State of the Art: 'Parthenon of Athens: A Challenge Throughout History'

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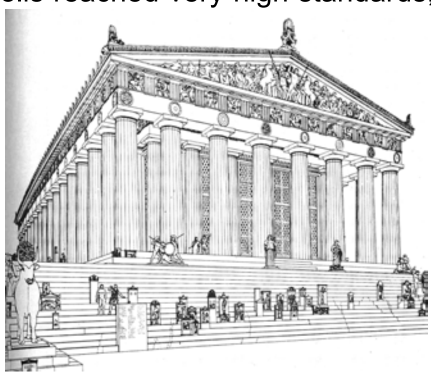
1. Introduction

1.1 History

On a rocky hill in the centre of the city of Athens, the hill of Acropolis, it stands among others, the famous temple of goddess **Athina the Virgin**, *the goddess of wisdom* for ancient Greeks. **Parthenon** is the name of the temple and it was constructed in the middle of the 5th century BC. The fine white marble used on the building was carried out in blocks from a quarry up to the Penteli Mountain, near to the city of Athens. In the 5th century, stone craftsmanship was a traditional living art and at the ambitious program of Acropolis reached very high standards, meanwhile masons came there to work from Peloponnese, the islands and even Ionia. The building combined the heavy Doric with the delicate Ionic style in many of its constructive details and was regarded as the masterpiece of its architects Ictinos and Kallicratis. The temple was constructed in a very short period of 9 years (447 - 438 BC) and since then, it attracted thousands of pilgrims throughout the centuries.



However, Parthenon was not always a shared value. Its long and tumultuous history subjected to earthquakes, a catastrophic roman fire, and Christian vandalism resulted to the structural deterioration and dispersion of its blocks. Dark centuries caused underestimation and devaluation of the monument. Its main disaster took place in 1687 during the Venetian-Turkish wars (the Morosini explosion). A cannon ball passed through the roof and blew up the central building (cella) of the monument. After this explosion, it became roofless and partly demolished. Consequently, over the last centuries the building suffered from stone and metal robbing: the neglected ruin has provided a tempting source of ready cut and dressed stone and metal of the dowels of the blocks; this pillage of the marble members contributed to the structural deterioration. Nowadays, the contemporary pollution of the Athenian atmosphere provokes severe problems on the marble skin, especially on ornaments and sculptures and the action of water in all its forms contributed to the physic-chemical deterioration of the marble matrix.

The present situation of the monument is the result of the restoration attempts since the middle of 19th century and specifically of the beginning of 20th century. A civil engineer named Balanos restored as much as he could for almost 30 years. His restoration was a severe incident for the monument. Misplacing of the members due to an aesthetic aim than an accurate and severe archaeological study and architectural research, smattering on the ancient techniques of iron metallurgy[1], difficulties of funding, and the poor conservation experience of his era were factors of the failure of this extended restoration. The techniques he used were drastic, often ignorant and unskilled, harmful for the material, though the integration of the visual impression of the monument was improved, which, in fact, was his aim.

Since the first decade after this restoration the problems were already visible. The reports for the confirmation of the destruction of architectural parts by corrosion and swelling of the iron components were brought up in 1943. Since then, small repairing works took place. Only in 1983 the **Committee for the Conservation of the Acropolis Monuments** was established and since then, new programs for a scientific conservation are going on.

1.2 The Parthenon conservation project

The contemporary **Parthenon conservation project** is mainly of a rescue nature. It has three general aims:

1. The removal of the causes of the continuing deterioration: The contemporary program 're-restores' the previous restorations; the intervention is a structural conservation. From the other hand, it tries to eliminate the harmful effects of the pollution, transporting the original sculptures in the museum and replace them by casts. The more severe attempt is the stabilization of the marble surface and the delay of the material deterioration.

2. The improvement of the conservation state of the temple: In addition to the modern causes of damage there is also a question of the unavoidable aging of any structure under natural conditions. The confrontation of the pathology of the monument in a contemporary spirit, under the international theoretical principles of a modern conservation (reversibility, authenticity, documentation…) is the main concern. Acknowledging that no intervention is harmless, preferring though, to act than to hesitate, the main concept of this intervention is to preserve as much as possible. The aim is not a drastic change of the image of the building, but a qualitative alteration on the conservation techniques.

3. The improvement of the value of the monument: Under such principles the intervention aims to improve the value of the monument itself, not only from the technical point of view. The improvement of the condition of the building promotes its significance as ***a historical and scientific document, a work of art and a functioning building*** *(as an open-air museum)*[2].

2. Pathology

2.1 Structural Deterioration

2.1.1 The fracturing of the Parthenon blocks

Only a few of the blocks of the temple preserve their original form. Most of them were fractured in various ways. After verification that the form of fracture of a block is depending on a certain cause, there are only two, clearly distinctive, forms of fracturing[3]:

A. Primary thermic fracture leads to conflagration (rapidly or slowly). With the term thermic fracture of a block we mean the fracture caused by a

[1] Greeks knew how to treat metal of high standards especially wrought iron, subjecting it to heat treatment processes of successive cold and hot puddling, which made a material like steel, with additional strength and toughness, resistant to the corrosion.

[2] H. Bouras, M. Korres: Study for the restoration of the Parthenon, Athens 1989, p.690.

[3] K. Zambas: 'Structural interventions on the Acropolis monuments', Acropolis Restoration, Academy Editions, London, 1994, p 107.

sudden increase of the temperature around a block. It is a short-time event and explosive crack, or bang accompanies it. This tremendous overheating occurred during one or more **great fires** in the past and the consequent surface disintegration by the sudden temperature changes. Thermic fracture corresponds to the geological phenomenon of exfoliation of the so-called spheroid fracture. The expansion and the bowing of the exterior parts of the block tend to detach the heated zone from the internal mass of the block, causing the fracture.

The study of the thermic damage allows us to distinguish the harm done by the ancient fire of the roman period from that done by the later ones. This damage constitutes an indirect indication of the kind and position, not only of the wooden parts, but even of many stone parts, which are not preserved now. That fire destroyed all the interior surfaces of the cella. Many parts cracked by thermic fracturing and immediately collapsed and others, though cracked, remained in position as they were interlocked with the blocks next to them, till an apparently insignificant cause provoked their collapse (a storm, vibrations, small earthquakes).

B. Load fracture can be distinguished to **static and dynamic fracture** due to several causes.

1. **Static fracture:**

- swelling of the iron connective components in the blocks due to the corrosion,
- blasting, overstrain on connecting components,
- destructive unequal load distribution due to various geometrical modifications,
- frost

2. **Dynamic or impact fracture:**

- vandalism
- extensive hammering with heavy implements, in order to make smaller pieces,
- detonation of a gunpowder charge in holes of some of the blocks in order to break them,
- bombardment and violent impact by shells during military undertakings,
- crashing of the blocks during earthquakes,
- impact collapse[1].
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2.1.2 Damage caused by the swelling of structural iron and connecting components

Balanos' restoration (1894-1932) is known by its aesthetic results as well as for the excessive use of iron components. There was an agreement as to the application of 'ancient methods', as the scientific committee decided. Thus, iron clamps were used covered by lead in the same ancient cuttings on the marble blocks.

Unfortunately, not only the proportions iron-lead and the quality of the metal clamps were not equal to the ancient ones, but also the condition of the joints of the reconstructed blocks was no perfect, unlike to the original construction. As the metal elements were insulated against the surrounding and the damp, the rainwater could easily penetrate the joints and corrupt the iron clamps. The oxidization and expansion of the iron supporting and connecting elements applies to almost all the metal components used in Balanos' restoration, and also to those ancient clamps and dowels which were left in adverse conditions as a result of the Morosini explosion. The expansion of the rusted elements causes splitting and scaling of the surrounding marble and even completely crumbling of the block. Large cracks on the blocks due to large iron clamps and beams

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[1] H. Bouras, M. Korres: Study for the restoration of the Parthenon, Athens 1989, p.686.

can be observed to every part of the monument. There is also disintegration and crumbling of the reinforcement of the cement additions and coverings used by Balanos, especially at the columns of north side.

2.2 Surface deterioration

The **marble matrix-veins,** other inclusions and its foliation- are the primary reason for its certain deterioration. The term foliation indicates a final orientation of the layers of the metamorphic rock. It was observed through the different wear of the surface layers that the erosion of the surface follows the foliation. The different erosion of the aluminosilicate veins has contributed to greater humidity retention, which in turn favors biological growth. As a result, both the veins and large cracks have been filled repeatedly with materials (Meyer mortar), which have contributed to the deterioration of the marble.

The free flow of rainwater through the superstructure is particularly harmful. The water itself expands when it freezes, with damaging effects on the strength and appearance of the stone. The distinctive poor porosity of the pentelic marble and the limited period of under zero temperatures in Athens make this kind of deterioration insignificant. Anyway, the large number of cracks due to the vivid history of the building may produce conditions for frost to occur in the cracks.

Due to the exposure to different causes a loss of strength and continuity of marble has occurred. The continuous and the isolated action of mechanic, chemical and biological causes combined to the microclimate of the environment and the microstructure of marble, are causing the following shape of deterioration[1]:

Mechanic Causes:

a. **Cracking:** interruption of the integrity of marble by a network of fissuring, which can link to deeper cracking, or breakaway and fall of small or larger marble pieces.

b. **Exfoliation:** formation of parallel to the surface fragments and frequently danger of falling of groating marble pieces.

c. **Flaking:** formation of small fragments with loose mechanical strength.

Chemical Causes: Weathering

d. **Disaggregation (sugaring):** the typical ‘baked marble’ decay form, loose of coherence of the crystals of the surface and consequence in depth diffraction grating of fissuring.

e. **Gypsum concentration:** In exposed areas, due to **the sulphatation**, *the erosion of the acid rainwater* (acid attack and repeated crystallization of soluble salts), gypsum tends to dissolve exposing a new marble surface which is more prone to deterioration. Thus, the whiter washed areas have already lost their original surface finish (patina) and became roughened. The gypsum layer is thinner in areas where the monochromatic layers are preserved.

f. **Differential decay**: uneven reduction of the surface of marble, due to a geological heterogeneous texture of the material. The pentelic marble contains non-carbonate confinements, which are creating a level of discontinuity. Thus, these elements have a different way of decay (faster or slower) creating cavities or snags. It has been observed mostly on the south side.

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[1] A.Galanos, Y. Doganis: ‘The west frieze of the Parthenon – Conservation Report’, *Study for the conservation of the Parthenon,* Athens, 1994, p.184.

g. **Pitting (alveolar decay):** Appearance of small cylindrical, hemispheric pits in group or isolated, especially on the north side (north corrosion).

h. **Dark deposits**: Soot and loose particles are deposited on protected areas. They show a brownish or grayish soiling or shade.

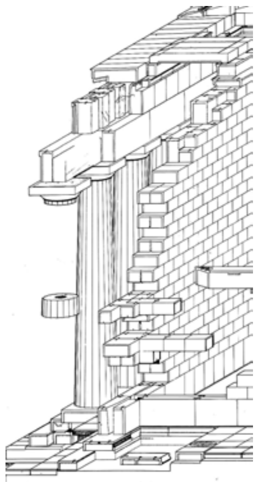
i. **Black crust:** compact black deposits occurred at the unwashed areas is the worst stage of black crust, frequently in a dendritic formation. It is covering the 70 – 80 % of the horizontal underneath freestanding areas and reaches a depth 1,3 cm.

j. **Blistering:** this kind of phenomenon probably linked to a former surface treatment.

Biological Causes:

k. **Biodeterioration:** it is observed a microbiological growth (algae, mosses and fungi) on the surface of the marble and especially in the cracks and fissures (chasmoendolithic algae, and cyanobacteria). Bird droppings also are an unsolved problem (*Pigeons are using now the scaffolding, meaning they are everywhere around the temple).*

3. Intervention



Since 1983 the Conservation Committee and the Conservation team work together on the initial archaeological questions of the anastylosis and the architectural research for an appropriate treatment of the monument. There are 12 intervention programmes concerning different problematic parts of the Parthenon. Some of them are already completed, but still there is a long way in front of us.

The intervention started on the **East Peristasis**, which was completed in 1991, continued to the south side and the repair of the **Fifth Column** and its superstructure. The salvage work concerning the transportation of the existing sculptures to the museum began in 1992 till 1993. Before the removal of the existing pieces of the **west Panathenaic Frieze** out of the monument a serious preparation work of surface consolidation took place and the consolidation continuous in the workshop. From 1997 to 1999 there was the program of the consolidation work on the six columns of the **West Prostasis** (west inner colonnade, Opisthonaos). The particularity of this intervention was that the columns were untouched by any modern restoration, so they had to be conserved *in situ*, without being dismantled. The other concern was that the cracks of each drum of the columns should be grouted and consolidated separately, since each drum had to conserve its individuality.

In 1998 the program of the **East Prostasis** (east inner colonnade, Pronaos) started concerning the re-erection of the six columns of the entrance of the inner building (cella) of the temple. This time, most of the pieces used in the anastylosis were scattered fragments, which were identified and reintegrated to the original location into the building fabric. This program is going to be completed this year. The **North Peristasis** program and the program of the **Entablature of West Prostasis** started last year and they are going to be completed in 3 years.

Salvage work has also progressed along the length of the **Side Walls** of the cella. Some three hundred stones that had been repositioned at random in 1842-44 were dismantled and conserved. The wall program considers the correct reposition of the blocks and matching of 400 hundred more which were scattered around This study is almost completed.

Today, the workforce, for the restoration project of the Parthenon, includes almost 40 specialist marble masons, 6 architects, 2 civil engineers, 3 draftsmen, 12 surface conservators and 20 supporting personnel.

3.1 Structural conservation

Subject of the **study** of the structural conservation is how critical a certain damage is, each architectural member is been examined in an individual manner, but at the same time the study takes in consideration the whole area where the member is and where the intervention is taking place. For the planning there are theoretical aspects according to the international charters, as the Charter of Venice, which are posing the theoretical background and the principles the most appropriate for an *ancient classic* building.

The principles of **respect of authenticity** and **maintenance of the autonomy of each member** of the structure institute reconciliation to the structural system of the building. This is the best choice also for structural reasons. As the intervention is limited only to the most problematic parts, a possible change of the structural system could provoke an uncertain behavior in the case of an earthquake. Also, the original structural capacity of the members of the building is the upper limit of our reinforcement.

The scepticism on the anastylosis methods and the possibility of a necessity of a new intervention in the future, due to a possible misbehavior of a restored part, leads to the acceptance of the **principle of reversibility,** in addition to the rest conservation ethics[1].

The steps followed at the structural intervention are:

1. **Dismantling** of the previously restored sections by Balanos, and transportation of the architectural members to the workshop.
2. **Removal** of any cement additions, the iron or bronze clamps, dowels and beams out of the original member.
3. **The documentation** of each member will provide evidence for its original position on the building. Thorough measurements of the members are a serious aspect of the research, since the previous restoration misplaced most of the restored members, which were scattering on the ground since then. Every member, having small differences from each other of the same type, keeps a unique place on the building.
4. **Reparation of the monolithic of the blocks:** The re-fitting of the broken fragments of the ancient members is done with fine Portland cement using ties and rods made of titanium, a metal that behaves similarly to iron, though with great resistance to corrosion.

   When a block misses parts of its original mass, new addition of fresh marble is added to complete the form. All the additions are of pentelic white marble from a modern quarry. The system followed is, at the beginning, the extraction of a **gypsum mould** of the crashed surface and, after, the transformation to the new infill using a **sculptural pointing devises** to match exactly the fragment surface of the ancient part. The work is done by the traditional way of carving by hand. There is, also, a system of mechanical transformation from the mould to the stone, but only for small pieces, though a **laser scanner** solution is now investigated for larger pieces.

   The joining of the fragments (ancient-new addition) is achieved with white **Portland cement** and **rods reinforcement** of threaded titanium cut to required length. The drilling and injection of holes to receive cement and reinforcement requires great care and

[1] K. Zambas: 'Structural interventions on the Acropolis monuments', *Acropolis Restoration,* Academy Editions, London, 1994, p.108.

thoughtful preparation of the site. The final surface of the new part is carved by hand in a similar way to the ancient technique.

5. **Re-erection**: The blocks are reintegrated into the building fabric, as the study of the certain part indicates. The joining of the independent architectural members is done with ties and clamps of titanium using the ancient tie-cuttings and a filling/covering with a special mixture cement mortar with pigments. The dimensions of both the clamps and the reinforcement rods subjected to the general rule, to which, in the case of excessive stress the clamps should only break, and not the marble block. An artificial coloured patina is required on the new marble infills, in order to decrease the impression of chromatic alteration between new and ancient marble.

3.2 Surface conservation

In addition to anastylosis the surface conservation is a severe and urgent operation, which has two aims:

A. the **consolidation** of the small cracks and fissures and the **stabilization** of the marble skin:

The methods followed are:

- removal of the previous pointing of the joints of the blocks,
- preconsolidation,
- re-attachment of the small fragments and flakes,
- grouting of interior voids and cracks,
- pointing of cracks and aluminosilicate veins which have been previously grouted,
- consolidation of the surface.

The use of polymers is not acceptable for the conservation of Acropolis monuments, as their long-term behavior is more or less nebulous, so the materials used in the conservation are inorganic.

For the preconsolidation of the surface **lime water spraying** (with the addition of 6% of calcium carbonate) is used for the friable areas. Also, the 'facing' of these areas is done with Japanese paper, gause, methylcellulose adhesive and 2% addition of bioxide.

Mortars used today on the building are based on **white Portland cement** (low in sulphates) and **lime**. **Quartz sand** has been selected as an aggregate with resistance to acid attack. The mortar also includes an 6% addition of calcium carbonate, for faster carbonation of the material and **iron oxides** as pigments. In some specific cases, a natural hydraulic lime mortal with marble powder as the aggregate is used.

Eroded areas are consolidated with lime water spraying in a frequent repeated way.

In structural joining of large marble blocks, a cement mortar is adequate, but in cases where a weaker mortar is needed, a cement-lime mixture is more appropriate.

B. the **safe cleaning of the surface** and the prevention of the increase of the disintegration of the material.

The stalactite formation of the black crust not only alters the original form of the members, but also discolors them. The revealing of the mechanism of sulfation automatically prohibits the use of any washing agent such as water or steam and any mechanical method of cleaning.

The removal methods are:

- **Absorbing clays** for loosed deposits, soot and metal oxides, like sepiolite poultice of water saturated in sulphates.

- **Microblasting** under a microscope: it is a dry, controllable method, which leaves no byproducts on the stone. It is used still in experimental way.

-**Laser cleaning** of the black crust has progressed a great deal, and it is an attractive case, which has been approved, still for experimental cases, just few months ago. It seems that, by this cleaning, both the gypsum layer and the natural patina of the marble are preserved, without discoloration. Another advantage of the method is that especially deteriorated areas can be cleaned without preconsolidation to be needed. It is a controllable, dry, albeit slow method, which does not leave byproducts on the marble[1].

4. Epilogue

In all the, *in situ,* preserved parts of the Parthenon, the **structural accuracy** is astonishing, the peculiarity is witting, the **adhesion of the architectural members** is perfect, the **sculptural accomplishment** up to the smallest detail of each part of the building is extraordinary. This ancient structural achievement is maybe the best interpretation of the, so-called by the ancients, *Harmonia.*

We realize that we are dealing with a tremendous task, trying to rescue this monument, beat the natural process of aging and the unavoidable decay of any structure. I think though, we all agree that we owe to try to submit the chance we had to admire the beauty of this masterpiece to our descendants._

[1] A.Galanos, Y. Doganis: 'The west frieze of the Parthenon – Conservation Report', *Study for the conservation of the Parthenon,* vol. 3c*,* Athens, 1994, p.186.