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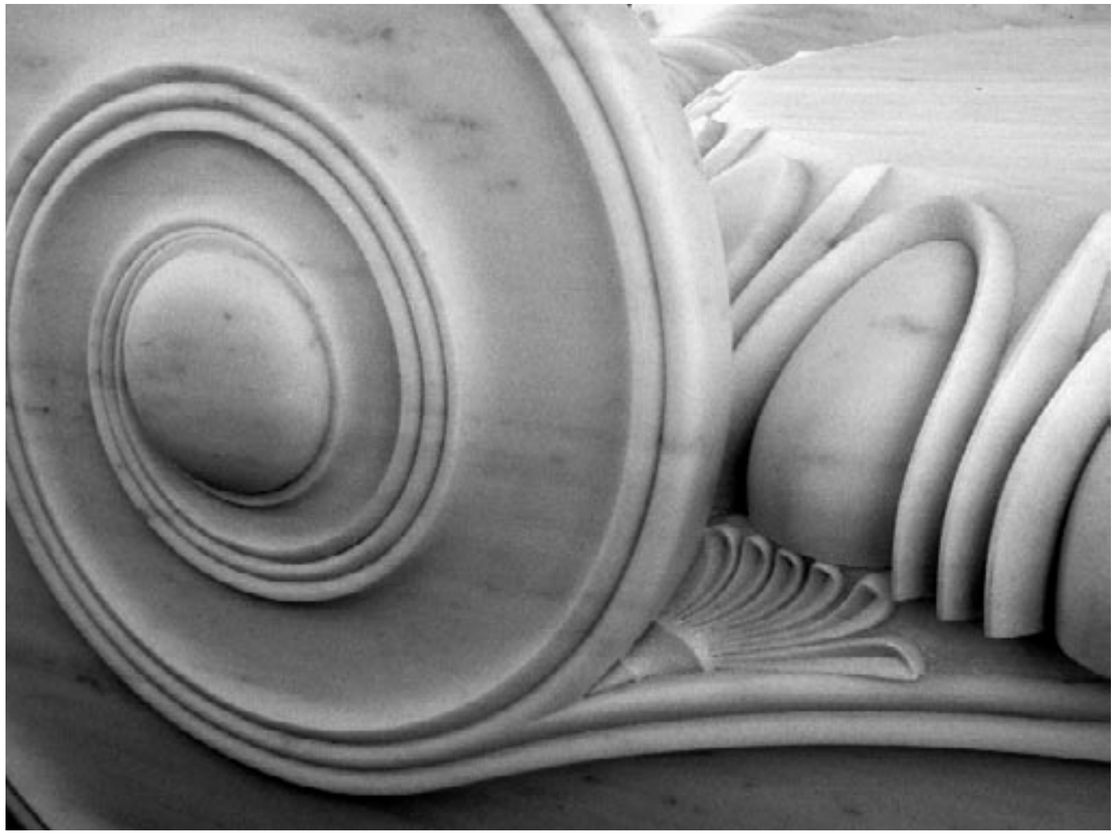
The Acropolis Restoration News

6 • July 2006



Detail of volute of the new Ionic column capital of the Propylaia. Photo T. Tanoulas, 2005

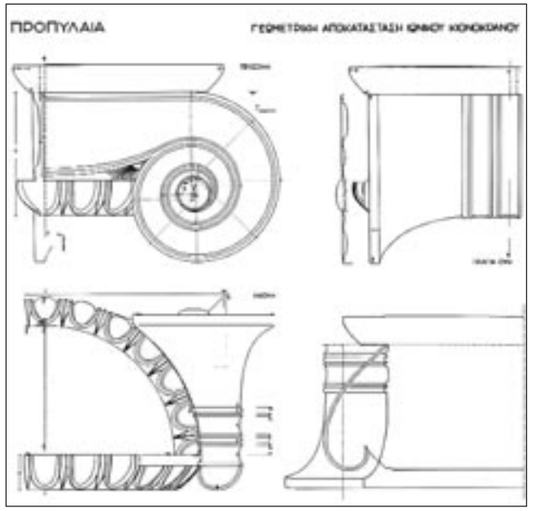
The moderm marble copies of the Ionic column capitals of the Propylaia

It is difficult for anyone today to imagine the astonishment that would have been felt in antiquity by someone who, having passed through the Doric columns of the west façade of the Propylaia, suddenly found himself in a wide and shaded hall with six exceedingly tall Ionic columns. The capitals that crowned them were the most beautiful Ionic capitals ever designed, for they combined the feeling of plasticity and elegance of the Ionic style with the geometrical clarity and minimality of the Doric. Their curving forms were in harmonious juxtaposition with the squared grid formed by the beams and ceiling coffers and they played a principle role in the architectural composition and the space it contained.

The Ionic column capitals and the ceilings they support were still in place to astonish those who saw them until the year 1640. Then the central building of the Propylaia was blown to pieces by an explosion of gunpowder that had been stored there by the Ottomans. From that time on, most of the architectural material of the superstructure of the central building of the Propylaia has been in such broken and deformed condition that it is unrecognizable today.

In his restoration of the superstructure of the Propylaia between 1909 and 1917, Nikolaos Balanos combined the four largest ancient fragments preserved of four different Ionic capitals in order to reconstruct a single Ionic column capital. In order to join the pieces, the broken surfaces were cut down so as to create smooth surfaces for joining. Used also were cement and many iron clamps and dowels, sealed in lead. Later on the iron rusted causing the marble to fracture.

The restored column capital was removed in 1992. Since it had been made up of original fragments, it provided a model of high precision for studying the geometry of the Ionic column capital of Mnesikles. For this reason, before dismantling the pieces that comprised it, I made a complete survey and I arranged the making of plaster casts With the separation of the ancient fragments it was possible to study them in connection with the other, smaller fragments of Ionic capitals of the Propylaia. The study of a total of 78 fragments led to their arrangement in six units that correspond with certainty to the six Ionic column capitals of the Propylaia. The main criteria for identifying the fragments were the quality of the marble, the wear, the traces of serious damage and the minute differences in design and in the technique of cutting. The contribution of the marble technician, Giorgos Vidos, was decisive in identifying the fragments.



Geometry of the new Ionic column capital of the Propylaia, restored. Elevation, side view, view from below, section across the middle and the top end of the pulvinus. Study-drawing by T. Tanoulas, 1999

Documentation of the identification of these pieces included a complete set of drawings: for each group there are six drawings that show all the existing fragments in their position in the total mass of the column capital. The drawings for the reconstruction of the form of Mnesikles' Ionic capital on a scale of 1:1, already completed, were exceedingly important for the study of the fragments and for the survey. I decided that study of the form and precise definition of the dimensions of the column capital in its entirety should not be based on the capital of Balanos' anastelosis, but on a separate examination of each of the four large fragments that comprised it. When it was discovered that the size and forms defining the geometry of the column capitals were in each case the same, I decided to use as a basis the fragment preserving the southwest corner of the capital that Balanos had restored because it preserved the ancient marks for the darts on the curve of the echinus, the tenon of the empolion in the base of the echinus and other important details.

For the reconstruction of the form of the helix or volute of the capital I used: a. the volute of the fragment of the southwest corner of the restored capital, since the plan was drawn from this, thus allowing the volute to be positioned accurately in the capital as a whole. b. the volute of the northeast corner of the column capital of Balanos' restoration, since it preserved the elevation of the volute practically complete. Finally, the successive centres were determined, the lengths of the corresponding radii and the degrees of the corresponding arches composing the volute. In this way the volute can be reproduced exactly.

Comparison of all the fragments from all the capitals shows that all the forms and sizes that can be defined geometrically –such as the overall measurements, the volutes, the cross-section of the echinus and of the Ionic cymatium of the abacus, the taenias of the arrowhead darts and the border of the eggs around the outer surface of the echinus etc.– are exactly the same on all the column capitals. Features with a freer more sculptural character –such as the anthemia and the eggs– have been carved with relatively greater freedom, a fact that enables us to discern different technicians and to attribute fragments to a specific group.

It was absolutely necessary to reconstruct the form of the column capitals so as to make two new capitals of new marble to be incorporated in the present anastelosis. First of all, the necessary blocks of marble had to be found at the Dionysos quarries. The two massive blocks arrived at the work-site of the Propylaia in March, 2002. They had already been reduced by means of an electrical stone cutter to the point where there was a layer of at least 3 cm. as protection for the final surfaces of the capitals. Two teams of marble technicians continued the work by hand.

Giorgios Desypris and Aristeidis Kladios were the two permanent members of the teams working on the column capitals. Work-ing with them, however, were other marble cutters, some temporary and others more regular. The exceedingly experienced technician, Giorgios Regos, took part in the first stage of preliminary work of laying out the basic incisions made for determining the position of the column capital within the volume of unworked marble. By the end of 2002, Modestos Bon and Giorgos Kayiorghis were working on the project on a permanent basis. Work of the column capitals was temporarily stopped at the beginning of 2003 because of the Olympic Games of 2004, with priority being given to the anastelosis of the exterior façade of the Propylaia, specifically the north wall and east colonnade of the central building. Work on the column capitals was resumed in September 2004 by G. Desypris and A. Kladios, assisted by Makis Kladios and Roberto Vidalis.

The first column capital was completed in March, 2006. From the moment when the marble arrived at the worksite of the Propylaia restoration, it took, on an average, the work of two men and twenty-seven months for its completion. The second capital is expected to be finished in the coming month of September (2006). The experience we have gained is very valuable, since this is the first time that an architectural member of such complicated form has been made according to such strict specifications, so as to be an exact copy of an ancient original. We may note that the column capitals seen in neoclassical buildings may be derived from or simply inspired by an ancient original, but they are not faithful copies.

In the first stage, beneath the unworked marble, the final surface of the upper resting surface of the column was determined, that is to say the upper surface of the abacus and, three cm higher, a flat reference surface was made that was smoothed out in the finishing. With this surface as a starting point, the two axes of symmetry of the column capital were determined and, following this, the two slightly inclined levels of the volutes, the lower resting surface of the capital –that is, the lower surface of the echinus– the periphery of the echinus, the lower side of the abacus and, roughly, the pulvinus. In order to have full control of the continuously changing curve of the pulvinus, a specific kind of pointing tool was devised, the so-called "stela", with the help of which the position of many other points were marked on the new marble corresponding to those on the two large original fragments that had been used for the drawings for reconstructing the form of the capitals.

The Ionic column capital completed. Photo T. Tanoulas, 2006

The Ionic column capital temporarily exhibited in the east portico of the Propylaia. Photo T. Tanoulas 2006

Using the design procedure described above, a metal stensil was made, with the traces of the volute pierced in it so as to make precise traces of the volutes on the faces of the capitals. The sections of the various details were continuously checked with templates, i.e. with thin metal sheets out of which each section had been cut to replicate the sections corresponding to the ancient fragments, leaving space to insert the piece of marble that was to be checked. A particularly complex mental exercise was required for drawing on surfaces that were curved (such as the echinus) or hollow (such as the anthemion) the decorative themes to be carved in three dimensions.

Thanks to the ingenuity and technical skill of our marble technicians, the original design of the Ionic column capitals of the Propylaia has been rendered with technical integrity worthy of that of the ancient originals. We can say that the new capital is as close to the original conception of Mnesikles as the authentic Ionic column capitals made by the technicians in the 5th century B.C. It is exhibited at present in the east colonnade of the Propylaia, north of the central pathway made for visitors. It has been set up on the three column drums that will be restored at the top of the southeast Ionic column of the west hall. The beauty of its form is fully apparent. It will remain there on exhibition until the moment when it is finally set in place at the top of the northeast Ionic column.

Since the column drums in their final position will be at a height of some ten metres, it would be worthwhile making a third column capital to be displayed at a lower level, in the Acropolis Museum or in the Pinakotheke of the Propylaia north wing, for which roofing is planned. This would enable visitors to appreciate the high aesthetic quality of the design and the astonishing quality of the marble working in all its detail, and it would provide students of ancient Greek architecture with much valuable information.

Tasos Tanoulas
Architect Ph.D.
In charge of the Propylaia Restoration Project

2005 was a year of tremendous effort and an intensive rhythm of work that made use of the economic funding provided by the state and the advantages of continuity, by which I mean the experience of the scholarly and technical personnel, the rich infrastructure with all kinds of machinery and the advantages of an independent administrative and economic functioning given the Acropolis Restoration Service (YSMA) by the well-known Presidential Decree of 1999.

The work was impeded, as in 2004, by the continuous discovery of damage to the architectural members that had been dismantled, the difficulties of finding suitable marble for fillings, worry on the part of the technical work-staff about impending work-agreements of indefinite time and a number of delays in payment.

The general problem of delay in the Acropolis restoration project, however, comes consistently from the Press, the supervising Ministry of Culture or from ordinary citizens. At the beginning of 2005, a certain amount of mistrust arose in the Ministry about the programming of the works and as a result the intention was to cut the funds budgetted for 2005. Fortunately this all came to an end when the necessary explanations were given and when, in April, an account of the works was presented with diagrams and a time-schedule. The visit of the then Deputy Minister of Culture, Petros Tatoulis, and the press conference on July 20, provided the opportunity to elucidate the broader programme and the time calculated for the works: completion of the three main programmes currently in process by the end of the present year, completion of the other rescue interventions during the next three or four years and the continuation of works of improvement and display of the monuments and the archaeological site by 2020. This last rightly elicited concern and comments. It should be emphasized, however, that the Committee for Conservation of the Acropolis Monuments (ESMA) was called upon to carry out the rescue works and that the surface conservation of the marble should be continuous and never stop. The possibilities for enhancing the monumental wealth of the Acropolis are limitless and the motive force of ideas in itself may well lead by 2010 to new intentions if not to new requirements.

The ESMA was renewed by the Ministry of Culture last September. New members were appointed: Olga Palagia, Professor at the University of Athens, Ismene Triandi, Professor at the University of Ioannina, Vasileia Regopoulou-Kaselouri, Professor at the National Technical University of Athens, Iordanis Demakopoulos, Honorary General Director of the Ministry of Culture, and Miltiadis Chronopoulos, Professor at the National Technical University of Athens. These replaced, respectively, Evi Touloupa, Professor V. Lambrinoudakis, the recently departed Theodore Skoulikidis, Manolis Korres and Kostas Zambas who replaced Professor Kostas Syrmakezis. Mr. Zambas, although appointed by the Ministry, did not wish to join the Committee. Here I must express my sorrow over the total severence of Manolis Korres from the Acropolis. His great experience, his wisdom and his ability to solve the many problems we face, is internationally known. Theodore Skoulikidis, who died in March 2005, was a founding member of the Committee. For thirty years he was in charge of the conservation of the materials and surfaces of marble and he was the author of many articles on the subject. We shall always owe him our gratitude.

The secretariat was in the hands of the archaeologist Dorina Moullou, to whom we owe, among other things, the analytical minutes of the ESMA meetings. In these are recorded not only the scholarly discussions on many matters, but the efforts of the members to resolve all the administrative and economic matters as well as work coordination, efforts sometimes frustrated. The spokesman, according to the Presidential Decree of 1999, is the Director of the Service, the civil engineer, Maria Ioannidou, who last year (and continuing) made a great effort not only on matters related to her field, but on all the questions of the organization of the works, the administration, relations with the supervising officials of the Ministry, funding and the drawing up of estimates for the budget and accounting, etc. To Mrs. Ioannidou we owe the complicated technical report on the carrying out of the works on the basis of their schedule, difficult tasks involving a high degree of responsibility. We owe her also the replies to daily requests from within and without the Service, indubitably time consuming.

The participation of Mrs. Alkisti Choremi, Director of the 1st Ephorate of Prehistoric and Classical Antiquities, and our continuous collaboration with her, resolved many of the problems concerning the Acropolis. With this we come to the presentation of the works of 2005.

The north colonnade of the Parthenon under restoration from the NW.
Photo S. Mavrommatis, November 2005

In the **Parthenon**, the programmes of the pronaos and the opisthonaos having been completed in 2004, emphasis was on the larger and more difficult work of the north colonnade. The director of the works on the Parthenon is the exceedingly experienced architect Nikos Toganidis. Five other architects (Lena Lambrinou, Rozalia Christodoulopoulou, Aikaterini Paraschi, Angelos Papandropoulos and, recently, Vasiliki Eleftheriou), all specialized and experienced, both oversee the work and record the documentation, and carry out the studies to be submitted to the Central Archaeological Council of the Ministry of Culture. Working with them are the civil engineers, Marilena Mentzini, Eleni Toubakari, Antigoni Vrouva, the archaeologist Eleni Karakitsou, in charge of keeping the day-books and entering the documentation for the interventions, and the conservator, Anastasia Panou.

Work on the pronaos is considered finished, except for the fact that it became evident both to Acropolis staff and to the general public, that the new fillings of the columns in new marble, which had been left unfluted, were in complete disharmony with the whole. The Central Archaeological Council had decided that these drums should be left unfinished, in February 1994, when the Committee proposed partial restoration of the east inner prostasis of the temple (the pronaos), and it had the character rather of a trial intervention. Already by September 2004, the Committee was unanimous in deciding that new drums should be fluted mainly for aesthetic reasons, in other words, in order to restore the continuity of form, just as specified in the Charter of Venice. Another reason was that the Mechanical and Elecrical Engineer, Spyros Oikonomopoulos, had created a specific cutting maching that allowed the flutes to be cut by mechanical means. The matter did not proceed at that time in the Archaeological Council because the corresponding project had not been included in the budget. The Committee, however, met again in 2005 and, after the expansion of the Technical Report, the subject was discussed at three meetings, with a final decision on September 19 to submit the request to the Archaeological Council. To date, however, it has not been discussed there.

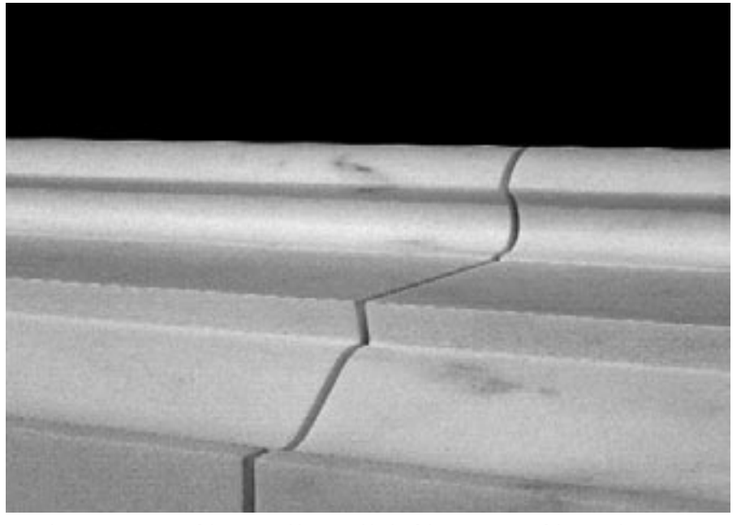
In 2005, the filling and setting of the drums of the eight columns of the north colonnade were completed, after a new, exhaustive study by Lena Lambrinou. She has carried out inspection of the work together with Mrs. Mentzini who is in charge of the static stability of the columns. There is little use in reviewing again what is known already

The north colonnade of the Parthenon restored. Photo-realistic drawing by P. Konstantopoulos, 2005

Resetting a column capital in the north colonnade of the Parthenon.
Photo A. Papandropoulos, March 2005

about the dangerous condition of the architectural members some sixty years after the Balanos anastelosis and how much effort has gone into their reconstruction. As we noted, the study of the columns and architrave was carried out by Mrs. Lambrinou; study of the overlying frieze and cornice by Rozalia Christodoulopoulou. They were submitted and unanimously accepted by the Central Archaeological Council at the end of the year. Both studies, which are to be published, are the result of extraordinary effort and the application not only of methods already known, but also of new approaches to the preserved material. The new measuring of the ten diameters of each column drum revealed the slight difference among them, which proved to be of definitive significance in demonstrating the contiguity of two vertically continuous drums. To check the entasis, they were compared with two columns that were undamaged since antiquity, the third and the twelfth from the east. The column capitals were subsequently set in their correct places on the basis of their height, thus revealing the total height of each column as 10 metres, 43 cm and 6 mm. The architraves, which comprise three pieces across the width, were placed correctly on the basis of four identifying factors: orientation, original design, joining and the damage suffered. Located in addition were the correct positions of fragments that have been recovered and belong to the architrave.

The crown block (thranos) *of new marble of the Propylaia east portico. View from N. Photo S. Mavrommatis, November 2005*



Joint between two pieces of the new marble crown block of the east portico of the Propylaia. Photo S. Mavrommatis, November 2005

The overlying sections of the entablature, the Doric frieze and the cornice, were studied by Rozalia Christodoulopoulou. On the outer side are the triglyphs and metopes, on the inner side the continuous frieze. After separating a number of members that belong to the south colonnade and had been incorrectly placed here by Balanos, all the rest was studied on the basis of the cuttings for clamps, dowels and lifting devices, beginning with the inner frieze and with the superimposed cornice as reference. The difficulty is increased by the absence of all the metopes, many of the architrave backers and the rear parts of the cornice blocks, which have been destroyed. In this case, the author of the study succeeded in grouping many of the members and in making an entirely convincing proposal, despite the fact that a certain amount of information is missing.

The amount of new marble that must of necessity be added in order to support and structurally restore the ancient members, is 15% for the architrave, for the frieze and cornice practically 20%. The photo-real-istic drawings of the expected final result of work on the north colonnade, by Platon Konstantopoulos, enable us to evaluate aesthetically (as did the members of the Central Archaeological Council) the new reconstruction as a whole.

During the work, other difficulties surface. Some of the column capitals of the Balanos anastelosis, made up of many ancient and new fragments as well as fragments belonging to other monuments, created structural problems difficult to solve. One of these capitals was transferred to the Museum and replaced by a new one, according to a decision made already in September 2004. One of the guiding principles is that architectural members that are composed of joining fragments must retain their self-sufficiency, but also they must acquire the structural resistence they had in antiquity. This leads to delays because of the time decreed in the regulations for the mortar to harden. The unavoidable addition of new marble was decided after endless discussion on the authenticity of the monuments.

Director of works on the **Propylaia** is the experienced architect, Tasos Tanoulas. Collaborating with him is Konstantinos Karanasos, also an architect, the Director of YSMA, Mrs. Ioannidou and the civil engineer, Vasilis Papavasileiou. In this same group are the archaeologist Evi Petropoulou, the conservator Aikaterini Babanika and the experienced draughtswoman, Yiota Moutopoulou.

The month of April saw the approval and beginning of work on the supplementary study by T. Tanoulas for the "Resetting of the frieze blocks of the east portico and the Ionic architrave of the west hall of the Propylaia". In addition, the civil engineers M. Ioannidou and V. Papavasileiou made a study of the reinforcement of both lintel and backer of the middle doorway of the monument so that it can support the additional weight of the marble ceiling. This is proceeding in accordance with the study.

The project of the west hall progressed greatly in 2005 with the procurement and setting of the crown blocks on which the architrave and ceiling beams will rest, the incorporating of fragments and the resetting of the column drums. One of these, which had been used as a well-head, will soon be set in place. Included in this same project is the carving of two required Ionic column capitals, exact copies of the originals. These column capitals (one of which has been exhibited in the passageway of the Propylaia since last March) are sculptural masterpieces, truly demonstrating the great ability of the marble technicians of the YSMA.

Work continued on the anastelosis of the architectural members of the Doric frieze of the east porch of the Propylaia and the cornice blocks with the removal of fragments that had been incorporated by Balanos and the addition of new marble fillers. The tasks of restoring and filling the architrave and beams of the west hall were time-consuming and pressing.

The marble technician, G. Desypris, working on the new Ionic column capital of the Propylaia. Photo Tanoulas, 2005

Restoring the NE column of the west hall of the central building of the Propylaia. Photo K. Karanasos, July 2005

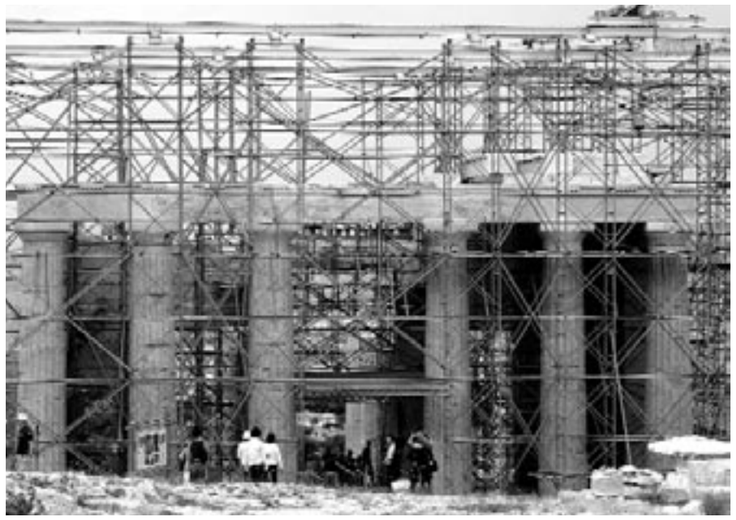
In the **Temple of Athena Nike**, despite efforts to increase the pace of work, the numerous fillings required in the blocks of the cella walls and the ambiguities resulting from their cutting during previous restorations of the monument, have made the work of restoration extremely time-consuming and adhering to the schedule has become problematic. The director of the works here is the civil engineer Dionysia Michalopoulou. Collaborating with her are the architect Kostas Mamaloukas, the archaeologist Evi Lempidaki and the conservator Anthi Tsimereki. In 2004, a completely rigid grill of stainless steel was set over the space beneath the temple. Last year eight enormous floor slabs and the blocks of the *crepis* of the temple in new marble were set in place. Following this, work has begun on resetting the orthostates and blocks of the cella walls. Last June the Committee decided to add two more works to the technical report: 1) reinforcement of the old reinforced cement slab around the temple and 2) anastelosis of the frieze and cornice together with rebuilding part of its east pediment. Studies for these two projects have not yet been submitted to the Central Archaeological Council for approval.

Matters concerning the **Circuit Wall** of the Acropolis are being handled by Vaso Manidaki and a specialized sub-committee of mechanical engineers and archaeologists that is examining the problems of its structural stability and construction. The subject is complicated because much of the ancient Wall is covered by a rubble wall built after 1715, another section was destroyed and rebuilt, and so on.The visible cracks in the Wall are insignificant but there is always concern about erosion from rain water and the additional great weight of machines and material that are neccessary for the work. It was therefore decided not only to employ a specialized civil engineer for the Wall, but to make new measurements of great accuracy, employing the latest technology, apart from the surveys that had been made during the past two years. The following five operations were put into effect and are being accomplished to some extent: a) new monitoring surveys with GPS at 52 selected points on the Wall, b) 18 crack metres have

been set in place at points that are presumed to have cracks, c) Invar wires, non-expandable, have been placed connecting the Wall and the solid foundation of the Parthenon, d) an electronical system has been installed to record every movement of the Wall and the Rock with great accuracy, e) geophysical prospection of the ancient Wall and of the invisible surface of the Rock. We note here that a suspension platform has been installed for direct inspection of the mortar and the condition of the stones of the south Wall.

Connected with the north Wall of the Acropolis is the matter of protecting the foundations of the **Arrephorion**, which was discussed also last year. Despite the great archaeological significance of the monument, its poros foundations had remained unprotected since the excavations about a century ago. In 2005, after it was finally decided to fill in the foundations, other problems arose when it became evident that in the unexcavated part of the monument there were all sorts of stones and fragments of architectural members that would have to be removed, examined and put in order. It is worth noting that with the removal of earth from the Arrephorion over 100 fragments of members of the Parthenon and the Propylaia were discovered, including fragments of sculptured decoration, that have been taken to the Acropolis Museum. The matter was taken up with the Central Archaeological Council, which decided that there should be in addition full documentation (drawings and photographs), temporary buttressing of the foundations. A new study for the construction of fill with placement of geo grid reinforcement between horizontal layers of granular fill material has already been submitted to the Archaeological Council for approval, following new discussions during eight sessions of the Acropolis Committee.

The group of conservators and technicians involved with the **Conservation of the marble surface of the monuments** worked during 2005 on all the monuments that required it during structural restoration. Overall supervisor of the group is the chemical engineer, Evi Papakonstantinou and, since last September, the work is supervised by the new member of the Acropolis Committee, Professor Regopoulou-Kaselouri. The Subcommittee for Conservation was reassembled with the new member D. Giraud replacing M. Korres. The group's activity was expanded last year as well to include the east porch of the Erechtheion. The Ionic columns of the temple of Athena Nike received special attention. They will be placed in their original positions when restoration reaches the height of the architrave. Finally, I note that the great achievement of the conservators, the conservation and cleaning of the west frieze of the Parthenon, was magnificently displayed by the Acropolis Ephorate in the new exhibition of the Acropolis Museum.



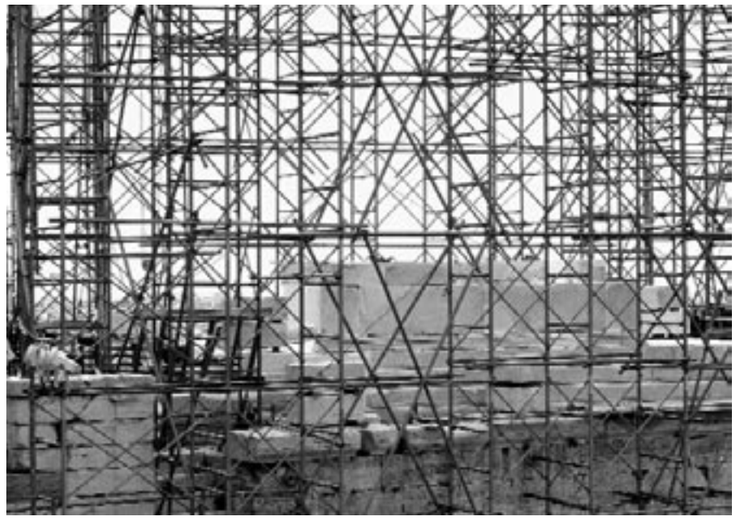
The east portico of the Propylaia. View from E. Photo S. Mavrommatis, June 2005

The group involved with **Recording the scattered ancient members** (or fragments of all sorts), led by the archaeologist Konstantinos Kissas, continued work in 2005, without greatly affecting the restoration of the monuments, since very few of the fragments now found belong to them. Mr. Kissas worked also on the fragments that were pulled out of the earth at the Arre-phorion. The crucial question of housing the inscriptions still in the open air on the Acropolis, unfortunately, for yet another year remains unresolved.

The archaeologist Fani Mallouchou-Tufano directs the Service Archive, the **Documentation Office** and the related data base. The personnel of the Office, information officer Yiannis Alexopoulos and the administrative officers, Katerina Liakopoulou and Stathis Tyropolis, inspect, complete and enter in the data base material documenting the interventions of the past years. The three archaeologists mentioned above supply the system on a daily basis with documentation produced at the Parthenon, the Propylaia and the Nike temple.

As is well known, the final reporting of a completed work, the scholarly publication of the changes, positive or not, resulting from an intervention, is the ultimate and absolute obligation of all who have cooperated in the work. Unfortunately at the Acropolis, the works accomplished have not yet been published to the extent demanded. The report on the restoration of the Erechtheion left by the late Alekos Papanikolaou is now in the process of being published, under the supervision of Mrs. Mallouchou and with philological editing by Mrs. Eleni Bechraki. The publication of work on the opisthonaos of the Parthenon, which was coordinated by Petros Kouphopoulos, had been allocated a year ago to various colleagues, but did not proceed because of the work load of all involved. In addition, publication of the work on the east façade of the Parthenon, undertaken by Manolis Korres, has not yet proceeded.

Scholarly research in the framework of studies for the works did not have direct results during 2005, but considerable progress was made. Already mentioned are the numerous measurements of the Circuit Wall and the Rock utilizing contemporary technology. Mrs. Karagouni, Professor at the University of Athens, studied the biological damage to the marble and she is working on ways of attacking this problem. Evi Petropoulou and Fani Mallouchou are making a public opinion poll on the Acropolis restoration project. Dorina Moullou has prepared two proposals for the YSMA to use in order to acquire funding from the European programme "Information Society", the positive result of which we have only recently learned. It includes the development of Geographical Information Systems, the creation of a general data base, virtual theatre for the New Acropolis Museum, utilizing the material of the educational programmes on the web and others.



The Temple of Athena Nike under restoration from NE. Photo S. Mavrommatis, November 2005

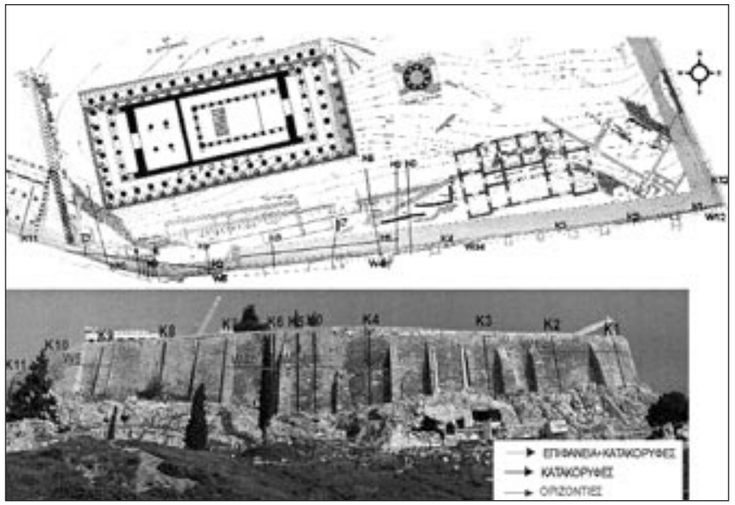
The Department of Information and Education, directed by Cornelia Hadziaslani, architect-archaeologist, informs the public about the works of the Service and has an educational programme for children about ancient Art, Architecture and the functioning of the Acropolis sanctuary in antiquity. The Department works closely with the first Ephorate of Classical Antiquities and is staffed by two archaeologists, Eirene Kaïmara and Asemina Leonti. The Department organizes educational programmes at the Centre for Acropolis Studies and on the Acropolis and produces educational material, both museum kits that are lent or presented and publications. The programme "Let's Go to the Acropolis" was attended by 1,700 students, the "Parthenon Frieze" by 270 and the "Restoring the Acropolis Monuments" by around 600. In cooperation with the Greek Parliament, lessons were conducted on the Acropolis for 800 students from the provinces of north Greece. There is productive collaboration with educators when the museum kits are lent to schools. The kits are also given to school libraries in Greece and abroad. In this framework, lectures and seminars have been held for around one thousand educators at Dion, Alexandroupolis, Komotini and at the Greek Embassy in Budapest. In 2005, a new publication was released: "The Gods of Mt. Olympos on the Parthenon Frieze" and an informative article on the activities of the Department was published in an English journal for educators.

The Parthenon west frieze, recently cleaned and conserved, on exhibition in the Acropolis Museum. Photo S. Mavrommatis, June 2006

Dorina Moullou renewed the website of the Service with information about the activities of the Information and Education Department and the results of the Acropolis Works. The annual, the "Acropolis Restoration News", is important as a source of information both for Greece and internationally. It is edited by Fani Mallouchou-Tufano, in Greek and in English, and it is sent to agents and libraries here and abroad. The fifth volume was published last year.

Other activities connected with communi-

cation and information may be noted as follows. Posters with photographs and drawings of the works were sent to an exhibition organized by the Union Internationale d' Architecture in Constantinople. The well known photographic exhibition of Sokrates Mavrommatis was sent to the Nashville Museum in Tennessee, after being shown at Fairfield University and Lawrence in Appleton, USA. The same exhibition, enriched by photographs of the Erechtheion, was shown at the Gounaropoulos Museum by invitation from the Municipality of Zographou.



Electrical resistivity tomographies on the South Wall of the Acropolis. Photo Applied Geophysics Laboratory, Aristotle University of Thessalonike, 2006

The Deputy Minister of Culture, Petros Tatoulis, was present at the opening and a series of talks was given by the Director and members of the YSMA on the subject of the Acropolis works, through the good offices of the Municipality. It was a great success. Mrs. M. Ioannidou reported on the anastelosis of the Acropolis monuments at the Conference of the Union of Greek Archaeologists in December at Thessalonike. She also reported on research and the use of contemporary technology in the Acropolis works at the 2nd Panhellenic Symposium on the Anastelosis of Ancient, Byzantine, Post-Byzantine and Modern Monuments, at the Ministry of Culture in October. At a symposium on the protection and restoration of monuments held at Constantinople in September, the Acropolis works were presented by Fani Mallouchou and the present writer. Mrs. Mallouchou also gave a report at the Conference of the European Organization COST in Florence and lectures at the Museum of the City of Athens Vourou-Eutaxias, at the University of Rome and at the National Museum of Dublin by invitation from the Greek Embassy there. Mr. T. Tanoulas and Mrs. V. Manidaki spoke at the Conference of the Society for the Study of Ancient Greek Technology.

Support for the works during 2005 was continuous and effective. We may mention the Secretariat, in charge of Chara Papanikolaou, the Accounting Office (with its new supervisor Panayiotis Katsimichas) and the group responsible for electrological and mechanological questions, under the continuous supervision of the Mechanical and Electrical Engineer Spyros Oikonomopoulos. Sokrates Mavrommatis, artist-photographer, continued taking photographs for documenting the works and for future exhibitions and publications. He was responsible too for the cinematographic documentation of the works.

The year 2005 was the 30th year from the founding of the Committee for Conservation of the Acropolis Monuments (ESMA). Under hopeful conditions after the fall of the Dictatorship, we dared to carry out an intervention on the noblest works of the architectural heritage of the western world. No one then could have imagined the size of the work undertaken by the Committee. It took courage indeed when personalities such as Anastasios Orlandos said that any attempt to remove Balanos' rusted iron would mean the destruction of the monuments. Now that the rescue intervention is nearing its end we must remember those who took such a responsibility, Konstantinos Karamanlis, then prime minister, Konstantinos Trypanis, Yiannis Miliadis, Yiannis Travlos, Nikolaos Platon, Socrates Aggelides and Theodore Skoulikidis.

Finally, once again, I should like to thank all those who work on this great cultural and technical enterprise. Above all the marble technicians, whose efforts to carry out the work is often under severe conditions. Then all those I have mentioned, engineers and archaeologists of the YSMA and the 1st Ephorate of Prehistoric and Classical Antiquities. Likewise I thank the political leadership of the Ministry for their understanding and the members of the ESMA, in both its old and its new composition. Finally, the Director of the YSMA, Mrs. Maria Ioannidou, for her belief in the work and for the tremendous effort she devoted in 2005 and continues to expend.

* From a talk given at the Centre for Acropolis Studies on 24 May 2006.

Professor Emeritus ***Charalambos Bouras***
President of the ESMA

The Acropolis monuments are built of cut stone in the form of rectangular blocks or drums, joined with each other by metal clamps and dowels without mortar. Extraordinary precision in cutting the surfaces and in fitting the stones together is the basic characteristic of their structure and it often creates the optical impression that the construction is monolithic. The joining elements [horizontal (clamps), or vertical (dowels)] are made of iron, are set in sockets specially cut for them in the stones and they are sheathed in molten lead. The joining elements of I – form connect adjacent members in the same course and absorb mainly tensile forces, whereas the dowels, vertical, connect members of successive courses and resist shear forces, when the friction bond between the blocks is overcome. The joining elements contribute to the general resistance of the building especially against seismic load or deformation from various causes (violent shifting or displacement, foundation yielding, etc.). The basic purpose of the lead sheathing is to isolate the iron of the joining elements from the environment in order to protect it from rusting. Apart from that, the lead sheathing insures mechanical continuity between joining element and stone and contributes, as malleable material, to the absorption of some of the shock and energy of an earthquake.

We know that the dimensions of the structural elements of the monuments were determined on the basis of formal and functional criteria, without preceding structural calculations in the modern sense of the term. Yet, the excellent mechanical behaviour of the monuments in all the actions of nature during the 2,500 years of their history shows that the mechanical properties of the materials that were used were known and that the static behaviour of the structural members had been estimated very closely. A feature of the Acropolis monuments, as structural systems, is that they fulfill today's requirements for an anti-seismic design: they are remarkable for their simple and clearly defined structural function, for the characteristic regularity of their plan, for the symmetrical arrangement of their bearing elements and mass and for their almost even distribution of rigidity. The great rigidity of the walls together with the diaphragm function of the ceiling and roof by means of friction, add to the resistance of the building to horizontal stress. Finally, the founding of the buildings for the most part on solid rock and the good quality of construction of the foundations favour their excellent anti-seismic behaviour. Indeed, it is notable that most of the damage we confront today is not from natural causes but from human activities and deeds.

General view of the western access to the Acropolis, from NW. Photo S. Mavrommatis, November 2005

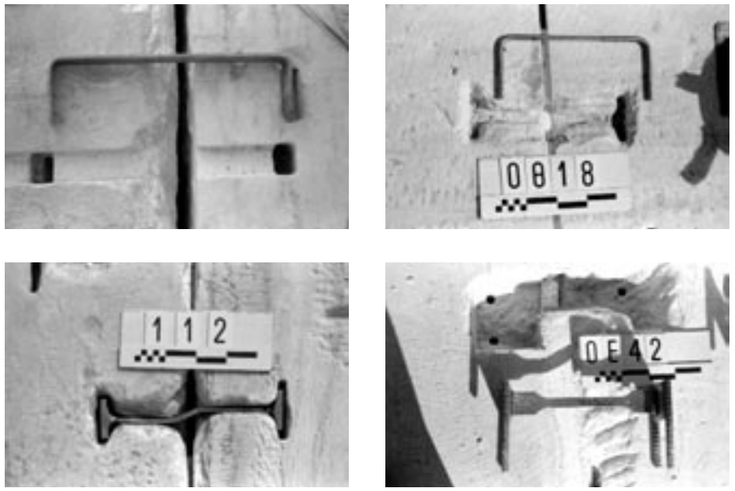
In future, the only strong mechanical strains are expected to be seismic, since we certainly hope that there will no longer be damage inflicted by mankind. It is therefore imperative to evaluate the efficiency of the monuments in seismic activity, taking into account the damage they have suffered through their long history, and with this evaluation as a basis to make the necessary interventions. Analysis of the seismic behaviour of the monuments in their original condition, in any case cannot in itself yield conclusions applicable to today's interventions.

Although recent years have seen great progress internationally in the protection of modern buildings from earthquake, a realistic method of evaluating the behaviour of the classical monuments when under seismic load has not yet been developed. The structure of the monuments is based on the perfect contact of the joints. The basic characteristic feature of the structure of the monuments, i.e. the presence of joints between the wall blocks, means that only compression and shear stresses are assumed, and not tensile. This results in a strongly non-linear behaviour of the structure. From the quantitative aspect, controlling the composite movement of the hundreds of members of a classical monument under seismic load is an extremely difficult problem. Apart from the number of joints, the problem is further complicated by cracks, deformations, shifts and failure of joining elements (clamps and dowels). On the basis of scientific knowledge today, it is impossible to make a reliable model simulating seismic load so as to design the interventions needed. Given the fact that the seismic behaviour has up to now been satisfactory, we carry out the interventions on the monuments according to the basic principles of respect for: the authentic material of the monuments, the original structural system, the retention of structural integrity of the architectural members and their original structural function.

These general principles lead to specific scientific choices, technical solutions and building details in the designing and application of interventions. These are:

1. Restriction of interventions to the absolutely necessary

The interventions are carried out on those parts of the monument where failures are apparent that could lead to the danger of collapse, breakage or cracking of members or large shifts with the danger of yielding: examples can be seen in the north colonnade of the Parthenon and the ceiling of the central building of the Propylaia, areas of the monuments with serious structural problems as a result of earlier interventions causing the architectural members to break or even to fall. The undisturbed areas of the monuments are left intact so as to preserve fully their authentic character and to provide future generations with the wealth of information that they hold.



New joining elements of titanium. Above: ΠΙ-shaped joining elements that replaced the clamps of earlier intervention. Below: joining elements of special shape. Photo R. Christodoulopoulou, 2003-2004

The lintel of the central doorway of the Propylaia, restored. View from E. Photo E. Petropoulou, June 2006

2. Respect for the original structural system of the monuments

Since the excellent seismic behaviour of the monuments is due to their original structural system, retention of that system in all its detail is of utmost importance. If in the course of the interventions the resistance and stability of the bearing structure are altered, the behaviour of the areas of intervention is affected in case of seismic strain. The result would be undesirable for the entire structure. We note here a number of characteristic examples:

• The structural restoration of the columns in situ in the Parthenon opisthonaos, which had been cracked by thermal fracture during a fire in ancient times. It was decided to fill the cracks with suitable hydraulic grout. This solution was chosen as opposed to dismantling, in order to avoid disturbing the original structure of the columns that was still preserved. In order to maintain the structural integrity of each drum after grouting, since the grout would necessarily pass through the contact surfaces of the drum, special research was carried out with the following results: two different grout compositions were applied, one within the drum developing great resistance and bonding force with the ancient marble and another in the vicinity of the joints between the drums with very weak initial resistance and bonding force with the marble, weakening further in time, in order to avoid bonding between drums in the contact area.

• The original structural function of the big lintel block of the central doorway of the Propylaia, weighing 10,5 tons, was that of a simply supported beam, on which the vertical load at the ends insured a large degree of fixed support. The demolition of the overlying members and the breaking of the lintel in the middle resulted in two separate stones, in equilibrium as a three-articulated arch. By restoring the stone in situ with grout and adding the overlying members so as to transfer the overlying load to the ends, the original structural function of the member is to some degree recovered (partially fixed on both ends).

3. Preservation of the original structural function of the architectural members during their restoration

Broken architectural members are restored to their original monolithic form by bonding the joining fragments with titanium rods and white cement. Because the members are placed on the monument in an isostatic system, with simple juxtaposition, each member can be considered as a integral unit in relation to the entire construction. Wall blocks are subject to single-axis compression, column capitals to bending and shearing and beams and architraves mainly to bending.

Members that have been subjected to bending can be structurally restored to their original resistance. If in this case the calculations result in very heavy reinforcements, thus considerable loss of ancient material, the resistence of these members is restored to withstand the total strain that may apply after the anastelosis of the monument. These forces include the structural vertical loads and the powerful seismic vertical and horizontal shocks. Critical for calculating the bonding are the stresses developed on the broken surface.

Analysis of the stress-condition of the combined structure of marble-titanium is performed by methods used in classic structural calculations, whereas distribution of the strain is determined by applying the general principles of the strength of materials. For determinig the strength of the bonding, the strains developing in the bonded crack are compared with the allowable strains of the material, i.e. the pressure of the marble and the tensile strength of the titanium. The amount of reinforcement determined by this method is very small (1-2%) and damage to the ancient material is thus slight. Particular attention is given to the width of the join in the area of bonding so that it is as small as possible and therefore less mortar is used. To obtain this result, the bonded fragments are kept well-tightened during bonding and during the first days of curing of the mortar.

4. Filling in the ancient members with new marble

New marble filling in the ancient marble is usually limited and it is always determined using as criteria the structural and aesthetic integrity of the member being restored and the area undergoing anastelosis. The surface to be joined is cut, using a pointing device or a copying machine so that the new piece can match precisely with the broken surface of the ancient piece. For the actual bonding of the filling of new marble to the ancient piece, the same procedure applies as described above for the joining of ancient fragments.

Structural restoration of a ceiling beam of the Propylaia east portico. Photo K. Karanasos, June 2004

5. Joining the blocks

The restoration of the joining elements that have been damaged by stress or by the rusting out of the iron is an intervention that contributes to the resistance of the building in seismic strain. In case of earthquake, it is the clamps and dowels that assume the load and, together with the friction bond, they reduce the relative displacement of the marble blocks. The new clamps and dowels are made of titanium sheet and they are secured in the ancient sockets with inorganic mortar. These metal reinforcements are designed to be the weaker element so that in cases of great strain they can yield to permanent deformation and, if a new intervention proves necessary, it can be limited to replacing the clamps/dowels.

Wherever the ancient cuttings (sockets) are preserved, I – shaped clamps are set, following the form of the ancient clamps with heads that are thicker in relation to the stem. The long stem has a neck so that when the clamp is under tensile stress and the material exceeds its limit of yielding, it will be deformed and will therefore absorb a considerable amount of energy before it fails. The space between clamp and cutting and within an area of 1-2 cm on both sides of the joint is left free, without cement mortar, to allow room for possible crosswise deformation of the clamp. If the original socket has been destroyed, two blind holes are drilled at the position of the original heads of the I – clamp. The holes are made to receive the vertical legs of the new clamp, which is now ΠΙ – shaped. If the area where the clamps should be attached is broken, specially shaped joining clamps are designed. The designing of dowels is handled in similar fashion.

6. Restoration of parts of the monuments by resetting the ancient members in their original positions and including also members of new marble

Apart from considerations of general principles of theoretical conservation ethic, these restorations are made on the basis of structural criteria. An increase, for example, of vertical load and the accompanying increase in friction between the stones, the supplementation of the original design and regularity of the ground plan of the monument, an increase of rigidity with the restoration of the walls and supplementation of the ceilings and roof, which add to a partial diaphragmatic function of the solid disk of the ceiling, are all favourable in assisting the building to withstand seismic forces. Relatively characteristic examples are seen in the restoration of the coffered ceilings of the central building of the Propylaia and the proposal for the restoration of the ceiling of the west *pteron* (perimetrical corridor) of the Parthenon, which is under study.

Resetting the marble ceiling beams in the east portico of the Propylaia. Photo V. Papavasileiou, August 2005

Structural restoration of a cornice block of the Propylaia east portico. Photo E. Petropoulou, 2005

7. Quality of construction

It is particularly important that a high quality of construction be maintained in the interventions in all phases of the work, for both structural and anti-seismic reasons. As in the ancient construction, exceedingly careful working of the contact surfaces and the perfect contact between the blocks insures the development of friction forces between them and through them the cohesion of the building. This concern, quite apart from aesthetic demands, is necessary for purely structural reasons, namely respect for the ancient structural system of the monument, which thus insured the safe transfer of the load to the ground.

The problem of the behaviour of articulated buildings during earthquake, such as the classical monuments, is an exceedingly complicated phenomenon with non-linear characteristics. During the past thirty years, in the works of restoration on the Acropolis and other monuments too, many relevant observations have been made and much experience and knowledge have been acquired, as noted above. Yet, we are still far from a realistic method of analysing the behaviour of classical buildings under seismic load. The depth of information that the monument itself gives us is the first and most valuable source of knowledge. The analytical and experimental research of the past years must be utilized, in the light of the above information, to illuminate the secrets of the monument's seismic behaviour and to help in choosing the necessary interventions. We may consider as realistic the analysis that takes into consideration the present condition of the monument as a ruin with immeasurable damage. Indeed, it is the resistance of the monument as a ruin that we are asked, in the last analysis, to evaluate rather than as a building in its original state. Understanding the structural system of the monuments in their condition as ruins is significant and basic, since it leads to the choice of intervention, the aim of which is to strengthen the structure of the monument, so that it is can withstand the expected seismic load rather than forcing the monument to behave as a modern construction. These are interventions that are compatible with the state of preservation of the monument's bearing structure and thus they do not harm them.

Maria Ioannidou
Civil Engineer
Director of YSMA

The Acropolis monuments, invaluable testimony of the past, constitute a cultural heritage and a value belonging not only to the Greeks but to humanity. Their worldwide recognition as a spiritual symbol, the effort being made to protect them, their conservation and their restoration are well known.

As early as 1975 the most recent phase of restoration in the history of the monuments began. The progress that has been made from then to now is the result of the tremendous effort of a group of people, of different fields, who have toiled and continue to work hard, employing both their professional knowledge and their technical skills. For them, the restoration of the monuments is a creative work, requiring the devotion of soul and body and they perform this work guided by respect and love for the monuments themselves, having in mind the idea of realizing the poet's saying, "on this, this marble, no evil rust doth cling". Among the specializations involved, structural engineering is the scientific branch that is particularly responsible for work on repair and strengthening of the monuments, so as to secure their preservation for generations to come.

Structural restoration of the monuments includes a great number of specialized tasks with many parameters that must be taken into consideration in order to resolve a series of problems before a final decision is reached. The problems vary from the elementary, such as the strength and deformability of the materials being used, to the more complex, such as the preservation of the structural system of the monument, the determination of the minimum possible intervention, its reversibility and, of course, its durability. The decisions made are usually a compromise between various and often contradictory points of view.

To be specific, the behaviour of the monuments is affected by three basic factors:

A) The special characteristics of the structural system which are the following:

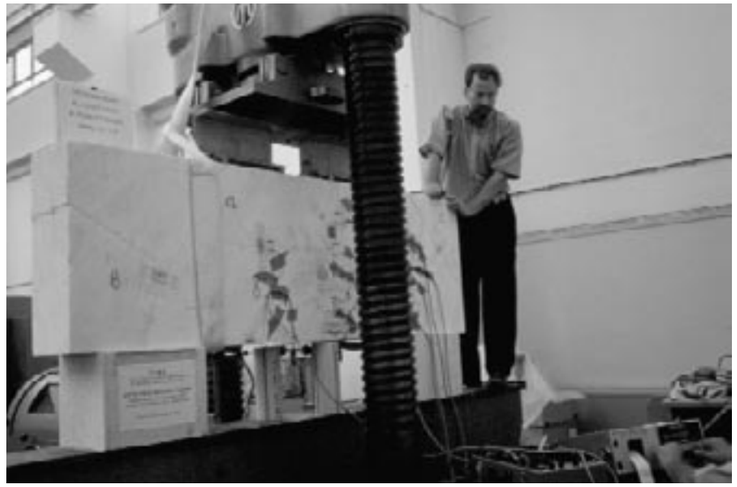
• its form [for example, in the Parthenon it is complex and includes: a) a symmetrical arrangement on a system of two vertical axes, which are formed by vertical bearing elements, the columns, b) frame function through the entablature, c) diaphragm function through the marble ceiling of the *pteron* (perimetrical corridor) and the wooden roof, d) the absolutly rigid core, the cella].

• the type of connection between the structural elements [which is characterized by a generally simple contact of the members, the lack of mortar between them, their joining by horizontal (clamps) and vertical (dowels) connecting elements that resist tensile and shear forces, and especially the development of friction's bond as the main connecting element]. Thus, an articulated construction is formed that reacts in a particular way in a strong earthquake, with the individual members able to slide or rock independently or in groups. The dynamic behaviour of such a system is highly non-linear and complicated. It thus makes it extremely difficult to find a reliable solution.

• the foundation of the building (which, in the Parthenon, for example, consists in general of a compact natural stone foundation on solid rock).

B) The nature of the building material. The main building material of the Acropolis monuments is marble, a particularly anisotropic material, with low porosity, uniform grain size and non-linear behaviour. The joining material is iron (clamps and dowels) and the insert between the marble and the iron is lead.The new materials replacing the iron and lead are titanium and white cement respectively.

C) The preservation of the monument until now. The catastrophic factors that change the form of the original structure of the monument and its building material are of two types: natural and man-made. Among the natural factors we may include the effect of time (aging of the material), the existence of discontinuities, *kommos* or faults in the main building material, decay from physico-chemical/biological action, freezing, the effect of seismic action, etc. Man-made damage includes fire, bombing, explosion, vandalism (ranging from the cutting of marble masses, dropping architectural members to the ground, to the destruction of joining elements in order to remove the lead, etc.) and even the effects of environmental pollution. The above factors, apart



The model of the architrave block during the experiment in the Laboratory of Testing and Materials of NTUA. Photo M. Mentzini, 2002

from changing the original design of the structure, have in addition degraded the mechanical and physical properties of the building material. The result of this is a reduction of its bearing capacity in critical places and in the building as a whole.

Design and execution of the structural interventions

The design of structural interventions on the monuments includes diagnosis of the damage, the study and the proposal for restoration. The design must address the causes of the damage sufficiently, insuring the necessary and most important structural stability with the minimum possible intervention so as not to disturb what is known as their heritage value. It should be noted that structural intervention on a monument is not only a cultural matter; it has also a social and educational aspect. The intention is not simply to preserve it as an ideal image for the future. It concerns both the visitor and the person working on the monument, serving at the same time the value of human life.

View of the back and resting surface of the model during the revealing of the reinforcements for control after the end of the experiment. Photo M. Mentzini, 2003

The designing of a structural intervention thus comprises a qualitative and a quantitative approach. Included in the qualitative approach is historical research (very significant for indicating and classifying damage when carefully interpreted so as to draw accurate conclusions) and the direct observation of damage and of phenomena likely to develop further. Direct observation provides the possibility of making immediate interventions, as in cases where immediate collapse is a danger, or to reduce destructive environmental factors (such as humidity, water flow, weeds, etc.).

The quantitative approach includes monitoring for observation of the monument (recording of changes in deformations, cracks, reaction to seismic activity etc.), laboratory analysis of chemical and mechanical characteristics and of physical properties of materials, either existing or intended for use in interventions (such as their compatibility with each other and with the ancient structural material) with testing and control of possible long term effects of the new materials on the monument. The quantitative approach to the design of structural restoration includes, in addition, numerical analysis of the programmed intervention, with the construction of an analogous numerical simulation. Numerical simulation has to be formed with great care, since a simple model may be far more reliable than a complicated one, which presupposes assumptions that cannot be evaluated or determined. Such a multi-parameter analysis may lead with minor alteration of data to large differences in results. The analysis therefore must be accompanied by experimental evaluation, that is, by constructing specimens simulating the ancient structural member or part of the monument to be restored as accurately as possible in form, type of material and loading conditions. Of special importance in the analysis is the scale effect or the difficulty of replicating precisely the exact conditions of usual or critical phenomena. A consideration - evaluation - calibration of the results of the numerical simulation with the corresponding specimen is helpful in locating the points that should be re-examined and approached with greater accuracy or perhaps in a different way. This can yield conclusions of greater accuracy in relation to the actual phenomena.

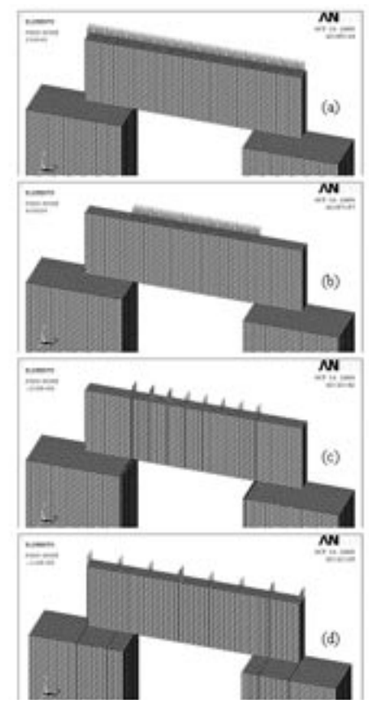
Determining the required reinforcement for joining together multi-fragmented structural members of the monuments is also a prerequisite for the correct solution of the problem of the structural stability of the monument as a whole. A pioneering, now well known, method has been developed for the restoration of fractured architectural members through the joining of their fragments or through the joining of the ancient fragments with new pieces, as complements, of Dionysos marble using titanium bars and cement mortar. For the method there is a choice between two different approaches: either to reach the initial bearing capacity of the member or to reach the capacity corresponding to the maximum load that the member is expected to bear, after the restoration of the monument to which it belongs is completed (also, taking into account all possible future interventions).

Problems arise in the course of the intervention because of the irregular shape of the fragments, which makes it difficult to join the new fillers with the ancient section of the member or to determine the direction of the reinforcements. This may work against the direction resulting from the structural analysis, making it necessary to redesign the study or risk coming into conflict with the principle of intervening as little as possible. This emphasizes once again the need to avoid changing the original structural system, out of respect for the technical and historical value of the monumental construction.
On completion of the intervention continuous observation and control of the results must be possible. For this reason, if the measures taken are not reversible so as to allow for correction or even total replacement the work that has been done, must at least not interfere with future interventions.
Finally, we should note the lack of a clear legal regulatory framework for restoration interventions, so as to apportion responsibility among the state, the service in charge of the work and the researchers.

The logic and complexity of design of the structural restoration of the members of the Acropolis monuments is demonstrated by the following example on the restoration of an architrave block of the Parthenon colonnade.

Searching for the best solution

At the last (5th) International Meeting on the Restoration of the Acropolis Monuments in 2002, the present author presented a model, at a scale of 1:2, of one of the most damaged architraves of the north colonnade of the Parthenon. Simulated in the model in full detail was the geometry, the cracks, the discontinuities and the geological stratification of the ancient member. The model was reinforced to agree with the results of the design concept. The specimen was subjected to eight-point bending in the Laboratory of Testing and Materials of the National Technical University of Athens (NTUA). The load was applied statically, and was increased gradually and its final value was two times the one expected for the specific architrave. Then the load was removed. The behaviour of the model is considered satisfactory since the specimen behaved as an intact structural element. Indeed the relation between the deflections of the lowest side of the model and its mid-span and the applied load is almost linear.



The four loading cases studied numerically: a) uniformly distributed load along the total length, b) uniformly distributed load along the span, c) eight-point bending along the span, d) eight-point bending along the total length

It is also be mentioned that at the design load a crack invisible to the naked eye appeared at the contact surface of the two main parts of the model. As the load increased further, the width of the crack increased to almost 1mm at the maximum load. After the load was removed the width of the crack decreased to a value of about 0,2mm.

It must be emphasized that serious marble exfoliations were observed on the surface of the marble in the area near the edges of the supports, just after the span, a place that in actual circumstances is the vicinity of the *scamillus*, i.e. the drafting margin relieving the edges of the capital from the superimposed load.

Then the results of the measuring system showing the behaviour of the model were studied and diagrams plotted. The results showed full agreement of the proposed theory with the experiment (for example, the strain gauges, which were placed at the middle of the lower surface of the test model, on each side of the central crack, showed no appreciable change).

There remained only to interpret the remaining width of the crack at 0,2 mm at the end of the experiment. For this reason, a cut was made in the back of the model revealing the titanium bars. These showed no signs whatever of the pull-out phenomenon. Samples of the reinforcement were then taken from the two lowest layers, and they were tested in tension in the Laboratory of Testing and Materials of the NTUA in order to check possible failure, under Assistant Prof. of the Department of Mechanics, S. Kourkoulis. It was evident from this inspection that none of these reinforcements had yielded.

The final conclusions of the experiment showed agreement between theory and practical application, and verified the strong ductility of the titanium. It was found that after the unloading, the crack at the point of joining (a desired presupposition in any

case) retained this miniscule width, probably because grains of the joining material had made their way onto the walls of the joined fragments.

In the course of the research on how to approach the behaviour of the architrave of the Parthenon under ordinary conditions or under expected unfavourable actions, and to evaluate the results of the numerical analysis and of the structural testing, the undersigned, by a thorough *in situ* observation, recorded all the cracks visible macroscopically in the architrave around the four sides of the temple. It was decided to record the cracks in those architrave blocks, which had never been removed from their original place since Antiquity and to ignore the cracks that are due to the function of the clamps and dowels, and to the "push over" phenomenon (due to significant horizontal actions, such as explosion and earth quake). Similarly, it was decided to ignore cracks resulting clearly from vandalism, bombing etc. or from faults in the marble construction.
From a total of thirty-two architrave blocks, with cracks of interest to us, and out of a total of fifty-one cracks, the following are recorded here:
• Seven (7) cracks in the middle of the support of the part of the architrave that rests on the *abacus*.

Structural restoration of an architrave block of the north colonnade of the Parthenon: a) setting the titanium bars, b) application of cement mortar around the titanium bars. Photo M. Mentzini, 2005

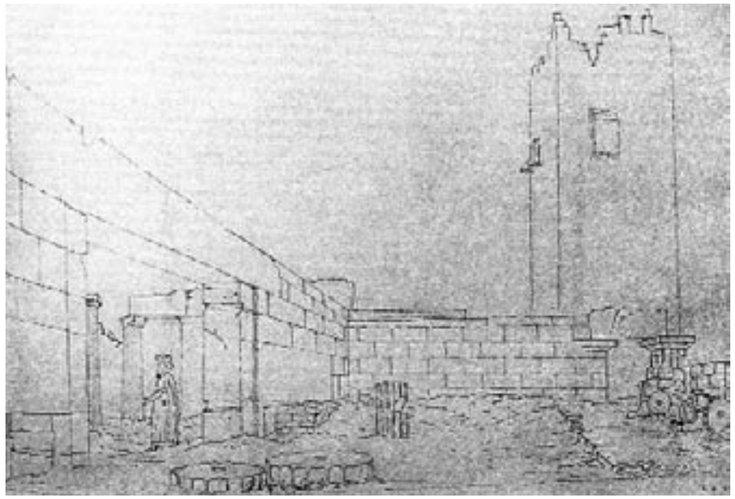
• Nineteen (19) cracks in the span of the architrave.
• Ten (10) cracks in the part of the architrave that rests on the *abacus*, next to the span of the architraves.
• Eight (8) cracks in the part of the architrave that rests on the *abacus*, just after the span.
• One (1) crack at the end of the span of the architrave, next to the beginning of the support on the column capitals.
• Six (6) cracks in the end of the architrave (not evaluated).
The above recording completed the evaluation of the experiment and confirmed the interpretation of the exfoliation of the marble at the ends of the span of the model, showing that it occurs at points subjected to the greatest stress.

Conclusions
Experimental approach to the behaviour of the architrave blocks is continuing at the School of Applied Sciences, Department of Mechanics of the NTUA. A new detailed numerical study of the architrave is already being made with the help of Assistant Prof. S. Kourkoulis and Mrs E. Yiannari, in order to determine the points that are subject to the greatest stress. Two more marble beams –models of architrave blocks– have also been made at a scale of 1:3, one symmetrically fractured and restored using titanium bars as reinforcement, the other intact. These will undergo experimental testing.

The aim is to find the exact points of support of the architrave blocks for the following purposes: to see if it is possible to reduce the reinforcement in the central section of the architrave blocks to give the proper attention to the existence of the drafting margin (*scamillus*) at the edges of the *abacus* of the underlying column capitals, which must be deep enough to be carved, in the new marble fillings of the column capitals, with rounded corners. Special attention must likewise be given to the contact between the architraves and the underlying column capitals, in order to be as satisfactory as possible, so that if, with the wear of time, the contact between the resting surface of the architrave and the upper surface of the column capital were to be altered, it could be repaired by means of suitable insertions.

Marilena Mentzini
Ph.D., Civil Engineer of the Parthenon Restoration Project
In charge of the Pronaos and North Colonnade Programmes

The description of the French antiquarian Jacob Spon, who visited the Acropolis in 1676, thirty-six years after the explosion of dynamite in the central building of the Propylaia (1640), makes it clear that an important section of the ceiling of the west hall together with the corresponding Ionic columns had remained in their places after the explosion. The Englishman, George Wheler, who accompanied Spon on his visit to the Acropolis, mentions in his memoires that in the central building of the Propylaia he saw the ceiling "supported in the interior by four beautiful Ionic columns that hold up two large marble beams covered by large marble ceiling blocks". Illustrations showing the Acropolis from the West and comments by travellers after the destruction of the Parthenon (1687) show that the west façade of the central building of the Propylaia was still intact. It appears that of the six Ionic columns of the west hall, drums were missing only from the easternmost, the northeastern column having suffered the greatest damage. With the demolition of the rest of the superstructure of the central building, in order to build vaults over the intercolumniations of the west façade with a platform above for the installation of an artillery battery, their original height was permanently lost along with the rest of the columns of the west hall. Pillars around the columns were required for this construction in order to support the vaults.
A watercolour by Smirke, probably of 1803, shows the interior of the east portico of the central building from its north end. Through the central opening in the doorway wall the southeast column of the west hall can be seen, preserved up to and including its ninth drum. In Gell's drawing of the same time, of the interior of the west hall after the construction of the vaults and the platform for the canons between the columns of the hall, only the two uppermost drums of the southeast column can be seen (eighth and ninth from the bottom), while in the foreground of the drawing are two Ionic column drums, evidently moved from their original position. In a drawing by Dodwell of around the same time, showing the interior of the central hall from the NW, the southeast column appears to have only one drum above ground. At the end of the 18th century, the construction with the vaults was reinforced so that more powerful canons could be installed. As a result, the column capitals and the underlying drums were removed from four of the six Doric columns of the west façade of the central building. This alteration meant the final loss of five upper drums and four columns of the west hall, which had been preserved up to the height of the final drum.



The interior of the west hall of the central building of the Propylaia from N. Drawing by William Gell, 1801-1804

With the formation of the modern Greek state came archaeological activity and the demolition of mediaeval and Turkish buildings on the Acropolis. In 1836 and 1837, the vaults in the central building were taken down. Thus, the Ionic columns were liberated from the pillars that had surrounded them and from the screen walls that had been built in the intercolumniations. After these works, the southeast column, just as the other four, was found to preserve *in situ* seven lower drums, while the northeastern column, which was restored by Balanos between 1911-1914, had suffered the greatest loss, preserving only its two lowest drums. The source for this information are the relevant studies by the architect Tasos Tanoulas, in charge of the restoration of the Propylaia.

The "Study for the Restoration of the Superstructure of the Central Building of the Propylaia" by Tasos Tanoulas and Maria Ioannidou was approved by the Central Archaeological Council. Included in it, in addition to the restoration of the section of the ceiling in the west hall that had been restored by Balanos in the past, is part of the ceiling that is above the central passage. Extending the restoration toward the south was justified in that it allows the visitor to walk beneath a section of the ceiling over the central passage, thus experiencing the feeling of a roofed space (and this will continue in the east portico). The decision is justified also in that a large number of fragmentary coffers from the ceiling of the west hall, now preserved on the ground, can be used in the restoration. To carry out this restoration it was necessary to restore the easternmost column of the south Ionic colonnade. An entirely

new marble capital will be set on this column as well as the five drums above the seventh drum, preserved in situ. Research on identifying the drums to be restored included the drums preserved on the ground and the five upper drums of the column restored by Balanos. This column was dismantled in 2002, a necessary step for the application of the above study.

These Ionic columns are not in very good condition. Many of the drums have been reworked for use as well-heads and some were found broken into at least two large fragments. As described in the "Study for the Restoration of the Superstructure of the Central Building of the Propylaia", a total of eleven drums belonging to the columns of the west hall are lying on the ground. Most of these (five) represent the ninth drum and the rest the eighth, tenth and twelfth. So far, no eleventh drum has been found, so that an entirely new marble drum for this position is needed. The measurements of this drum will be adapted to the total height of the Ionic column and to the diameters of adjoining surfaces of the drums above and below.

The basic criterion for choosing the drums to be used in the present restoration was the agreement of the diameters of their adjoining resting surfaces. Detailed study of the drums while on the ground showed that the drums used by Balanos in his restoration of the column in the north Ionic colonnade, had not been wrongly set.

Examination of the seventh drum *in situ* and a drawing of its upper resting surface showed the following: a crack running through the upper surface on a E-W axis is visible for about half the height of the drum on its outer side. The diameter of the upper resting surface taken on the deepest point of the channel of the flutes is 886,5 mm and the height of the drum 782 mm. It is necessary to reinforce the seventh drum with titanium rods, in order to increase its structural strength in view of the load the column is expected to bear in accordance with the approved study. Of the two available eighth drums still on the ground, the drum numbered 5679 of the Archive of Members Scattered on the Acropolis (AAD) was chosen. Its original height is not preserved because the lower resting surface has been trimmed. An estimate of the diameter of the lower surface is around 885 mm, thus 1,5 mm less than the upper resting surface of the *in situ* seventh drum. After restoring the lower resting surface of the eighth drum with an addition in height of about ten centimeters, we think that the difference is not particularly evident. While the drum has been hollowed out on the interior for use as a well-head, evidence for the use of the monument as a source of building material during the Ottoman domination, it was finally preferred for use in the restoration because the other eighth drum, AAD No. 5680, while complete, has a lower resting surface with a diameter of 882 mm, at least 4 mm less than the underlying seventh. The diameter of the upper resting surface of the drum that was finally chosen is the same, 873 mm.

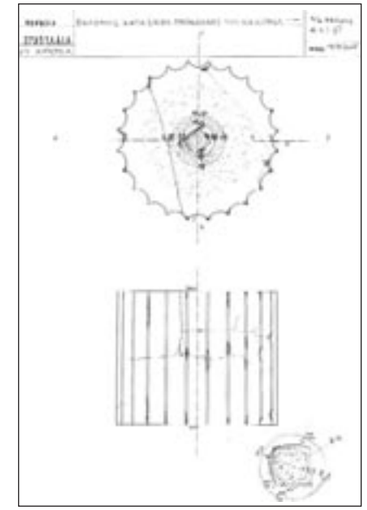
The west hall of the Propylaia from S. Photo W. Hege, in the 1930's

Of the five ninth drums that could have been used in the column's restoration, AAD No. 5161/5192 is closer to the the upper resting surface of the underlying eighth drum, with 874 mm. The full height of the drum is not preserved. One of the two large component fragments, however, preserves the bottom of the *empolion*, thus providing an estimate of the original height of the drum. Both fragments have considerable surface damage, making their use in the restoration of the column problematic. Of the other ninth column drums, the diameter of AAD 5160 was closer in measurement. It preserves, however, only the lower resting surface, as the rest of the drum is in the British Museum. It was decided not to use this fragment so as to leave open for the future the possibility of joining it with the rest of the drum in London. The ninth drum finally chosen as the most suitable is AAD 5163, which matches with AAD 5172. The drum is preserved to its full height, where part of the lower surface remains, and the diameter measured in the fluting channel is 868 mm. Most of the drum has been hollowed out incompletely, in preparation no doubt for use as a well-head. The new filling, which will restore the lower resting surface, will include two smaller fragments that match together (AAD 5163B and 5163Γ).

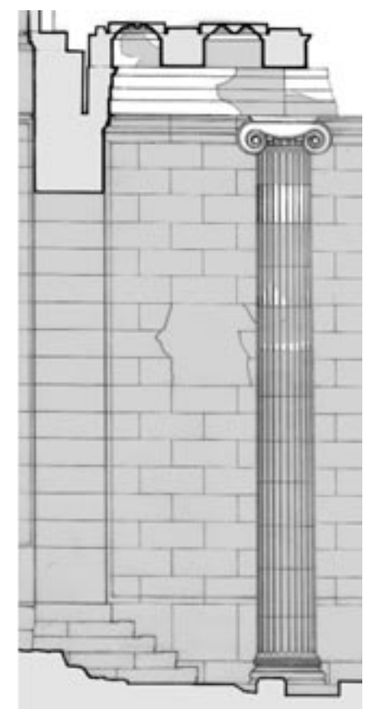
Of the two tenth drums among those on the ground, AAD 5681 has a lower resting surface diameter of 852 mm, the same as the that of the upper resting surface of the underlying ninth drum. It's general condition is good and the small fragment, AAD 5155, belongs to it. As noted above, the eleventh drum will be made entirely of new marble. The diameters of the two resting surfaces will be adapted to those of the underlying tenth and overlying twelfth drums. The fact that the underlying eleventh drum would be entirely of new marble was decisive in the choice of the top, twelfth, drum. Of the two existing drums, AAD 5684 was chosen despite its having been hollowed out for use as a well-head. It preserves the two resting surfaces, the *apothesis* and most of the egg-and-dart, unlike the other candidate (AAD 5683), which preserves little of the *apothesis* and none of the egg-and-dart (*astragalos*). Most important, AAD 5684 preserves the entire upper resting surface with point marks, probably made in hollowing this too for use as a well-head. The eighth and the twelfth drums, that were hollowed out as described above, will be filled in with new marble so as to be used in the anastelosis of the column.

The total height of the Ionic columns of the West Hall is 10,299 mm, including the plinth and stylobate, which is 101 mm high. Once the drums were chosen for use in the anastelosis of the easternmost column of the south Ionic colonnade, we knew the height of the eleventh drum that was to be made entirely of new marble. It would be 67 cm, that is, considerably smaller than the other drums of the southeast column.

The restoration of yet another column of the Propylaia west hall, in addition to that restored by Balanos at the beginning of the second decade of the 20th century, is indeed a significant event in the history of the monument. With the setting of the chosen column drums and the new capital, after some three centuries the column will regain its original height and soon its overall form.



Drawing of the upper contact surface of the seventh drum of the SE column of the west hall of the Propyalaia central building, preserved in situ. *Survey-drawing K. Karanasos, 2005*



Proposal for the restoration of the SE column of the west hall of the Propylaia. Study-drawing, K. Karanasos - T. Tanoulas, 2005

It is well known that a restoration contributes greatly to the understanding and legibility of the building being restored. Yet, it is of utmost importance that the intervention respects the historical value as well as the form and character of the monument as the ruin. A main feature to be respected in these interventions is structural integrity, which is often revealed in filling in the form of an architectural element. Restoration of the form of the southeast column of the west hall, which took priority in the demands of the programme to restore the superstructure of the central building of the Propylaia, was carried out on the basis of the principles noted above and with respect for its integrity.

The columns of Ionic style in the Propylaia are notable for their special proportions and, above all, for the perfection of form of the column capitals. The ESMA decided not to use any of the four large ancient capital fragments that had been set in the previous anastelosis of the northeast Ionic column, because these unique samples had to be preserved. They are the only ones to have survived as witnesses of the artistic creation and aesthetic taste of Mnesikles' workshop. The construction of the new column capital in place of the Mnesiklean, if nothing else, is an accomplishment of equally high standard. It was based on drawings by Tasos Tanoulas to show the geometry of the ancient capital, based on study of the large fragments of the capital restored by Balanos. The purpose of this new creation was not to rival the incomparable artistic value of the original, nor to confuse future generations over its authenticity.

As Cesare Brandi has rightly observed in his well-known theory, the difference between the copy and the fake lies primarily in the intention of the producer. This past year discussion has focussed on two copies of Ionic column capitals in the process of being made and which will soon be seen high up on the two eastern-

most columns of the west hall. In fact, these creations are two new Ionic column capitals, breathing their own artistic inspiration. While they are faithful reproductions of the basic Mnesiklean original, just as were the six capitals made in the 5th century, without question these are two new creations based on the same prototype. The inspired marble technicians, Giorgos Desypris and Aristeidis Kladios, together with their assistants Roverto Vidalis and Iakovo Kladios, who undertook the work, followed carefully the details of the restoration drawing and while persistently observing two of the four large ancient fragments. They made the two column capitals in full knowledge that these will belong to their moment in time and that they express the aesthetic preferences of their epoch. The two new Ionic capitals could never be precise copies of the Mnesiklean, even if these capitals had been preserved complete. This does not mean that the modern work is automatically excluded from being a work of art. Since the capitals are made using the same technique, rather than by mechanical means, they can be termed a contemporary expression of the work of the YSMA skilled marble technicians, valuable witnesses of the historical period in which they were made.

Konstantinos Karanasos
Architect of the Propylaia Restoration Project

Filling in with new marble of the twelfth drum of the SE column of the west hall of the Propylaia central building, which had been used as well-head in the Middle Ages. Photo K. Karanasos, 2006

Carving the new Ionic column drum of the Propylaia. Photo K. Karanasos, 2006

Inserting an ancient fragment in the third drum (from below) of the NE Ionic column of the Propylaia. Photo K. Karanasos, 2006

Historical review

In the great 5th century B.C. building programme of the Acropolis, it was the Circuit Wall, more than any other work, that gave the sacred rock its recognizable form, thereafter determining its topography. The building of these walls was indeed an intervention on a grand scale and it was based on a unified architectural concept. Especially strong retaining walls were raised outside and around the Mycenaean Circuit for a length of 740 m to support the heavy fill needed for the new terracing created as a gigantic foundation for the building of sanctuaries. The area of the Acropolis was thus expanded, while the uneven surface of the rock was organised into large horizontal terraces, reaching an area of 29,000 sq.m.

The North Wall, known generally as the "Themistoklean Wall", was one of the first works to be carried out after the Persian Wars and the destruction of 479 B.C. The architectural members of the ruined sanctuaries were used as building material in its construction. Incorporated in the part that is in front of the Erechtheion, together with the crepis blocks of the ruined pre-Parthenon, are 26 half finished unfluted drums. Their unfinished surfaces are visible. Poros column capitals of the "Archaios Naos" were placed further east, upright with the *abacus* toward the outer side, while members of the entablature (architrave, triglyphs, metopes and cornice blocks) were laid in a continuous row as crown or cover blocks in the central area of the Wall. With the display of destroyed/damaged architectural members above the most important public areas of the ancient city, the Athenians memorialized the barbarity of the Persians and exhibited their strength. Preserved today is most of the ancient construction, which has been restored only in places with rubble masonry in later repairs.

The South Wall, known as the "Kimonian Wall", was built after the victory in the naval battle of the Eurymedon (466 B.C.). Looking at the outer face today, it is difficult to discern the authentic part of the monument, since the façade comprises for the most part rubble masonry sometimes as built repairs, elsewhere as filling in sections that had fallen. Despite the change in its outer appearance, the core of the South Wall remains unaltered and its outline gives a general picture of its ancient form. The South Wall comprises two long legs measuring 130 and 165 m, with a height surpassing in some places 18 m. It is constructed for its full width of large rectangular quarried poros blocks, in horizontal courses in the isodomic system, together with reused building material. The outer surface, slanting inwards, makes a stepped 2-3 cm incline. In its lower layers, estimated to exceed 5 m in width, it includes poros architectural members from the first peripteral Parthenon, such as architrave blocks, cella wall blocks and column drums.

The East Wall has been reconstructed for the most part in more recent times, after it collapsed, probably during a great earthquake in the 18th century.

In the long tumultuous history of the Acropolis, the Circuit Walls were continuously repaired. Extensive defensive works were carried out by the Ottomans in 1687, when canon bastions were constructed. In the 19th century, the first programme for restoration of the Acropolis monuments included the removal of most of the later additions to the fortification system. The crenellations were taken down and a parapet was added to the top of the Wall. Between 1899 and 1940, works of consolidation were carried out by N. Balanos. In the most recent repairs of that time on the South Wall, cement mortar was employed in an imitation of the isodomic system of construction.

Pathology

The continuous repairs that have been made to the Wall over time have helped to preserve them to today. Yet, structural damage is evident in many parts of the ancient construction, just as in the more recently repaired sections. Cracking, gaps and extreme deformations – bulking and sliding of some sections can be observed. The reasons vary: the lack of sufficient bonding of repaired sections with the body of the original construction causes the building material to separate in the interior. Lateral earth pressure on the retaining Wall causes deformation of the façade. In some areas structural damages indicate aging effects on the building material and gradual loss of mechanical strength. Atmospheric erosion and moisture are exceedingly serious parameters of damage. The rain water that lies in pools on the surface of the Acropolis and percolates into the interior of the Wall –in addition to increased hydrostatic pressure– causes the ancient poros blocks to exfoliate and alters the mortar used in the later repairs.

Reports on the Circuit Wall of the Acropolis

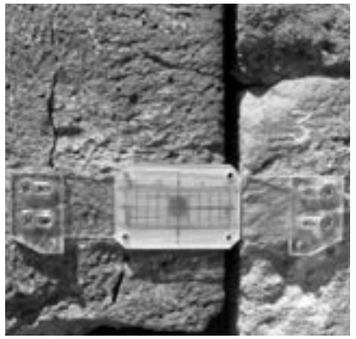
In a series of reports over the past 25 years (of M. Arvanitakis, G. Beis, M. Korres, P. Kouphopoulos, A. Mantis, D. Monokrousos, T. Papathanasopoulos, K. Syrmakezis, T. Tsitroulis) the lack of available data and the need of a systematic compilation of information about the condition of the Wall have been noted. The advocates and members of the research committee cooperated in proposing a strategy and in programming an interdisciplinary approach to the problem. It became clear that documentation of the form and state of preservation of the walls as well as collection of data were necessary before any future intervention. Likewise, the need for additional computational data for a clearer evaluation of structural efficiency was noted. These reports mentioned the need for establishing a unified system of reporting in connection with the study of deformations. Detailed specifications were drawn up for their topographical and photogrammetrical survey.

At the same time a number of areas of the Wall were drawn, such as the west section of the North Wall from the Propylaia to the narrow Gate, that leads to the Cave of Pan (T. Papathanasopoulos) and the interior side of the SE corner of the Wall (P. Kouphopoulos). In terms of documentation, it was also realised that the historical phases required investigation and the incorporated ancient architectural members and sculpture fragments that had escaped no-

tice in the façade of the Wall had to be recorded. The question of their removal from the Wall was also posed.
In relation to the problem of superficial erosion, the causes were determined and the areas where the poros stones showed exfoliation and cracking (ancient) and others where the binding material had been damaged (repairs) identified. Samples were taken and laboratory tests performed to determine the mechanical damage of the mortar. Proposed was improvement of the mechanical strength of the poros stones, restoration of the cracks and filling in of the gaps. Consolidation was con-sidered necessary but not urgent. Proposals were made to initiate structural restoration of a section of the North Wall west of the Belvedere, with the removal of brittle mortar and the filling in of joins with material of the latest technology, for which the required technical features were specified.
Going back to the earliest reports on the structural damage of the Circuit Wall, it is noteable that for the most part they comprise observations and in a number of cases isolated proposals for consolidation. Until the present, however, there has been no overall plan of intervention. The lack of basic analytical drawings, measurements of the slight movements in the deformed parts of the Wall, the lack of systematic research on the historical phases and the limited bibliography on the subject, all these are and continue to be reasons preventing the immediate launching of a systematic programme of restoration.

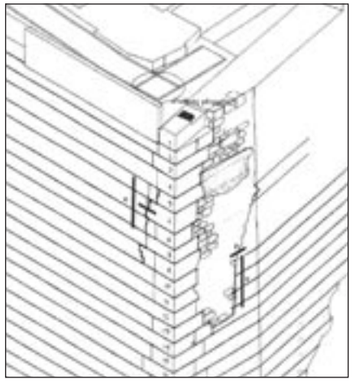
Programmed studies - Installation of monitoring systems

At present one of the main programmes of the YSMA under way is the monitoring of the structural damage of the Acropolis Circuit Wall. A specialised interdisciplinary group has been assembled for this purpose, the members of which are D. Monokrousos, civil engineer, D. Moullou, archaeologist, S. Oikonomopoulos, mechanical and elebctrical engineer, E. Toumbakari, civil engineer, T. Chatzitheodorou, topographer, and the undersigned, with M. Ioannidou, director of the YSMA, as coordinator. After relevant research on the various methods of monitoring, it was decided to use a combination of mechanical methods (crack meters, INVAR wires) and other recording systems, most all of advanced technology (topographical with automatic target recognition, electronical recording), which are original applications and presume special research. Evaluation of all the data to be gathered will provide the basis for special studies on consolidation of the Wall.
Mechanical crack metres have already been set on the cracks in the Wall. The information they provide is local but useful, since they collect reliable information as to whether and to what extent the cracks are "active". In 2004-2005, eighteen acrylic crack metres were installed in order to monitor the cracks in the southeast corner of the Wall. They are inspected regularly. To date, indications of minor movements at the base of the Wall have not surpassed



Acrylic crack-metre installed on the South Circuit Wall of the Acropolis. Photo V. Manidaki, 2004

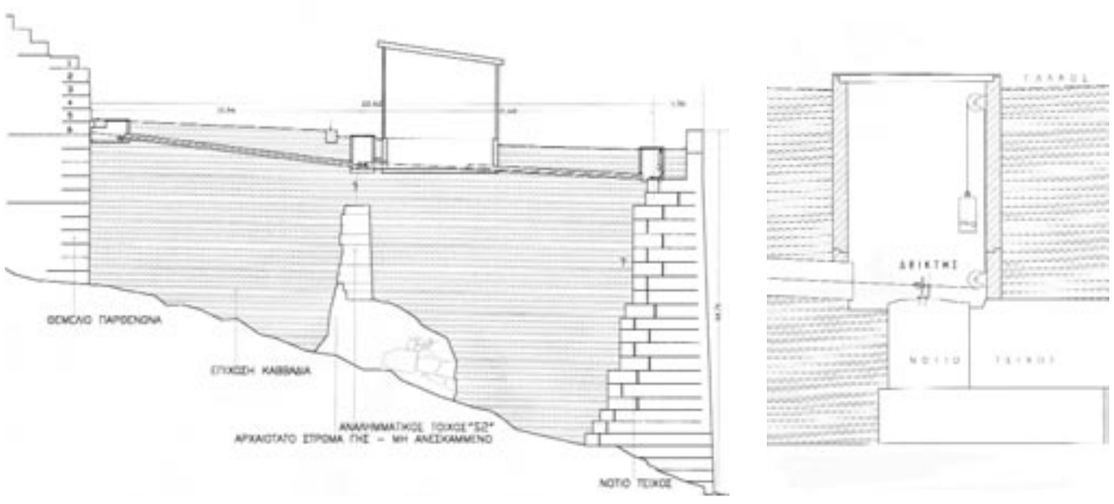
2,3 tenths of a millimeter and they are at the very edge of measurement error.
Also at the end of 2005, an underground non-expanding wire INVAR was set in place for monitoring the small-scale movements of the South Wall. The INVAR is an alloy (Ni 36%, ~ Fe 64%) that remains dimensionally stable in temperature changes. As had been observed earlier, the firm foundation of the Parthenon provides a suitable reference point for the measurements. An underground connection was made between a stone in the sixth layer from the top of the Parthenon foundation and a stone in the uppermost ancient layer of the South Wall. The INVAR wire (~22.70 m), 1.65 mm thick, was inserted into a tube (it is at a depth of ~1.30 m below the surface) and it can be inspected at three points through vertical shafts. It is firmly fastened at the Parthenon, whereas at the South Wall it is tightened by a 10 kilo counterweight on pulleys. Any movement of the Wall will be shown as a change of relative distance in the recording system.
High accuracy monitoring-surveying of predetermined points in the South and East Walls of the Acropolis is a second method that has been chosen for measuring the micro-movements. Monitoring-surveying is relatively less accurate but it provides information about the surfaces of the Wall as a whole and it is therefore valuable for the overall image. The monitoring-surveying instrument that is planned for use is a total station and it is accurate to 0,5 mm regardless the angle or the distance. The instrument is also equipped with "Automatic Target Recognition", which enables it to recognize automatically the monitoring prisms and to assure that the measurements are always taken at precisely the same points, thus actually excluding all the observer's errors. So, that the instrument has the best chance of being set always in the same position, fixed bases have been made for the two positions chosen for the instrument. The network of points to be monitored comprises, to date, 46 specific monitoring prisms on the South and East Walls, which are monitored at regular intervals.
The use of electronical systems for automatic and continuous recording of the deformations is the fourth system of monitoring that has been programmed. Electronical sensors (sensors of displacements, of mass temperature, crack meters and inclinometers) on the surface of the Wall, connected with an electronical measuring station (mini-computer), will make it possible to record automatically all the effects of static and dynamic stresses on the Wall with excellent accuracy (to 0,1 mm).
The present YSMA programme has likewise scheduled the combining of documentary work with modern methods for a full geometrical recording of the existing condition of the ancient Wall: photogrammetric recording has been programmed for the full extent of the Wall, and the South Wall unit has already been done. There are considerable difficulties involved as the original photography is done with a balloon and the instruments are operated by radio remote control.
Finally, during the first six months of 2006 a series of electrical resistivity tomographies of the façade of the Wall were undertaken, so as to examine its invisible sections (the work has been undertaken by the Applied Geophysics Laboratory of the Aristotle University of Thessaloniki). A trial tomography was made in June 2005, the results of which verify approximately what we know about the cross-section of the Wall and the contour of the rock at that location. After adequate calibration of material parameters, we expect to obtain measurements of the thickness of the Wall as well as to locate of the areas with increased moisture both in the Wall and in the earth fill behind.
Three dimensional scanning (3D) of the rock slopes and the Wall is under investigation, mostly in relation to the density of the scanning points and the positions from which they will be scanned. Electronical scanning can provide a three-dimensional digital model of the Acropolis that will be available as a precise base for all future studies.



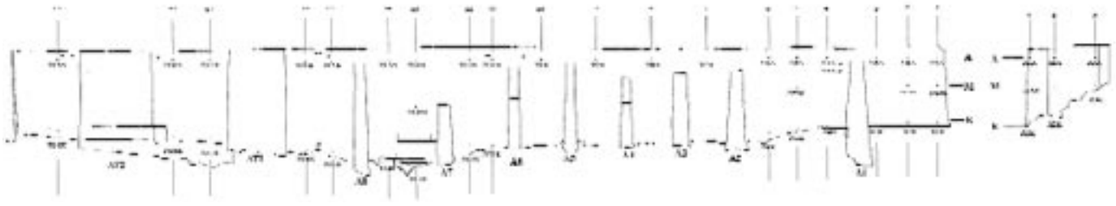
Positions of the electronical sensors on the SE corner of the Acropolis Wall. Drawing V. Manidaki

Inspections

Aside from the use of the above technologically advanced methods, inspection is always a reliable method of examining structural damage. It was considered necessary to acquire a suspended work-platform system that would allow access to the exterior surfaces of the Wall. A small hand-operated work-platform accomodating two people was chosen. It is made of aluminium so that it weighs very little (75 kg) and can be transferred from place to place by hand (to be sure, with all the difficulties involved in such transfers). The platform



Installation of INVAR wire on the South Circuit Wall of the Acropolis. Application drawing. Cross-section and detail of ending shaft. Drawings by V. Manidaki



Installation places of specific surveying prisms on the South and East Walls for monitoring the deformations. Drawings by V. Manidaki

(measuring 2 x 0,8 m) is suspended on cantilevered beams with counterweights at their opposite ends. While moving above the upper surfaces of the Wall, the machine can easily be adapted to whatever irregularities there are in its surface. The suspension platform has been in place since late April 2005 and it has been used a considerable number of times at different places on the South Wall for installing monitoring instruments (crack meters, surveying prisms). Access to these places has enabled us to obtain surveys of the cross-sections and of the deformations of the Wall with traditional, well established, methods. Together with this, weeds are removed from the South Wall and, where needed, accretions in the drainage system are cleaned out.

Filling in of the Arrephorion

Work on the Circuit Wall includes also complete filling of the foundations of the Arrephorion, since this directly affects the Wall. It was decided that the best means of protecting the particularly soft and delicate poros stones of the monument was to bury them. The poros blocks will be covered over in their entirety by a soil material, strengthened in suitable fashion during its compaction in layers (i.e. reinforced earth), in order to avoid lateral thrust on the adjacent part of the Wall. This is a pilot work since it encounters wider problems on a smaller scale, such as the general arrangement and display of the Acropolis ground: study of the structural efficiency of the Wall, research on the physical and mechanical properties of the filling material, drainage of rainwater, recording of location of the buried foundation walls in the new ground level. Apart from exploring the technical problems, this will allow a better evaluation of the large future work of forming the surface of the ground.

Future interventions

In future it will be necessary to continue monitoring the inevitable and unpredictable evolution of the cracks and deformations of the Circuit Wall in a more extensive and dense network than that which has been set today. The evaluation of all the information to be collected will provide the base of future specialised studies on the consolidation of the Wall.

Also to be completed is the particularly demanding and time-consuming recording of all the ancient architectural members that have been incorporated in the Wall. General research on the Circuit Wall, detecting and dating the numerous repairs carried out from time to time, should improve our knowledge of the ancient form, material and ways of construction, as well as our understanding of the historical phases of the Acropolis Wall, which in itself is a monument of extraordinary importance.

Working platform on the S Wall. PhotoV. Manidaki, 2005

Acknowledgements

The work carried out on the Wall during the last two years would not have been possible without the collaboration of the staff of the electro-mechanological workshop of the YSMA. Particularly productive has been the collaboration with the director of the workshop, S. Oikonomopoulos, mechanical and electrical engineer and the workshop members S. Gousis and S. Nikolopoulos, who ingeniously confronted the peculiarities and difficulties of the work. I particularly thank them.

Vaso Manidaki
Architect of the Circuit Wall Project

Applying electrical resistivity tomography SW of the Parthenon. Photo Applied Geophysics Laboratory of the Aristotle University of Thessaloniki, 2006

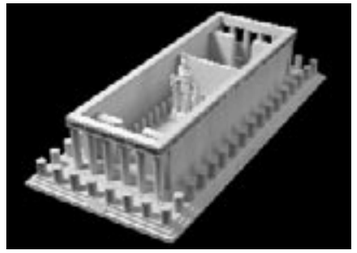
In 2005 and during the first six months of 2006, much activity was devoted to informing both the general public and specialists about the anastelosis of the Acropolis monuments. Education of the young on the subjects of ancient art, architecture, history and the restoration of its monuments, likewise received much attention.

Educational activities

The activities of the YSMA Department of Education and Information in 2005 included carrying out educational programmes for 3,370 school children, giving lectures and holding seminars for 940 educators and students, the distribution of educational material to 1,246 people and 179 institutions. Altogether in 2005, a total of some 14,030 school children studied with the museum kits of the Department and 74 kits were presented as gifts in Greece and abroad.

In 2005, a new museum kit appeared with the title "Restoring the Monuments of the Acropolis". A special programme based on this kit was organized in which 20 schools from Attica participated with some 600 students. The programme began with a seminar on November 26, 2005, held at the worksite of the Propylaia. It was attended by 45 educators. The seminar was held to inform the educators about the works of restoration being carried out on the Acropolis monuments, so that they in turn could present and teach this to their students.

The seminars continued and the educational material was distributed to Greek regional schools in cooperation with the educational districts responsible, with emphasis on the districts of Pieria, Evros and Rodope. As part of this effort the Department's museum kits were shown at Alexandroupolis, Dion and at the Archaeological Museum of Komotini. The seminar held at Dion was attended by 136 educators and 384 students from 18 school classes worked with the kits. At Alexandroupolis, 135 educators participated in the seminar and the kits were examined by over 600 students from 25 schools in the district. The seminar at Komotini was attended by 40 educators and around 355 students from 14 schools worked with the museum kits. In April 2005, an educational seminar was held at Budapest, which was attended by 40 Hungarian educators. All the above received educational material for their schools.



The new educational model of the Parthenon, scale 1:60

The educational leaflet "The Gods of Mt. Olympos on the Parthenon Frieze"

Published in Greek and English, in 2005, was a new educational booklet, "The Gods of Mt. Olympos on the Parthenon Frieze". In addition, an abstract model of the Parthenon at a scale of 1:60 was made with funding by the Organization for the Building of the New Acropolis Museum (OANMA) and under the supervision of the President of the OANMA, Professor D. Pantermalis. The model was designed especially in order to at act as a base for the educational game of reconstructing the Parthenon frieze. Likewise in 2005, an article entitled "Education through the Athenian Acropolis" by C. Hadziaslani, the head of the Department, and her colleagues E. Kaïmara and A. Leonti was published in "The Journal of Classical Teaching", the specialized journal devoted to the teaching of classical studies in England.

In 2006, C. Hadziaslani gave a talk on the educational programmes of the Acropolis at a one-day conference of the International Council of Museums (ICOM) held in May at the Byzantine and Christian Museum of Athens. She also gave a report entitled "Education through a Classical Architectural Museum: the Athenian Acropolis Case" at the symposium of the International Confederation of Architectural

The exhibition "Thirty Years of Restoration Works on the Acropolis, 1975-2005" in the Gounaropoulos Museum. Photo T. Souvlakis, 2006

Museums (ICAM), held at the Benaki Museum last June.

Exhibitions

The well-known photographic exhibition of the Acropolis works by the YSMA photographer, Mr. S. Mavrommatis, continued its course in the United States. It was shown from November 11 to December 18, 2005, at Lawrence University in Appleton, Wisconsin and from February 25 to April 22, 2006 at the Nashville Tennessee Museum, the location of the full scale copy of the Parthenon.

The exhibition was held also with great success from December 21, 2005 to March 19, 2006, at the Gounaropoulos Museum in the Municipality of Zographou, under the title "Thirty Years of Restoration Works on the Acropolis, 1975-2005". The core of this exhibition was S. Mavrommatis' photographic exhibition, which was enriched by the addition of a unit dedicated to the Restoration of the Erechtheion (1979-1987) and by photographs of the works of the years 2002-2006. The exhibition was inaugurated by Mr. P. Tatoulis, Deputy Minister of Culture at that time. The exhibition was organized on behalf of the Municipality of Zographou by the archaeologist K. Tzortzi, and on behalf of the YSMA, by the draftsman, P. Psaltis.

There were various events during the exhibition, such as continuously alternating projections of the YSMA films: "The Works on the Athenian Acropolis. The Men and the Monuments", "Conservation and Cleaning of the Parthenon West Frieze", by S. Mavrommatis, "The Erechtheion and Time", by A. Drakopoulou, "The Sacred Rock", by M. Paraschi, "The Rescue of the Acropolis", by K. Vretakos and "Parthenon: the Restoration of the East Façade", by D. Vernikos, and a number of lectures.

The first lecture of the year was given on January 11, 2006, by the President of the ESMA, Professor Emeritus Ch. Bouras, on the subject "Principles, Procedures and Methodology of the Interventions on the Acropolis Monuments". This was followed, on January 25, by a lecture given by the Director of the YSMA, M. Ioannidou, on

YSMA Poster at the Exhibition of the Union Internationale d'Architecture in Istanbul. Design and text: P. Psaltis - D. Moullou

"The Anastelosis of the Acropolis Thirty Years Later." On February 8, S. Oikonomopoulos spoke on "The Technology of the Acropolis Works" and C. Hadziaslani on "The Educational Programmes of the Acropolis". On February 22, N. Toganidis spoke on the "Anastelosis of the Parthenon" and E. Papakonstantinou-Zioti on the "Conservation of the Acropolis Monuments". On March 8, T. Tanoulas gave a talk on the "Anastelosis of the Propylaia" and F. Mallouchou-Tufano spoke on the "Anastelosis of the Erechtheion". The lecture series ended on March 15 with talks by D. Michalopoulou on the "Anastelosis of the Temple of Athena Nike" and K. Kissas on "The Recording the Ancient Members Scattered on the Acropolis".

The YSMA participated with photographs and drawings of the works accompanied by informative texts, edited by P. Psaltis and D. Moullou, in an architectural exhibition held in June 2005 by the Union Internationale d'Architecture in Constantinople. Likewise, the YSMA participated in the exhibition of the symposium, organized by the Union of Greek Archaeologists in December 2005 at Thessalonike, on archaeological works by the Ministry of Culture, funded by the 3rd Community Support Framework.

Lectures

The President of the ESMA, the Director of the YSMA and the research staff members of the Service gave lectures and reports in Greece and abroad on general or specific topics connected with the restoration works on the Acropolis.

Professor Emeritus Ch. Bouras presented the Works of the Acropolis in September 2005 in Constantinople at the Workshop on the Restoration of Monuments organized by the "Elliniki Etaireia" for the Protection of the Environment and Cultural Heritage, the Council of American Overseas Research Centres and the University of the Bosporos. At the 2nd Panhellenic Symposium on the Restoration of Ancient, Byzantine, Post-Byzantine and Modern Monuments, organized in October 2005 by the Union of Engineers of the Ministry of Culture, M. Ioannidou reported on current research and on the use of modern technology in the Acropolis works. She also presented the Acropolis works in December 2005 at the Symposium on "The Present and the Future of our Monumentts. Cultural Heritage and the 3rd Community Support Framework: the Contribution of the Archaeological Service to the Community of Citizens", organized at Thessalonike by the Union of Greek Archaeologists. In February 2006, she participated with a paper entitled "Seismic Action on the Acropolis Monuments: Improved Technical Solutions in the Restorations" in the Two-day Conference held in Athens by the European Centre for Protection and Forecasting of Earthquakes of the Council of Europe in collaboration with the Organization for Anti-seismic Design and Protection.

T. Tanoulas gave a report entitled "Observations on the clamps and dowels of the central building of the Propylaia", at the 2nd International Symposium of the Society for the Study of Ancient Greek Technology (EMAET) held in October 2005 in Athens. In June, 2006, N. Toganidis gave a lecture on the anastelosis of the Parthenon at the University of Catalonia in Barcelona.

In January 2005, L. Lambrinou gave a report at the Symposium of the Institut National du Patrimoine. She also gave a lecture entitled "New Observations about the north colonnade of the Parthenon", in March 2006, in the series of lectures of the Department of History of Architecture of the National Technical University of Athens. Lectures and reports on subjects of their own specialty were given by the civil engineers E. Toumbakari and M. Mentzini, in the framework of the Interdisciplinary Programmes of Post-graduate Studies of the National Technical University of Athens. E. Toumbakari participated in the Interdisciplinary Post-graduate Programmes "Structural Designing and Analysis of Buildings" and "The Protection of Monuments". M. Mentzini participated in the 1st Panhellenic Symposium of Mechanical-Electrical Engineers in March 2005 in Athens and gave a talk entitled "Heritage, Weathering and Conservation" at an International Symposium held in Madrid in June 2006. V. Manidaki took part in the EMAET Symposium held in Athens in October 2005 with a report on "Triangular roof-tiles on the Acropolis and roofing systems of apsidal buildings".

E. Papakonstantinou gave a talk on the conservation of the Parthenon West Frieze for the Association of Friends of the Acropolis in February 2005. The same intervention was discussed by K. Vasileiadis and G. Marakis at the 6th International Symposium on the Use of Lasers in the Conservation of Works of Art, in September 2005 in Venice.

F. Mallouchou-Tufano gave a lecture on the Acropolis works in February 2005 at the Vourou-Eutaxia Museum of the City of Athens. On June 1, 2005, she gave a report on the Works at the National Museum of Ireland in Dublin, in a public lecture organized by the Greek Embassy there. She also participated with a paper in the symposium "COST and Cultural Heritage: Crossing Borders" of the European Organization COST (Cooperation Scientific and Technological) held in Florence in October 2005. In January 2006, she reported on the Acropolis Works in a public lecture arranged by the Programme of Modern Greek Studies of the University of Michigan at Ann Arbor in the USA. In the course of her visit there, she also gave a lecture at the Kelsey Museum on "Anastelosis and Research (1975-2005): New Discoveries about the Architecture, History and Anastelosis of the Acropolis Monuments". A lecture on the same subject was given by Mrs. Mallouchou-Tufano in June 2006 at the Architectural School of the University III in Rome.

Finally, reports on the Acropolis works were given by M. Ioannidou, L. Lambrinou, E. Toumbakari and V. Manidaki at the 1st Symposium on Anastelosis, organized by the Society for Research and Promotion of the Scientific Anastelosis of Monuments (ETEPAM), held at Thessalonike in June 2006.

Presentation of the award to N. Skaris, chief marble technician of the Erechtheion Restoration Project by the ESMA President, Prof. Emeritus Ch. Bouras. Photo G. Vasilaras, March 22, 2006

Presentation of the award by the EFA to the marble technicians of the Acropolis Restoration Works on March 22, 2006. From left: E. Touloupa, N. Skaris, F. Mallouchou-Tufano, Fr. Alexopoulos, Ch. Bouras, K. Theotikos, I. Armaos, N. Toganidis, Y. Theotikos, S. Kafouros, M. Ioannidou and I. Kladios. Photo G. Vasilaras

The marble technicians of the Acropolis works honoured

On March 22, 2006, the Association of the Friends of the Acropolis (EFA) honoured the recently retired marble technicians of the Acropolis works in a ceremony full of memories and emotion held at the Centre for Acropolis Studies. The marble technicians honoured were Frantzeskos Alexopoulos, Joseph Armaos, Stelios Kaphouros, Georgios Paparidis and Yiannoulis Theotikos of the Parthenon restoration team, Kosmas Theotikos of the Propylaia restoration team and Iakovos Kladios, marble technician from the Department of Surface Conservation of the Acropolis Monuments. These marble technicians were each presented with an honourary diploma and commemorative gift by the President of the ESMA Professor Emeritus Ch. Bouras and the Vice-President of the EFA, Mrs. E. Touloupa. The Director of YSMA and civil engineer in charge of the restoration of the Propylaia, Mrs. M. Ioannidou, N. Toganidis, in charge of the Parthenon restoration, and E. Papaconstantinou-Zioti, in charge of the Conservation Department, spoke on the work and contribution of these men as top marble technicians.

Likewise, honoured at this event was the veteran marble technician, Nikos Skaris, who had been the chief foreman technician of the Restoration Work of the Erechtheion from 1979 to 1987. The General Secretary of the EFA, F. Mallouchou-Tufano, spoke about the great contribution of N. Skaris, not only in the Erechtheion work but generally in the anastelosis of ancient, Byzantine and modern monuments. Mrs. Mallouchou-Tufano read a relevant exerpt from the final report on the Erechtheion work by the late A. Papanikolaou, who was responsible for the project. Professor Emeritus Ch. Bou-ras likewise spoke about N. Skaris, remembering the collaboration they had on the restoration of the refectory at the monastery of Hosios Loukas.

The Deputy Minister of Culture, P. Tatoulis, on the Acropolis with the foreign committees for the return of the Parthenon sculpture, November 2005

Visitors

On July 20, 2005, the Deputy Minister of Culture, Mr. P. Tatoulis, visited the Acropolis and was guided around the worksites of the monuments by the engineers responsible for the works. On November 25, 2005, the Foreign Committees for the Return of the Parthenon Marbles, who had held a meeting in Athens, were accompanied by the Deputy Minister of Culture in their tour of the Acropolis works.

Finally, on April 12, 2006, the new Minister of Culture, Mr. G. Voulgarakis, visited the Propylaia work-site where he was informed about the making of the new Ionic column capital.

The Minister of Culture, G. Voulgarakis, admiring the new Ionic capital of the Propylaia. April 12, 2006

New digital applications using state-of-the-art technology on the Acropolis

On June 28, 2006, the Minister of Culture, Mr. G. Voulgarakis, visited the Parthenon worksite, where he was informed about the progress of the work by the YSMA Director M. Ioannidou and the President of ESMA, Professor Emeritus Ch. Bouras. Following this a press conference was held at the Centre for Acropolis Studies. During the conference Mr. Voulgarakis announced the new digital applications using state-of-the-art technology, to be developed by YSMA on the Acropolis during the next two years in the framework of the European Operational Programme, "Information Society". These digital applications will be of both scientific and informative-educational use. The scientific applications will include: the development of a Geographical Information System (GIS) for the Circuit Wall of the Acropolis and for the Erechtheion. The GIS will be combined with and update the already existing data base of the documentation of the Acropolis Restoration Works. Included also will be the monitoring-surveying of the entire Acropolis rock with orthophotos and 3D scanning as well as a monitoring system for following the minor movements of the Circuit Wall.

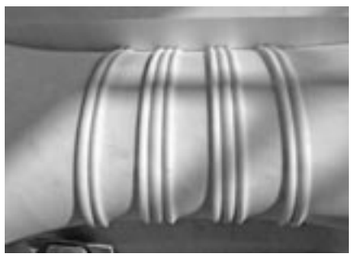
The main informative and educational application for the monuments and the works will be a virtual theatre at the New Acropolis Museum for the projection of 3D films. Included also are the installation of infokiosks in the archaeological site of the Acropolis, the digitation of the YSMA archives, the creation of an electronic library, the creation of programmes of e-learning and of educational multimedia applications.

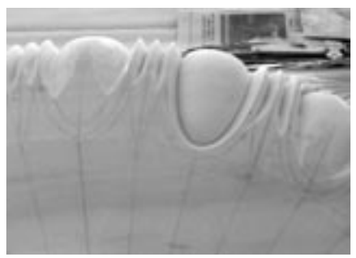
All the above applications, scientific and informative, will be entered on the Internet, through a new portal on the YSMA website, so that they are available worldwide to scholars and the general public alike.

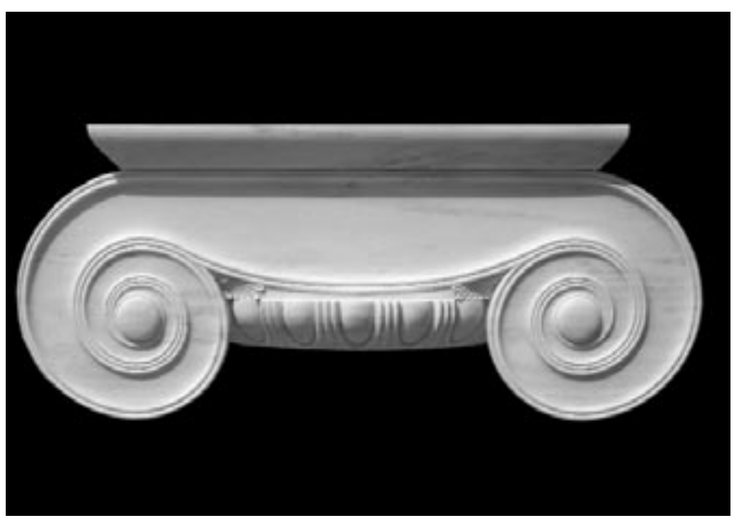
The Minister of Culture, G. Voulgarakis, announcing the new digital applications of YSMA, on June 28, 2006. At his left Ch. Bouras and D. Pantermalis. At his right M. Ioannidou and V. Vasilopoulou

Fani Mallouchou-Tufano
Archaeologist Ph.D.
Head of the YSMA Documentation Office

The successive phases of construction of the new Ionic capital of the Propylaia. Photo K. Karanasos, 2002-2003







The successive phases of construction of the new Ionic capital of the Propylaia. Photo T. Tanoulas, 2004-2006

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