

## PARTHENON RESTORATION PROJECT

N. Toganidis

Greek Ministry of Culture, Acropolis Restoration Service, 10 Polygnotou str. 10555 Athens, Greece (toganidis@gmail.com)

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### ABSTRACT:

The solid rock of the Acropolis on which it was built, the material and the quality of the construction, are most probably the reasons thanks to which, in a country with so many earthquakes. The present condition of the temple is mainly a result of human actions. With the present restoration of the Parthenon, we wish to: to conserve the structure of the monument, to correct the positions of the stones restored earlier, to complete the restored areas with original fragments laying on the ground, to replace all the chip concrete completions with marble ones, to stop the continuous action of the corroded iron, to protect the original sculptures from the pollution and finally to clean and protect the exterior surfaces of the marble. The work is carried out on the basis of studies, which in accordance with the legal and scholarly- scientific requirements, have previously been approved by the appropriate State Services, after critical evaluation. Today we have specific studies for the most areas of the monument.

On the other hand, all these years we are working hard to obtain accurate.

### INTRODUCTION

The Parthenon, the masterpiece of Classical art, was built on the Acropolis of Athens in a short period of time, between the years 447 and 438 B.C by the architects Iktinos and Kallikrates and the sculptor Pheidias who spent 5 years more, to place the sculptures in position on the pediments. The temple it was dedicated to Goddess of wisdom Athena and still exists, till our days. It was financed by public money, but mainly money that deriving from the silver mine of Lavrion



### HISTORICAL PHASES AND RESTORATIONS

The solid rock of the Acropolis on which it was built, the material and the quality of the construction, are most probably the reasons thanks to which, in a country with many earthquakes, Parthenon counts already a life of 2.444 years. The present condition of the temple is mainly a result of human actions.

It is useful to mention, the most important of them.

1. A great fire at the Roman period (267 A.C). A team of warriors from the North arrives to Athens and destroys the city. They also burn the Parthenon. All the wooden constructions, especially the huge wooden beams of the roof, caught fire. The fire lasted many days and destroyed all the inner faces of the cella, the roof and the inner faces of the exastyle colonnades of the short elevations (figure 1)



Figure 1

2. In the 6<sup>th</sup> century the Parthenon was converted into a Christian church. The entrance from the east door is cancelled and in its position the semicircular apse was built, using blocks from the east wall. Windows were opened breaking marble members. About 9-10 windows on the sidewalls and 6 on the freeze area (figure 2).



Figure 2

3. In 1687 the Venetian forces, fought the Turks at the Acropolis fortification. A bomb exploded the gunpowder, stored by the Turks inside the Parthenon. The temple was split in two and except the walls of the cella, 14 columns of the North and South side gunpowder collapsed (figure 3)



Figure 3

4. In 1802 workmen of Lord Elgin removed large sculptural ensembles, breaking the edges of the surrounding marbles. The Turks, after these damages, demolished the major part of the walls.

5. After the deliberation from the Turks, begins the first effort for restoration based on a schedule by the distinguished architect Leo von Klenze. Thus we succeed to obtain a partial restoration of the sidewalls and the erection of 2 columns on the North side.

6. The second extensive restoration effort starts in 1898-1902 and continues in 1922-1933 by the civil engineer Nikolaos Balanos.

7. In 1984 starts the third extensive restoration work. The result of the strong earthquake that took place in 1981 affects the corners of the east side and obligates the authorities to take action. Fortunately, the first study for the restoration of the Parthenon by the architect Manolis Korres, already exists. The works are under the scientific supervision of the Committee for the Conservation of the Acropolis Monuments (figure 4).



Figure 4

### THE AIMS OF THE RESTORATION PROGRAMME

With the present restoration of the Parthenon, we wish to:

- To conserve the structure of the monument,
- To correct the positions of the stones restored earlier,
- To complete the restored areas with original fragments laying on the ground,
- To replace all the chip concrete completions with marble ones (figures 5, 6),



Figure 5



Figure 6

- To stop the continuous action of the corroded iron,
- To protect the original sculptures from the pollution and finally
- To clean and protect the exterior surfaces of the marble.

### THE RULES OF THE RESTORATION

Generally the restoration works are in accordance with the 'Carte of Venice'. According to our experience, the classical monuments have specialties and according to their condition, in some cases need a different approach.

We are not changing the structural philosophy of the monument.

An approved study always exists, before any restoration work. Every 4-5 years the president of the committee for the preservation of the Acropolis monuments, organize an international meeting, where the engineers present their recent studies to the experts and take their opinion.

The works should be reversible. The type of the dry construction of this kind of temples helps. The damaged individual architectural members never can have their original strength.

We do not use chemical materials as surface preservatives, because they don't have a long-term guarantee.

In areas where we intervene, we replace the metal construction elements with titanium ones (figure 7). This material is 500 hundred times more resistant to corrosion, than iron. So practically is a non-corrosive material.



Figure 7

Titanium is also our selection for the necessary reinforcements at the individual architectural members. The collaboration of titanium with the Pentelic marble is perfect (figure 8).



Figure 8

We take off all concrete completions and we replace them with marble (figures 9, 10).



Figure 9



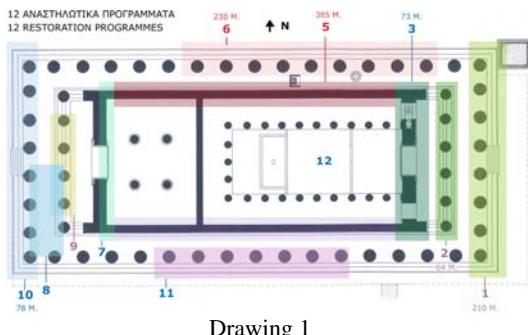
Figure 10

Any marble completion is an exact copy which matches absolutely to the broken original member. We restore members to their original positions. Fragments, which do not belong to previously restored members, remain on the ground.

### THE RESTORATION PROGRAMMES

Due to the extension of the works and the size of the intervention to the monument, the whole project is divided in 12 programs. Today some of these programs are already completed (Drawing 1).

1. EAST ELEVATION (finished 210 members)
2. EAST INNER EXASTYLE COLONADE (finished 64 members)
3. EAST WALL (73 members)
4. SOUTH WALL (partial 570 members)
5. NORTH WALL (partial 385 members)
6. NORTH ELEVATION (under construction 230 members)
7. WEST WALL (unknown)
8. PARTIAL ROOF OF THE WEST CORRIDOR (35 members)
9. WEST INNER EXASTYLE COLONADE (finished)
10. WEST ELEVATION (78 members)
11. SOUTH ELEVATION (partial 112 members)
12. FLOOR/CRIPIS (partial 36 members)



Drawing 1

During the preparation of the restoration site, we collect all marble members around the Parthenon on the Acropolis as well outside the Acropolis area. For the transportation of the marbles, we use a flexible system of metal beams and metal tubes and a lifting machine, due to the irregular soil of the area (figure 11).



Figure 11

After the installation of a crane on the concrete working floor at the interior of the Parthenon (figure 12), the restoration works started from the East elevation, as a matter of major priority. The two corners suffered from the strong earthquake of 1981. After the dismantling of the members above the corner columns, the columns were released from the pressure, relaxed on their bases. The SE column together with its capital was rotated due to the earthquakes. To correct the curvature of the eastern architraves, we designed and executed successfully the rotation of the SE corner column to its original place. The total column weight is about 60 tons. This is a completely prototype work. We replaced all the original "metopes" and statues with concrete copies and we rearranged some members to their original position. Newly founded ancient fragments were added to the pediment.

In total, we removed, conserved and replaced in position more than 300 tons of marble.



Figure 12

The next program was the restoration of the East inner hexastyle colonnade. Due to the quantities of the new marble, a lot of discussions rose between the members of the committee and affected the degree of restoration.

I think now that they have chosen the proper one among the 4 proposals. This restoration will mostly affect the final appearance of the monument.

Removing and rotating a complete column of the South elevation, executed a partial work successfully. We refer to the 5<sup>th</sup> south column (figure 13,14,15,16) which weights 50 tons and presented a strong inclination to the south. We raised the complete column some millimeters and removed it, sliding it on a concrete basis. After completing the lowest drum with new marble, the column came back to place. During the transports, we rotated the column by some centimeters. This is a prototype work too.



Figure 13

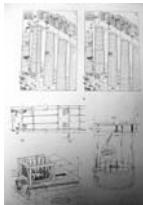


Figure 14



Figure 15



Figure 16

We continued with the long walls of the Cella (figure 17). At the beginning we noticed a wrong restoration of 20 stones at the base of the North wall. The area was corrected and completed with original material. Then we continued with the walls. It was clear that we found a wrong restoration. We took the approval to dismantle the restored areas. In this way we gathered a total of 750 stones – those dismantled and those scattered on the ground - looking for their original position. We developed a lot of techniques to approach the solution. One of them was the design of a special computer program. Finally, we approached the solution with an optimum total of 52 criteria per member, using excel tables.



Figure 17

Today we finally know the original position of 450 stones (figure 18).



Figure 18

The next program was the West inner hexastyle colonnade. We dismantled the area above the architraves and conserved the original members, but we stopped the dismantling due to our fear about the stability of the original columns, which were seriously damaged by the fire.

After many tests, which lasted for 2 years, we developed special grouts, capable to pass thru the cracks of the burned marble. Having increased the stability of the columns with this grout, we continued the dismantling and conservation of the rest of the members. Cast copies, using a special anchoring system, replaced the original sculptures of the west frieze.

In the meantime we started the program of the North Elevation which is continued till today. This is the most extend and difficult one. Most of the damages are due to the corroded iron. It is obvious that the previous restoration was done under pressure. Greece at that time was involved in a war. The money for the restoration works was not enough and the authorities accepted financial assistance by the Greek-Americans (figures 19,20,21,22).



Figure 19



Figure 20



Figure 21



Figure 22

This is the first time that we are restoring colonnades using marble completions and not concrete ones. A lot of scattered fragments are returning to their original position. It is also very important that rearranging the positions of the drums between columns succeed to the correct position for the drums and the correct height for the columns (figure 23).

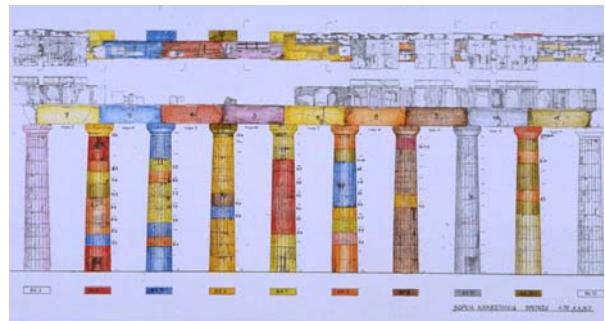


Figure 23

We estimate that by intervening to the 12 programs, we shall finally remove and restore about 1871 architectural members.

At the end of 2006 the 40% of the project will be completed. This means that we need about 15 additional years to complete the restoration of the Parthenon.

## INSTALLATION AND EQUIPMENT

The project started with the installation of a crane at the SE corner of the Acropolis. With this crane we transport all the necessary materials to and from all monuments. A small chariot moving on rails connects the crane with the site (figure 24).



Figure 24

A portal crane with a capacity of 12, 5 tons continues the transportation of the materials and the marbles along the long south side of the Parthenon. On this side the main workshops of the marble are situated, exactly on the same location as in the antiquity (figure 25).

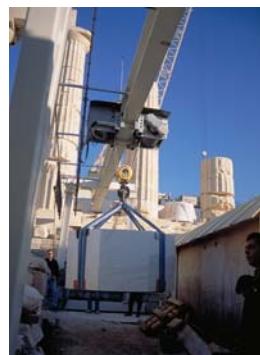


Figure 25

From the beginning of the project, a crane was installed inside the Parthenon, and recently in 2000 another one was installed on the exterior of the north side of the monument. Both cranes have special construction

specifications. Mainly about their speed. Taking into consideration that the assembly of the cranes had to be done only by manpower and not by auxiliary cranes. All cranes are visible from the city of Athens only while they are working (figure 26).



Figure 26

Two cutting machines are installed close to the workshops. One of them is our patent and is dedicated to cut the drums of the colonnade. In one week this cutting machine can complete the work of 20 flutes of the Doric drum, using 8 different cutting disks (figures 27, 28).



Figure 27



Figure 28

A third cutting machine is installed at the basis of the Acropolis hill.

In order to fix the broken marble fragments, using titanium bars and white cement with very low sulfate, we developed a system consisting of heavy tables sliding on rails. After fixing the fragments, the marble member remains for about 20 days on that table, to gain its final strength before proceeding to the next step of works. We are using 7 tables of this type with a capacity of 7-10 tons (figure 29).



Figure 29

Two mechanical copying machines, known as pantographs are installed close to the workshops. These machines are used to form the completions to the damaged original members. First an exact cast copy is produced using gypsum. Then the machines, copy this model in marble. We have not selected the installation of CNC machines, because they have appeared most recently, they are expensive and they need a highly specialized operator. In the meantime the carvers follow the same procedure as

the cutting machines for other marble members (figures 30, 31).

Recently in the Greek market appeared a huge CNC private machine. We are trying to develop collaboration with it. We have order some completions and we are checking the quality and accuracy of the final product. It is certain that this machine is very fast. It can affect the speed of the restoration works.

Today the site equipment is considered complete.



Figure 30



Figure 31

## METHODS OF WORK

The work is carried out on the basis of studies, which in accordance with the legal and scholarly - scientific requirements have previously been approved by the appropriate State Services, after critical evaluation. Today we have studies for most of the areas of the monument, except for the west elevation (which has started recently), the south elevation and the floor.

Working close to a monument, famous among others for its precision, which has been measured many times by important architects, the feeling of responsibility is heavy for the engineers involved. In order to fulfill the technical necessities of the work, the engineers create special instruments and methods. For instance:

- The study of the profiles of the columns flutes in different heights, gave us a simple method to define the missing edges. Most of them are broken or deteriorated. We constructed a special profile to define the missing edges.

- An industrial fixture is used for the measurements both of the diameters and the heights of the drums.

- The inadequacy of structural connecting elements on the original broken architectural members creates a serious problem in determining the correct member order in the construction. We have noticed that the plantation roots grown between marbles mark the neighboring members. Comparing these marks, sometimes we get the proper answer (figures 32, 33, 34, 35).



Figure 32



Figure 33



Figure 34



Figure 35

The development of the topographical instruments in the last years convinced us for their accuracy and facilitates our work concerning measurements. In some cases where access is difficult this is the only possible way. The critical point for reaching to a successful result is the proper collaboration between the architect and the topographer.

We as well use Fotogrammetry for the West Elevation. Before the Athens Olympic Games an American team proceeded to a Laser scanning of the Parthenon.

#### BENEFITS FROM THE RESTORATION

The most important is that we have an extension of the monument life, removing the causes of its problems.

The original fragments have a second chance to acquire their original position and sometimes these fragments are better preserved than the rest of the marble. Thus we obtain a better aspect of the original construction.

Joining original fragments we increase the original mass of each member and sometimes this practice gives us unknown information or understanding of the construction.

Restoring a monument you help people to obtain a better idea about the volume of the building and its values. This is sometimes difficult even for experts.

In restoring an area you meet marks that give answers, or inform you for later constructions.

Working on a restoration, you find out the difficulties of the construction itself and finally you get closer to understand the original way of the construction. Thus it is possible to learn about the position of the cranes or lifting machines originally used the organization of the working site etc.

We have an analysis of the metal connective elements studied by the National Technical University of Athens, which proves the advanced technique in the metallurgy field. This explains why exposed metal elements are not corroded till today.

The technique to cast lead (figure 36) in the carved areas of the connective metal elements it is not such a simple procedure. You realize that you need to have a strong fire very close to the working point. You have to melt the correct quantity of lead to fill the entire gap. Due to the variety of the connective elements size we get an idea about the size of the metal pot for the lead melting.



Figure 36

In this way the magnificent trip backwards continues.