DETAILED RESTITUTION AND REPRESENTATION OF THE SEAWARD CASTLE OF CHIOS

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ABSTRACT :

The Hellenic Ministry of Culture has recently developed a programme for the restoration of the country's most significant Byzantine Castles. A team from the Laboratory of Photogrammetry of the NTUA, in close collaboration with specialized architects, has undertaken a detailed pilot survey and documentation of the Castle of Chios, in particular the façades of the seaward aspect. This consists of the internal and external sides of the wall (approximately 230m long) and of a large tower (up to 15m in height) with a block of internal corridors.
The project also entails the compilation of the technical specifications for the survey and the digital recording of similar large Byzantine monuments, on a scale of 1:50, together with the selection of the most appropriate methods for the representations of the façades. The results of the investigation are described in this paper, together with their application to the Castle of Chios. For the restitution, photogrammetric methods were followed. The metric cameras UMK Zeiss c=100mm, Rolleiflex 6006 c=80mm and the semimetric Hasselbland 500C/M c=50mm, were used. Digital rectifications were made for the flat surfaces of the wall (using software ARCHIS of SISCAM) and digital stereorestitutions were applied to all the rest (on the PC-based system VMAP of VTA). Photos were taken by boat, for the external side of the wall, or from the inside of the tower, along short, dark narrow corridors (2-5m width, 1.5-3m height). Wooden frames of fixed length (to reduce the number of control or tie point measurements) were used. The results given from the photogrammetric work were well within the required specifications of accuracy.
Digital recording, in 3-D, allows for the projection of the façades on proper planes or the creation of a development. Owing to the changeable curvature of the tower's shape and to the existence of conic scarpa at its lower and upper elevations, the adaption of parts of developable surfaces to specific parts of its external facade, is examined. The representation of the internal façades of the corridors, however, can only be achieved by using projection planes of short length.

1. INTRODUCTION

The Byzantine Castles of Greece, a significant part of the cultural inheritance of the country, are scattered all over the Hellenic jurisdiction, but mainly on the islands and the Peloponese. Until some years ago very few studies for their surveying, documentation, preservation and restoration have been compiled. Recently the Ministry of Culture has undertaken the big task of recording and studied the largest and most well-preserved castles. These castles are monuments of large size, with fortification walls and towers, parts of which require either immediate interventions to survive the damage or archaeological excavations in order to be fully revealed.

The School of Rural and Surveying Engineering of the NTU of Athens in its effort to contribute to the successful outcome of this task, assisted the Ministry to compile technical specifications for the geometric documentation of the Castles and undertook the compilation of detailed pilot restitutions of some Castles. A team from the Laboratory of Photogrammetry of the NTUA was involved in a project for the documentation of the seaward part of the Castle of the city of Chios, on an island of the northeastern Aegean Sea. All stages of work were executed in close collaboration with specialized architects working either for the Ministry of Culture or at the NTUA. It is only by multi-discipline cooperation of Surveyor Engineers, Photogrammetrists, Architects and Archaeologists that a successful outcome can be achieved (Ioannidis et al 1997).

The significantly large castle of Chios has become part of the urban area of the city of Chios. The inhabited buildings at the internal of the castle are in many cases even attached to the fortification wall. The seaward side of the castle, 290 m long, is soaked by the sea and its preservation and restoration meet the most serious problems. This side consists of the wall, approximately 230 m long, and a large round tower in the corner. The perimeter of the tower's basis is approx. 105 m long. An approximately 65m long part of the external side of the wall is already demolished and the on going erosion caused by the sea water, in combination with the absolute lack of preservation activity, helps the spreading of this destruction. The height of the wall, at the still preserved parts, is 6-8m at the external side and 3-6m at the internal side. The height of the external side of the tower varies between 7 and 12m and on the top of it there are fortification ruins at a height of 15m above sea level. Inside the tower, at various levels, there is a block of corridors which has not yet been fully excavated. Figure 1. shows a small part of the external side of the wall, where the destruction signs are clear and Figure 2. shows a part of the tower; the photos were taken by boat, from the sea.

Figure 1. Photo, taken by the UMK camera, showing part of the destroyed façade of the Castle (taken by boat)

Figure 2. Photo, taken by the UMK camera, showing part of the external side of the seaward tower

The need for a detailed survey of this seaward part of the Castle is obvious and the production of basic plans for the compilation of preservation studies, the fastening of the wall and the restoration of the internal of the tower is necessary. It was decided that the degree of details and accuracy of these plans should be that of the scale of 1:50 and should consist of:

- Aerial view of the seaward wall and the tower
- Horizontal intersections at particular levels of the internal of the tower
- Façades of the external and internal side of the wall
- Façades and intersections, to various directions, 16 in total, of the internal corridors of the tower.

The present paper is mainly focused on the surveying and documentation procedures of the façades.

2. TECHNICAL SPECIFICATIONS AND SURVEYING METHODS FOR THE FACADES

The first presupposition for the successful geometric documentation of the monument is the use of proper and up to date technical specifications. The complexity of the object and the difficulty in approaching various parts of the Byzantine Castles, demand a certain level of flexibility in the technical specifications. The extant rich international (i.e. Monti et al 1998) and local (i.e. Portelanos 1987) experience in similar surveys, in combination with the International Authorities for Restoration of Monuments' Guidelines (Carta of Venice 1964, Amsterdam Declaration 1975, Carta of ICOMOS for the protection of historical cities 1987 etc) provide the framework for the compilation of such specifications. The main characteristics of our proposal were:

- The compilation of technical specifications focussed on the result/product and not on the methods used. In this way both the needs of the employer (Ministry) and the experience of the employee (Engineer) for the improvements in hardware/software and data measurements and processing are satisfied
- The combination of the survey of the monument with proper documentation methods, i.e. Information Systems technologies, for multi-level applications of data, without any significant cost increase
- The use of surveying methods that respect the monument, avoiding any interventions on it or its exposure to possible damage or destruction
- The production of digital data, to enable easy reproduction and further processing of the data. The necessary drawings in analog format are also defined, together with the proper scale and symbolization (if possible, easily reproducible by CAD software)
- The recording of the alternative restitution methods, that can be applied (with no obligatory application but with a good reason for their rejection), according to the final plotting scale, the purpose of the study and the specific characteristics of the Castle and the surrounding area. The basic principal is the encouragement of the use of simple and user-friendly procedures instead of the adaptation of more complicated and cost-consuming methods. So, all the necessary directions are provided to the private surveyors for the better compilation of their work.

The plotting of the façades (or the intersections) may be the most significant part of the survey of a castle. In most cases the combination of photogrammetric and field surveying is necessary so that the best application of the technical specifications will be achieved. In the present case, it was considered necessary:

- To apply photogrammetric methods for the compilation of the general plan of the façades, with all the details of masonry. Digital rectification was selected, among the available alternative solutions, for the flat parts of the façades and stereoplotting was selected for all the rest surfaces. The demand for vector data production reject the use of orthophotos. In parallel, photos taken by non-metric cameras were used, whenever the circumstances and the accuracy needs allowed it. So a full use of the most simple tools would be achieved within the demands of the technical specifications
- To execute field surveys, for:
    - the measurement of control points necessary for the photogrammetric work and
    - for local additional collection of data at the places where no photographic coverage was achieved. For instance, at the sides of very narrow corridors of the tower (less than 2m width), at the parts of the internal side of the wall that was covered by trees etc
- To use direct tape measurements, for the completion and correction of the photogrammetric plotting of the façades. There are always details of the masonry which can not be recognised on the photos and cannot be restituted photogrammetrically, especially by monoplotting procedures. The execution of such field measurements, in collaboration with an architect, is absolutely necessary for the final restitution of each façade.

3. THE PHOTOGRAMMETRIC WORK

3.1 Executing photography

The location and the particular shape of the castle have caused a lot of problems during the execution of photography of the façades:

- The external side of the wall is soaked by the sea water along its whole length except a part of the tower. The photos were taken by boat from the sea as close to the coast as possible. The use of Zeiss UMK 10/1318 camera, with c=100mm, was selected due to the large image format. Figures 1. and 2. show such photos of the wall and the tower correspondingly
- In the internal side of the wall, there were some parts covered by trees or vegetation, that made the execution of photographs extremely difficult or even impossible. Figure 3. shows a sample of these photos that were taken to cover small parts of the wall between trees. The internal side was photographed by the UMK camera, at the open space parts, and by the Rolleiflex 6006 reseau camera with c=80mm and 5.5x5.5cm format, at the parts difficult to approach (due to some constructions close to the wall) or with dense vegetation

Figure 3. Photo, taken by the Rollei camera, showing part of the internal side of the wall -most of it covered by trees

- Restitutions of the façades, in the internal of the tower, were needed along very short (about 1.5-3m height), narrow and dark corridors. All the façades of the corridors with a width larger than 2m were photographed by the semi-metric Hasselbland 500C/M camera, with 5.5x5.5cm format, with a lens of c=50mm. Figures 4. and 5. show two photos of that kind, with parts of the central corridor (approx. width 5m) and a narrow corridor.

In total 243 photos were taken by the three cameras. More specifically 86 photos were taken by UMK, 50 photos by Rollei and 107 photos by Hasselbland.

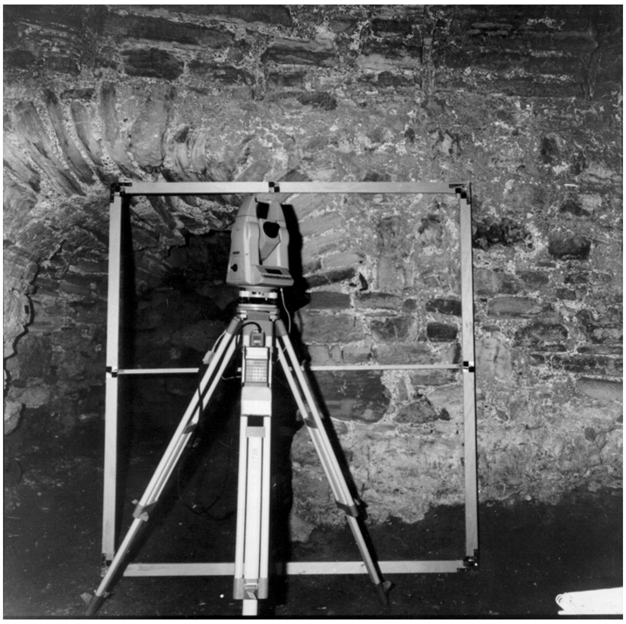

Figure 4. Photo, taken by the Hasselbland camera, showing an arch of the central internal corridor of the tower –use of the big wooden frame

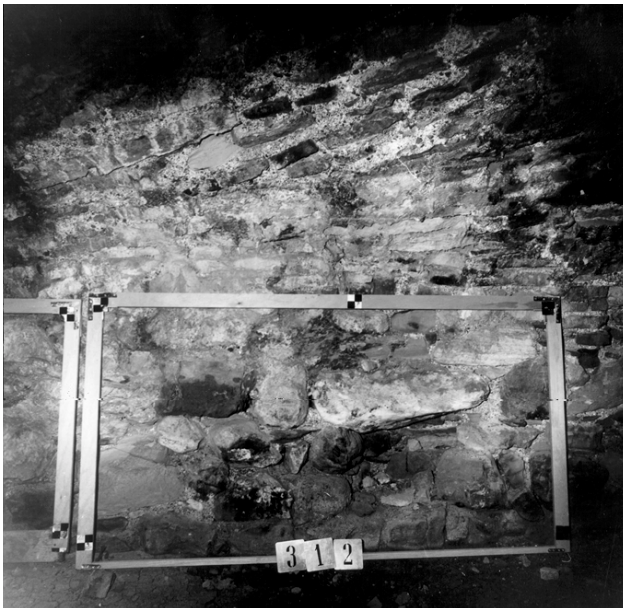

Figure 5. Photo showing the side of a narrow internal corridor of the tower –use of the small frames

Figure 6. shows a horizontal intersection of the internal of the tower, at a height 1m above the ground, with the photographic cones of the photos of the external side of the tower, taken by UMK camera, and the photos of one façade of the central interior corridor, taken by Hasselbland camera. The positions of the rest photos taken in the interior of the tower are not shown on the figure, to avoid making the plan too complicated.

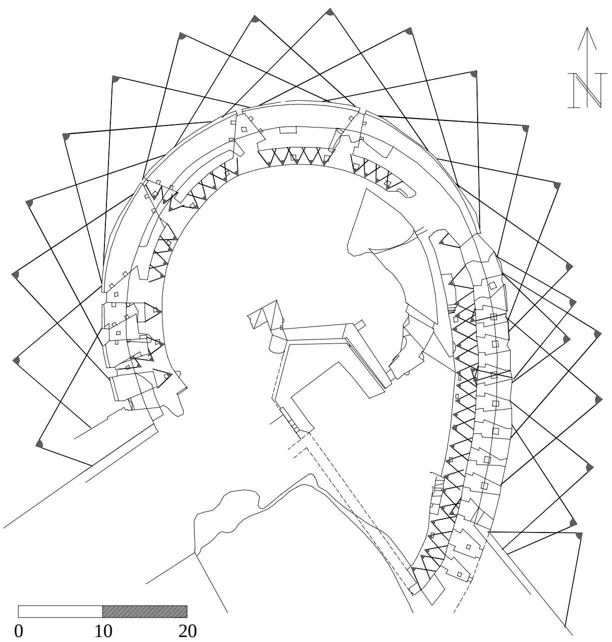

Figure 6. Horizontal intersection of the tower with the positions of the photos taken

Premarked control points were used in all photos. The targets were black and white squares of 5x5cm. Only at the semi-destroyed part of the seaward side of the wall were used few, well defined, natural points. In total 590 control points were measured by field surveys, with an accuracy of 1cm. The photo overlapping did not allow the use of photo-triangulation adjustment in order to reduce the field work. In most cases the field measurement of the control points coordinates was easier than the taking more photos.

The limited number of control points was achieved by substituting them, for the photos of the interior of the tower, by special structures – simple wooden frames of fixed and measured sides. Two types of frames were used, one of them 2x2m, for the large corridors, and the other 1x2m for the narrow corridors. Targets of 5x5cm each were placed on the frames, at standard well-measured distances. Figures 4. and 5. show the two types of frames, one with 8 targets and the other with 5. By this method, a need for much less field measured points for the photogrammetric procedures and the connection of their results to the topographic network is achieved (Ioannidis et al 1997).

3.2 Processing and results

The photogrammetric processing of the data was fully digital. The analog negatives were at large scales, between 1:50 and 1:150, so their scanning, by the HP ScanJet 6100C/T, at a resolution of 600 dpi, gave very satisfactory data for the calculation of the point coordinates, with an accuracy better than 2cm on the ground.

Since all the necessary control points were measured by field survey, no photo-triangulation adjustment took place. The methods that were applied for the compilation of the plans were:

- Digital rectification, by using the software ARCHIS for Windows of SISCAM. It was applied to 33 photos taken by the UMK, to 32 photos taken by the Rollei and to 107 photos taken by the Hasselbland camera, which covered:
  - all parts of the external and internal side of the wall that had not suffered too much damage and thus the masonry could be simulated by a flat surface quite satisfactorily. The erosion, the absence of small stones etc, which is quite common situation in similar monuments, do not create big enough deviations from the flat surface able to cause errors to the rectification method
  - all surfaces of the internal corridors of the tower. Although the relief of the masonry is rough, the scale of photos is larger than 1:100 thus allowing the use of rectification. The flexibility of the software to rectify photos by using measured vertical and horizontal distances on the object, made the use of the wooden frames much easier.

  The result of the monoplotting of the rectified photos in the AutoCAD r14 environment, was the production of 2D (on XZ plane) vector digital data, at a unique coordinate reference system

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- Stereoplotting, on the PC-based photogrammetric system VMAP of VTA Photogrammetric Consultants Ltd. It was applied to 48 stereomodels, 38 of them with photos taken by the UMK and 10 of them taken by the Rollei camera, which covered:
  - all the badly destroyed or collapsed parts of the external and internal side of the wall
  - the external side of the tower, in full height (photos taken from the ground level and from parts of the top of the tower) and all the curved parts in the internal side of the wall.

  The results of the stereoplotting was the production of 3D vector digital data. For the case of the tower, the full model of its masonry was created in space.

The completion of the photogrammetric processing followed additional field measurements and checks. A dense topographic network, consisting of 60 points, created to fulfil the needs of compilation of horizontal intersections both outside and inside the tower, made the described stage of the work very easy. Figures 7. and 8. show the external and internal side of the wall, up to the tower, each of them divided in two parts. All the details of the masonry contained at the original plans of the façades (scale 1:50) have been retained to the decreased plans of 1:500. Yet, all the other patterns and symbols used at the original plans to declare the phases and the various techniques of the construction, the type and size of the destruction etc, have been erased, because this information is directly related to the plotting scale. Only the pattern named ‘earth’ was used to declare the destroyed parts of the wall.

Figure 9. shows an internal façade – intersection along the arched central corridor of the tower (Figure 6. shows the positions of the photos taken for the compilation of this plan).

4. REPRESENTATION OF THE FACADES

The stage of collection and processing of data, for the precise restitution and the choice of the most proper symbolization of the object’s façades, follows the stage of consideration about the representation of the geometric results. The selection of either vector or raster format for the final product is defined mainly by the purpose of the study and, secondly, by the shape of the object. The possibilities for rectified photo and orthophoto production or even the digital photo-unwrapping of the façades in developable surfaces (Karras et al 1996) give alternative ways of presentation of raster products, similar to the vector ones. In the case of the Castle of Chios, the production and delivery of vector data was decided straight from the beginning. So, the only consideration was about the proper choice of the projection planes of the façades and also about the need for creating developments of the curved surfaces for the better conception of the monument and the utility of the drawings.

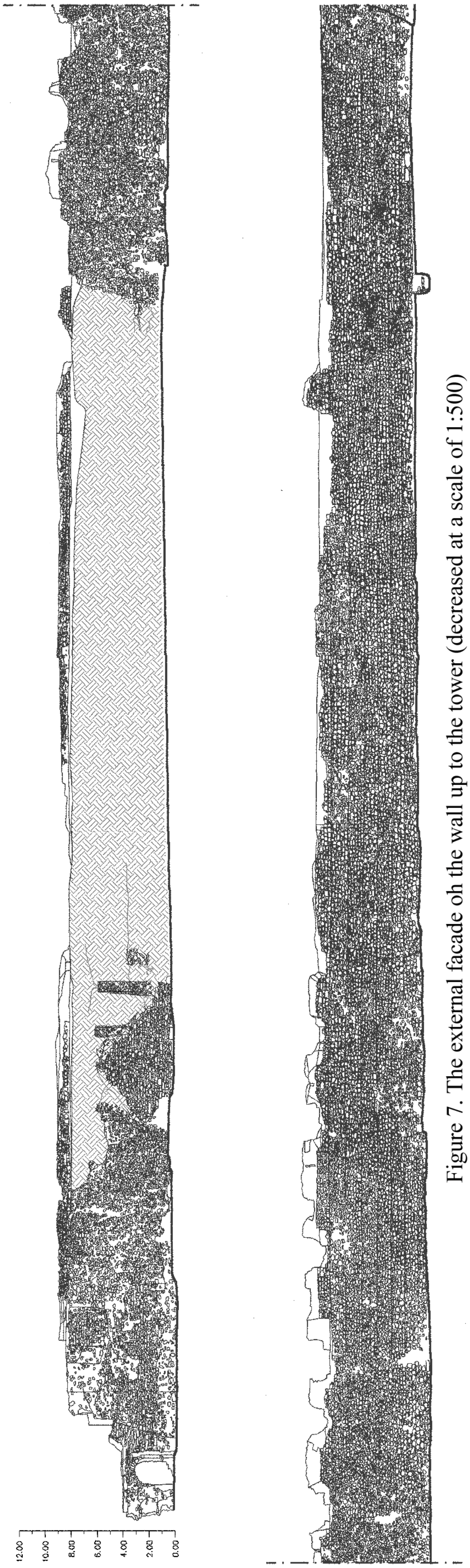

Figure 7. The external facade oh the wall up to the tower (decreased at a scale of 1:500)

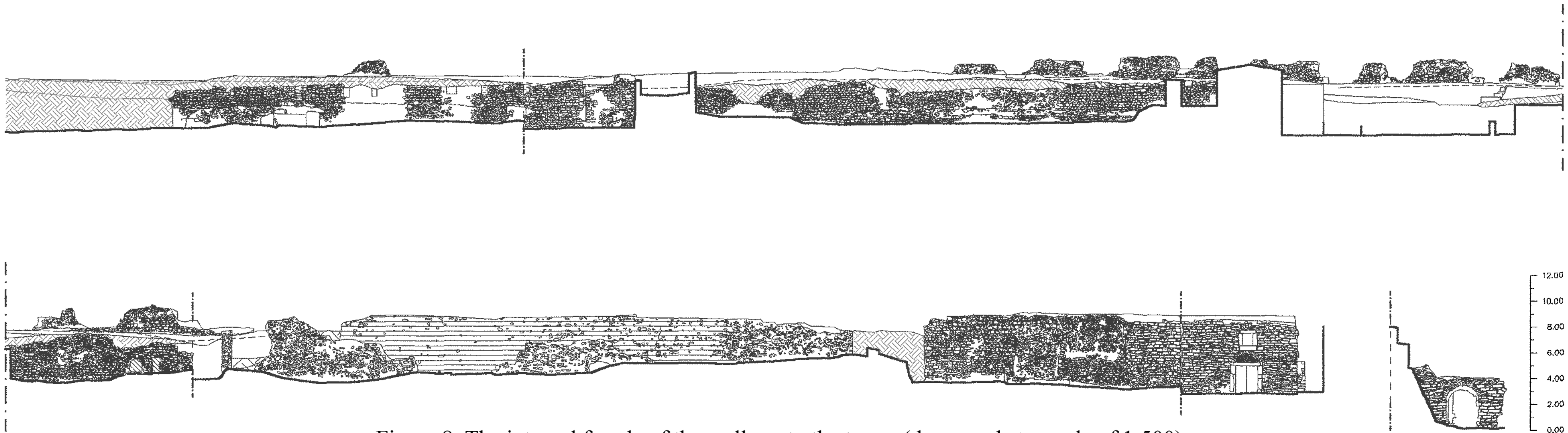

Figure 8. The internal facade of the wall, up to the tower (decreased at a scale of 1:500)

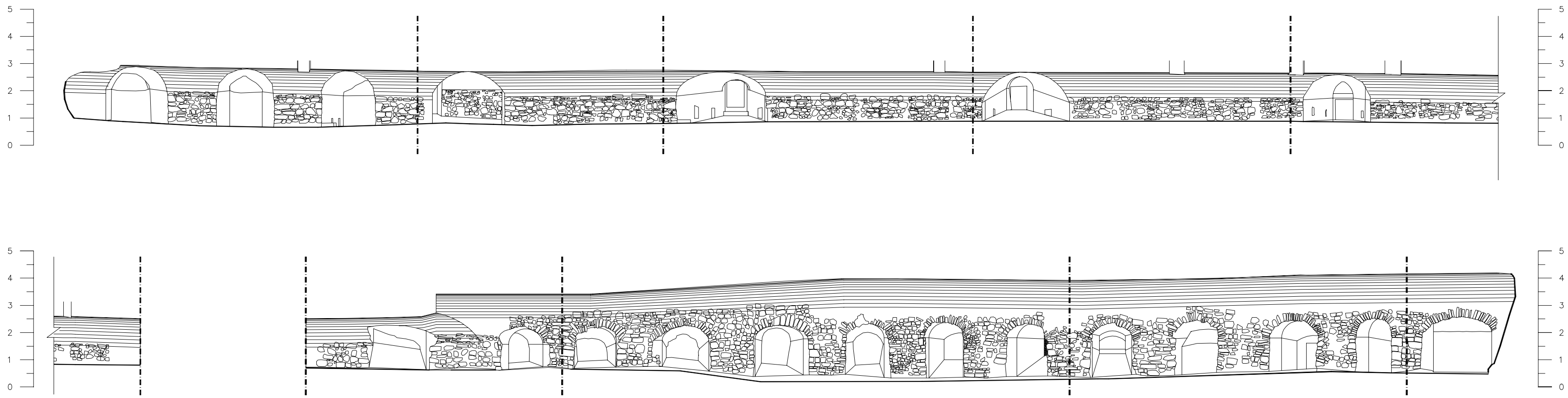

Figure 9. The facade of the internal central corridor of the tower, separated in two parts (decreased at a scale of 1:250)

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The approach of compiling projections of the façades onto specific planes, even in the cases of curved surfaces where the elements of the object are distorted, has the critical privilege of giving an easily recognizable picture of the object and not a mathematical construction which no one can meet in real world. The problem of distortions of the geometric characteristics can be solved by projecting the same part of the monument onto more than one projection planes, i.e. for the cylindrical surfaces on planes making 45^o angle with each other etc.

In the seaward part of Castle of Chios the consideration is focussed on the representation of the tower, since

- the sides of the wall are flat and vertical. Their projections are shown on Figures 7. and 8.
- for the sides of the internal corridors of the tower the only possible solution is the use of projection planes of short length, without any development. Their intersection with the ground level is a changeable curvature and their arched surfaces are very complicated. Figure 9. shows with thick vertical lines the turning points of the projection planes, so that the distortions will remain small.

In the cases where there are simple curved surfaces and especially spherical, cylindrical or conical parts, the creation of a development has critical advantages:

- for restoration studies, where the construction parts must be represented with their real dimensions
- for monuments with a structure of a 'normal pattern', i.e. of classical or hellenistic era.

A lot of applications can be found in the literature of CIPA Symposia and Commission V ISPRS proceedings, for the adaptation and the creation of development derived from photogrammetric data, mainly in spherical domes and cylinders (also in: Feltham 1990, Theodoropoulou 1996).

The external side of the seaward tower of Chios constitutes a more complicated case, which can be developed to help the needs of restoration. The difficulties faced here are:

- its construction with small stones, of irregular shape, and their damages especially in parts close to the apertures, the gaps created by the absence of some stones or the distortion of some others. So, the façade is not a 'mathematically regular' surface and the adaptation of the model is more uncertain
- the geometry of the object. The tower obviously consists of more than one mathematically defined objects in space, one on the top of the other. There is a conic scarpa at the lower part and a cylindrical surface on the top of it. Above the cylindrical surface, in one part of the tower another conic scarpa is still preserved. It can also be seen that the horizontal intersections of the tower are not parts of the a single circle (or ellipse). The possibility of composing the object by a number of developable surfaces and the individual development of these must be investigated.

The digital 3D recording of the masonry of the tower into a unique reference system, through the photogrammetric stereoplotting of the models, allows a comparatively easy mathematical processing of the surfaces and their individual parts. So, first the tower was projected onto the two (parallel to each other) projection planes of the façades of the wall, and the result is given at Figure 11(A) decreased to 1:500, and secondly an investigation for its development was done.

An adjustment was made, by applying the Least Squares Theory, of a large number of 3D points (more than 500 in total) to the most similar developable surfaces for each part of the tower: conical surface(s), cylindrical surface(s) and again conical, always with their central axis parallel to Z-axis. The results are schemes of great symmetry, with deviations less than 25cm, quite satisfactory for such kind of construction. Each part of the tower, along its height, consists of two mathematical surfaces, with circular sectors as horizontal intersections. As it can be seen in detail on Figure 10.:

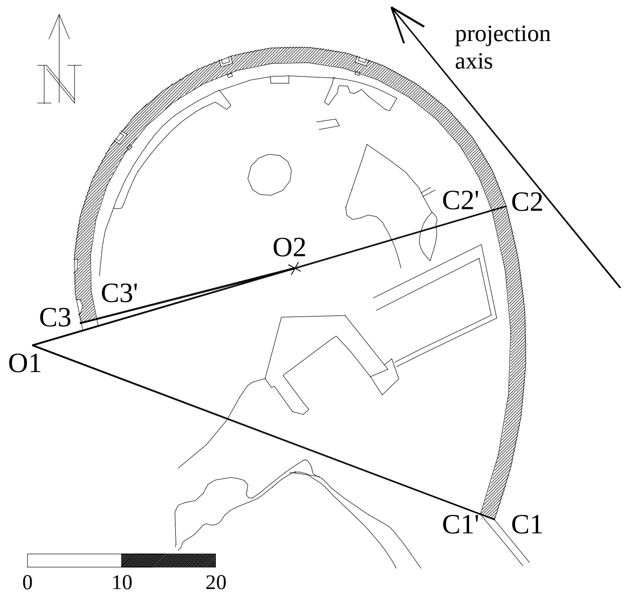

Figure 10. Adaptation of mathematical surfaces to the horizontal plan of the tower

- for the lower part of the tower, that is included between the elevation of 0.9m the elevation of 6.0m and which has horizontal projection the C1-C2-C3-C3'-C2'-C1', the lines C1-C2 and C1'-C2' are circular arcs with common centre the point O1 and radiuses equal to 52.45m and 50.85m correspondingly. The lines C2-C3 and C2'-C3' are circular arcs with point O2 as the common centre and radiuses 23.45m and 21.85m correspondingly. Within the same accuracy tolerances the point O2 belongs to the radius O1-C2, so the continuation of the construction of the tower and of the development of this part is assured. Consequently, the lower scarpa is composed, with acceptable accuracy, of parts of two conical surfaces, with a central angle of the cones approximately 18^o

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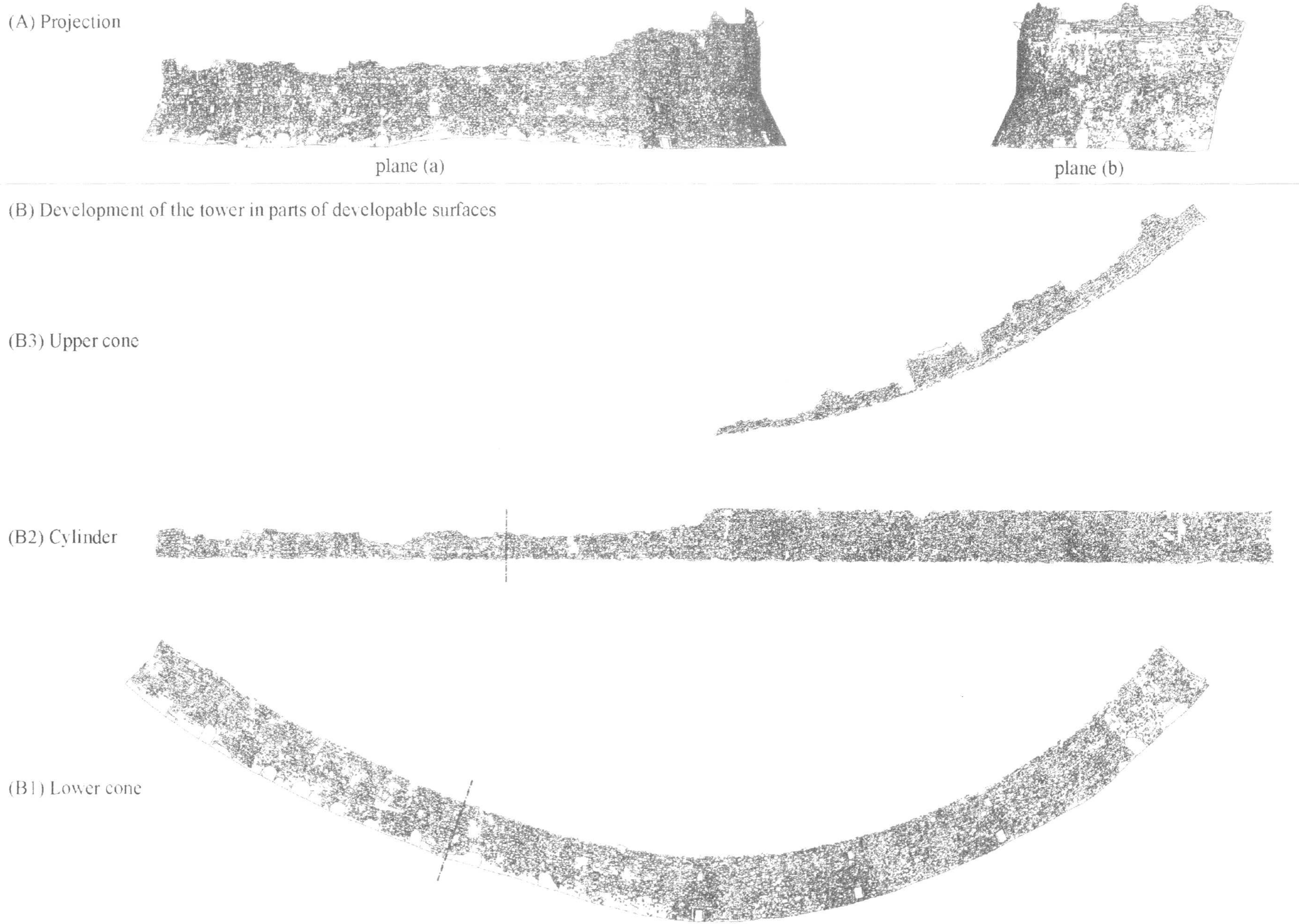

Figure 11. Representation of the external facade of the tower (decreased at scale of 1:500)

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- the part of the tower which lies above the previous one, with projection line the C1'-C2'-C3' and is included between the elevation of 6.0m and the elevation of 10.5m, consists of two cylindrical surfaces whose central axes pass through points O1 and O2 correspondingly, with mean deviation of 15cm
- the northern part of the tower, which lies above the elevation of 10.5m, constitutes a conical sector, with a central angle approximately 23^o.

Based on the above adaptations, individual developments of the surfaces were done, by calculating the conical or cylindrical coordinates of 3D points that belong to each part of the masonry. The origin of the coordinate system of each development was one known point on the relevant surface. The results are given to Figure 11.(B), at a scale of 1:500. Obviously the merging of these three developments and the creation of a unique plan is not possible because each one has a different coordinate reference system. On the contrary, the developments of the two lower cones and two cylinders can be adapted with each other (in Figure 11.(B1) and 11.(B2) the merging is shown with thick line).

5. CLOSING REMARKS

The existance of up-to-date and flexible technical specifications allows the use of all the alternative solutions for the geometric documentation of large and complicated monuments, like the Byzantine Castles. Having as pilot project the seaward part of the Castle of Chios, which is consisted of parts with varying degree of difficulty and complexity, the following possibilities were investigated:

- the use of low-cost hardware and software (including cameras, photogrammetric instruments etc) which meet the accuracy needs for the final products
- the representation of the monument with the most effective way, in raster or vector format, according to the purpose of the project. The compilation of developments is preferable for simple developable surfaces, otherwise it gives complicated and difficult to use drawings.

ACKNOWLEDGEMENTS

The survey of the seaward part of the Castle of Chios was commissioned by the Department for Restoration of Byzantine Monuments of the Ministry of Culture of Greece, with which we had an excellent cooperation. To the members of the Lab. of Photogrammetry of NTUA who have contributed to the work and especially to Prof. J. Badekas, for his valuable scientific assistance, we owe the good result of this project. Also, Mrs. S. Soile, Surveyor Engineer, should be mentioned here for her significant contribution to the compilation of the photogrammetric work and her exceptional devotion to that.

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