey to date. Modern restorations , reconstructions , concrete parts as well as other existing problems (cracks , twists , breakings , etc.) should be shown.

b. The detail survey in a scale 1:20 of the whole palace in plan . Also a great number (60) of elevations and sections , totalling in length 2500 m , through all characteristic and endangered parts of the monument. The survey should be related to the National Reference Network.

c. The establishment of a permanent survey network for monitoring the deformations of the ground and of the various structures over the time.

The accuracy requirements were :

a. ± 5mm for all three co-ordinates of the trig points and the survey stations.

b. ± 6mm for the control points.

c. ± 10mm in the final drawing for every surveyed point with discrete mathematical definition.

The resulting of the final plot covers up to 450 A0 size sheets, 300 for the horizontal plan survey and 150 for the elevations and sections.

That incredible amount of work was carried out with adopted solutions and specially designed systems as are discribed in the following.

2. METHODS ADOPTED

2.1 GENERAL

A combination of conventional survey and photogrammetric methods was thought to be the best way to go about the problem. Surveying would provide the position of the necessary frame (geodetic and topographic method),photogrammetry would produce the fill-in details (photogrammetric method) and additional tape measurements would give the completion of the survey wherever it is necessary (topometric method). The above mentioned three methods were used with variable percentage according to the demands of every element, each providing :

the first , points and lines
the second , surfaces and
the last , completion for the other two.

2.2 THE GEODETIC NETWORKS AND THE TOPOGRAPHIC SURVEY

A geodetic net of eight trig points was established within the area forming an heptagonal figure with a central point. Triangulation pillars with forced centering were constructed where possible (in all points except two); in cases where this would damage the monument, bronze rosettes, glued on the surface of the monument, were used. Two separate adjustments were carried out. The first one involved only the central trig point and three outer ones of the National Reference Network for the determination of the horizontal position and orientation. The second adjustment involved the eight new trig points holding the central point and a bearing constant. In this way no inaccuracies of the Reference Network were introduced into the new network.

At the same time, almost 300 survey stations were established within the site in such a way, that they ensured economy, intervisibility and, of course, optimum coverage of the area. The layout of the monument and the requirements of the job sometimes forced the traverse legs to be drastically unequal in length and quite often we ended up with traverses passing through dark corridors or winding upwards and downwards via staircases snailwise, as if Ariadnes thread was being unwound again, but this time with the help of theodolite sights and steel measuring tapes. Precise traverse measurements with optical centering were employed for the determination of the co-ordinates and little circular bronze studs for the permanent marking of the survey stations, glued on the surface of the monument; separate precise levelling was employed for the height determination of every trig point and station. This part of the survey work occupied 4 land surveyors for almost a month, which is not too long, considering the accuracy requirements. The accuracies finally achieved were ±2.5 mm for the trig points and ±5mm for the survey stations. Around 30 survey stations were connected through a further least squares adjustment in a system of braced quadrilaterals running from NE to SW in order to provide the stations for the structural deformation measurements.

An enormous amount of detail points up to 10.000 were determined with angles and distance measurements from the survey stations. A close range photo for every natural detail point shown by an arrow, with its index number was used instead of a hand made sketch. All these points were natural detail points (projected), or sections of the projection plan (horizontal or vertical) with limiting edges.

2.3 THE PHOTOGRAMMETRIC SURVEY.

While the classical survey part of the job, though vast, was quite straightforward the photogrammetric survey had to cover approximately an area of 30.000m² of floorings and walls, both for the horizontal survey and the elevation and sections. Stereo coverage of the whole area would be the obvious answer. However rectification methods were also considered as the object itself, by construction could easily be broken down to flat surfaces with little or no elevation differences at all. The accuracy losses would then be minimal and acceptable, considering the large scale of the photography which was anyway imposed by the structure of the object not allowing large taking distances. At the same time there would be an incredible gain in the number of photographs,and in their processing time,both directly related to cost.

Hence for reasons of nature of the objects and cost efficiency rectification methods were preferred with no practical loss in the final accuracy.Where that was no possible stereo pairs were taken. Wherever the conditions where favourable,or when the object presented special interest,an UMK 100/1318 metric camera was used.Its weight and its minimum focussing distance,(min. Y=3,6m),however, posed a severe problem for universality of its use.For the floorings the camera had to be elevated to considerable heights with its axis vertical and this would not be possible without endagering it. On the other hand one was forced to photograph the walls of very narrow corridors i,e. object distances upon which the UMK lens would not be focussed.Hence one was,somehow, forced to use non-metric camera due to lack of another metric camera with the above restrictions. A Bronica camera with negative format 60x60mm and two ZENZA lenses of f=75mm and f=50mm was chosen,as previous experience with it (Stambouloglou 1980) had shown that it was perfectly suited for the job. The camera was calibrated with both lenses and the total distortion values (radial distortion and film unflatness and shrinkage) showed a rather symmetric distribution.The maximum distortion values were 75mm and 120mm respectively at the edge of the format. These two values give the following (table 1) total distortion (dr) in the object scale (cm) for the respective object distance (y).

Table 1

	f=75mm							f=50mm				
Y(m)	4	5	6	7	8	9	10	1	2	3	4	5
dr(cm)	0,4	0,5	0,6	0,7	0,8	0,9	1,0	0,24	0,48	0,72	0,96	1,20

Thus with no considerable effects on the final accuracy a non-metric camera could be used.Cost effectiveness and time consumption would benefit by its use, compared to the use of the existing metric camera.As to the question of the surface covered by the negative there is no doubt that it is not an unbearable disadvantage,as it would slightly increase the number of the necessary rolls of film. Each photograph should contain at least three control points or,in extreme cases,two control points and some other scale information for each plane imaged.Self-adhesive 30x30 mm aluminum markers were used for the control points.For the elevations and sections about 2.000 pre-marked control points were determined by taped radials and 170 glass plates and 700 6x6 film negatives were taken in all.On the other hand about 3.000 pre-marked control points and 2.000 photographs were needed for the floorings.

2.4.THE TOPOMETRIC SURVEY

By that greek language term, we mean the measurements made with simple instruments like the tape and the plumb bob.Two sets of such measurements have been carried out.The first concerned measurements for the determination of sections of horizontal and vertical projection plans with walls and ceilings in conection with the detail points (between two of them). The use of this method for the determination of thousands of natural detail points proved the most cost effectiv, keeping simultaneously the accuracy requirements.The second set included the necessary completion for the survey of the parts of elements for wich the previous methods proved inadequate and their survey impossible.

3. SPECIAL PROBLEMS

3.1 PHOTOGRAPHY

The first most obvious problem when confronting a job like that,is of course,indexing the thousands of photographs and keeping track of their position.Main disadvantage is the fact that the ruins look very much alike in black and white.It was decided to number the photographs for the elevations and sections from 1 onwards,sketching at the same time the object with the control points and noting the number of the photograph and the section. When using the UMK we made use of its indexing facility. For the non-metric photography special numbered cartons were prepared and put every time into the picture.

Particular problem was posed for the indexing of the vertical photography.The whole area was divided in 24 sections,to each of which a letter of the Greek alphabet was assigned.This division followed a reasonable pattern offered by the layout of the construction complex.Thus in each section,i.e. letter,the photographs followed a separate numbering,while the alphanumeric index always pointed northwards in order to determine the orientation of the photos. At the same time the exact position of the photograph was marked on the existing 1:100 plan,which provided an ideal sketch.This method proved quite efficient,as there never was an ambiguity as to the exact location of each photograph.

Adverse lighting conditions,mainly in the interior parts of the monument were overcome by the use of a 2KW projector lamp for which about 300 m of wire to the nearest plug was necessary.The use of flash gun was generally avoided,because of the intense and mostly undesirable lighting that would produce.

3.2. SUPPORTING SYSTEMS FOR PHOTOGRAPHY

For the vertical photographs a bipod was initially used.Its classical design demanded three persons for its operation and proved quite awkward in stabilising and positioning it over the desired spot.To overcome these problems and the unavailability of manpower a new bipod-like system was designed and constructed,based on the above observations.Thus a tripod camera system was born. The tripod-camera system is based on the same conception of the bipod.The above mentioned practical experience guided us to add a third leg;in this way the new configuration has the following advantages:

(a).Only one person can handle it, once in position.

(b).The system can stand alone without human support.

A new metal join head has been designed and constructed to accommodate free and indipendent movements of the three legs. In certain areas the use of a mechanical device like the tripod was impossible and the photographs had to be taken with the camera handheld ("human bipod").

For the terrestial photographs and whenever the camera had to be elevated above the conventional tripod height (up to 1.80 m) the E.C.S.(Stambouloglou 1982) was employed .

Finally,and bearing in mind that mainly rectification methods would be used later, while processing the data,effort was made to photograph plane surfaces.The construction of the monument favoured this and care was taken to provide scale and tilt information for every plane imaged on each photograph(i.e at least 3 control points).Stereoscopic pairs covered the few areas where this was impossible.

3.3 DATA PROCESSING

A typical problem was posed for the required sections and elevations by the fact that the various elements of the monument did not run in parallel with the horizontal projection system of the National Reference Network.To overcome this problem the following solution was employed. Several main directional trends were analytically determined,that would cover the majority of the object.Each section,or part thereof where applicable,was forced to follow the more suitable direction.Thus firstly the levelling of each section was made easier and more exact and secondly the control points' coordinates were transformed accordingly.Rectification was performed on the basis of these transformed control points.In this way a truthful representation of each section was achieved and a unique transformed coordinate system was possible.

A Personal Computer was used for the compilation of the geodetic,topographic and topometric data,while a plotter gave the graphical results of the topometric measurements for the horizontal and vertical sections.

Rectification was performed on a DURST 138S Enlarger (max. negative size 13X18cm and tilting projection table) with the help of the relevant control points drawn in the desired scale.The final drawing was carried out by qualified droughtsmen and architects who,at the same time interpreted the images.Stereo plotting was carried out on a Wild A-10 autograph.

4. CONCLUSIONS-REMARKS

Invaluable experience was gained from this project,as such a detailed and laborious survey was carried out mainly with photogrammetric techniques for the first time to this extent in our country.The particular accuracy requirements,the large final drawing scale and the amazing complexity of the object itself lead to the necessity of a vast amount of special work, which could not be foreseen from the outset. Hence the initially set time schedule of six months proved to be quite unrealistic. Main reason for that, was the shortage of suitable manpower available, that could enable the various parts of the job to run simultaneously as far as this was permitted by the nature, a parameter underestimated for the set of time schedule. In all, 14 months were necessary for the completion of the job.

The final required time for every task of the project and the personnel involved is shown in the following table:

JOB	ENGIN+ASS	DAYS	MAN/DAYS	%
TRIANGULATION	4	7	28	1.16
TOPOGRAPHIC SUR.	8	30	240	9.95
TOPOMETRIC SUR.	8	90	720	29.84
PHOTOGRAPHY & CONTROL POINTS	2	180	360	14.92
CALCULATIONS	1	45	45	1.86
RECTIFICATION & STEREO RESTITUTION	1	180	180	7.46
DRAWING	4	180	720	29.84
FIELD COMPLETION	4	30	120	4.97
TOTAL			2413	100.00

The cost estimate of the whole project made by the service was 7.500.000 dr, approximately 50.000 US$. After the completion of the project the amount of the cost had to be modified in order to cover more realistically the achieved task. So, the final cost reach the double of the cost estimate.

Before concluding, one should mention the main causes of delay in the survey of Cnossos. Firstly the weather, which in winter and spring was unusually wet and during the summer months the sun and the heat were simply unbearable (≈ 40° C). Secondly the innumerable waves of visitors, most of whom thought that the self-adhesive marks on the walls and the floorings were precious, excellent and cheep (to " buy "), Minoan souvenirs to take away. As result we found, some times, ourselves in a " Minotaure " mood, ready to tear in pieces some of them.

Furthermore, experience has also shown that simultaneous work on the field could be performed by an extremely well organised and disciplined party, which would at the same time perform the survey measurements for the survey points and the photo-control points of the elevations and floorings. Such a mode of work, though difficult in application, would bring the field work and hence the cost to a minimum.

The last and concluding remark is that this kind of project needs and demands, most importantly from the people working for it, the instinctive love and devotion for the monuments and this special work.

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