CONDITION ASSESSMENT OF THE MARBLE FUNERARY MONUMENT TO ANTONIO CANOVA IN THE BASILICA DEI FRARI IN VENICE: A NEW MECHANISM FOR MARBLE DECAY

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Abstract

In recent decades, the funerary monument dedicated to Antonio Canova in the Basilica dei Frari has suffered serious decay phenomena. The sharp increase in deterioration processes observed in different areas has caused the loss of large areas of marble detail from the surface of the statues. As there is an urgent need to stop the increasing rate of marble decay the authorities responsible for protection of the cultural and monumental heritage decided to start a comprehensive survey to identify the causes of alteration. Macroscopic observation of the marble surface showed different forms of alteration as well as the massive presence of salt efflorescence. A number of different types of alteration were observed macroscopically and in order to assess the deterioration mechanisms samples were taken from the decayed areas. ESEM observations together with EDS analyses have enabled us to explain the stages, each corresponding to different features, through which exfoliation and lamination of surface scales is taking place.

A survey of the moisture content of the masonry structure under the steps of the monument has established that moisture from the ground is being transmitted by direct contact of the brick core with the marble. As a consequence capillary migration of water transports salt solution onto the marble surface, where it forms droplets.

In order to stop the rapidly increasing rate of decay, observed over the last ten years, there is an urgent need for action to prevent any further capillary rising damp by inserting a damp proof course and at the same time to detach the statues from the base in order to remove the salts embedded in the marble.

Keywords: monuments’ condition, soluble salts, marble decay

1. Introduction

Given the unusual and serious problems of decay that have for some time affected the Cenotaph of Antonio Canova in the Basilica dei Frari in Venice, the Superintendency for the Architectural and Landscape Heritage of Venice decided to undertake a study of its state of conservation in an attempt to understand the nature of the problems and their possible underlying causes (Amoroso and Fassina, 1983). The investigations, carried out between 2009 and 2011, were designed to provide essential preliminary information prior to planning and initiating the necessary and urgent restoration work. This stage was financed by the English Venice in Peril Fund in the
framework of the UNESCO-Private Committees Programme for the Safeguarding of Venice. The monumental cenotaph of Antonio Canova was built in 1827 inside the Basilica dei Frari, against the wall of the south aisle, immediately after the first altar. On the death of Canova in 1822, his friend and biographer, Count Leopoldo Cicognara, then president of the Academy of Venice, organized a Europe-wide public subscription to collect funds for the erection of a funerary monument to celebrate the illustrious artist and to provide a final resting place for his heart. The execution of the work was assigned only to pupils of the Maestro and his assistants. They followed, almost without change, the project that Canova had designed for a monument to Titian; this was never executed but the design was later adapted for the tomb of Maria Cristina of Austria in the Augustinian Church in Vienna.

The overall plan of the Canova cenotaph is very similar to that of the Viennese version, though twice as big (Fig. 1). In execution and the choice of materials and subjects, however, the Venetian work makes clear reference to many other works by Canova, who represented the artistic culture of this period and provided a highly distinctive cultural model. So it is not only the use of the pyramid shape, sculpted by Vincenzo Fadiga, but also the theatrical arrangement of the melancholy figures in the sad procession that underline the very close relationship between this and Canova’s other funerary monuments, which were so innovative and original compared with the tired culture of the period. On the right, two young women representing Painting and Architecture, sculpted by Luigi Zandomeneghi climb towards the central door, deliberately left half open to suggest the passage to the afterlife; together they bear a garland of flowers to offer to the deceased.

![Fig. 1. The cenotaph to Antonio Canova](image)

A young man with a torch stands between them and another young woman, veiled and moving slowly, her head bowed, holding the urn of ashes. This figure by Bartolomeo Ferrari represents Sculpture, Canova’s favourite of all the arts and the one
destined to hold his ashes. The group on the left is composed of two figures sleeping. Both are, in fact, images of the eternal sleep of death, which is celebrated in the monument. One is a great winged Lion, the emblematic symbol of the Strength that must assist the deceased, but also of Venice, a city much loved by Canova; the lion is by Rinaldo Rinaldi, who also sculpted the naked boys in the procession on the right. A Sleeping genius, also naked and winged, a young man with extremely soft and sensual features, was the work of Giovanni Fabris. An effigy of Canova, by Luigi Bosa, is the subject of a large medallion supported by two female figures in flight, in the centre of the pyramid, above the door.

2. Decay forms

The main aim of this paper is to assess whether there is a relationship between the decay observed and the presence of salt efflorescences and secondarily to ascertain the source of the salts and consequently to propose a method of stopping any further cause of alteration.

In recent decades the funerary monument dedicated to Antonio Canova in the Basilica dei Frari has suffered serious decay phenomena. The sharp increase in deterioration processes observed in different areas has caused the loss of large areas of marble detail from the surface of the statues.

Fig. 2,3. Details of exfoliation on the Sleeping Genius and on the womens’ dresses

Macroscopic observation of the frequent formation of droplets on some areas of the group of sculptures led the authorities responsible for their conservation to plan a survey to investigate the microclimatic conditions that could be responsible for the phenomena observed. Measurements of surface temperature on different areas of the statues’ surfaces have revealed the slow change of surface temperature with respect to
air temperature fluctuations (Camuffo et al. 1987, Camuffo, 1988). The thinner parts of statues such as arms, legs and hands show a faster change of surface temperature in relation to sudden air temperature fluctuations. The base of the pyramid, in contact with the church floor, has a constant higher temperature due to heat transfer from the soil. It was surprising that the areas where droplets form are not very damaged whereas some other parts have suffered serious damage.

Many areas, like the chest of the Sleeping Genius or the robes of the women (Figs. 2, 3), show the presence of salt crystals associated with a marked exfoliation of thin marble layers, while droplets are present on the face of the Sleeping Genius, which is undamaged.

Fig. 4. Droplets visible on the marble surfaces

Previous microclimatic studies on the monuments’ established that the formation of droplets due to condensation processes is not very frequent and the mechanism of marble deterioration is taking place inwards from the outside and the marble exfoliation is occurring with an increase in volume without any phase changes from calcite to calcite. According to these previous studies, biological colonization is responsible for the increase in volume which is detaching thin marble layers from the substratum.

As this biological mechanism seemed not to be reliable the project directors asked for the reliability of this hypothesis to be verified. Our diagnostic plan was designed to identify the causes of alteration taking into account the construction techniques used. In fact many problems are probably related to the structure, which is taking all the weight of the marble blocks of the steps, the pyramid and the sculptures. As the structure is closely related to the moisture in the ground it was also decided to investigate the water content in order to evaluate if the capillary rise is influencing the presence of water droplets on the marble surface and if it is in some way related to the presence of efflorescences.
3. Sampling and analytical methods

As we were not convinced that the marked decay observed was ascribable to biological action further samples from decayed areas were taken following the CEN TC 346 European guidelines: these were micro-flake samples, representative of the different forms of decay observed. Bulk samples for the measurement of moisture and salt content were also taken for investigations into the rising damp process.

An optical microscope (OM) and an environmental scanning electron microscope equipped with a dispersive energy micro-analyzer (ESEM-EDS) were used for thin and cross section observation. The characterization of bulk samples was performed by X-ray diffraction (XRD), while X-ray fluorescence (XRF) with WDS sequential spectrometry was used for the elemental composition analysis. Anion concentrations such as sulphates, nitrates, chlorides and oxalates were measured by ion chromatography (IC). The morphological characteristics of micro-flake samples were observed by examining 3D samples using secondary electrons of scanning electron microscopy (SEM). The presence of organic compounds was determined by infrared spectroscopy (FT-IR).

4. Results
4.1 Moisture content and constructional characteristics of the supporting structure

The supporting structure was investigated by the use of georadar and by drilling cores into the base to a depth of 2 metres. Georadar measurements established that the three steps are formed of marble blocks (35 cm thick) and the supporting structure consists of brick masonry. Georadar measurements also emphasized high water content in the supporting brick structure.

The moisture content profile from ground level up to the base of the pyramid was measured by drilling cores at different heights and depths. The water content is close to 25% up to a height of 80 cm and it slowly decreases to 18-20% up to 140 cm. At the base of the door (190 cm. from ground level), the water content decreases to 8.5% (Fig. 5). The data obtained indicated that the brick supporting structure is completely saturated with water and as there is no discontinuity between the brick structure and the marble blocks or statues the capillary rising damp phenomenon is causing the migration of salts from the brick structure towards the external surfaces of the marble blocks and statues.
4.2 Macroscopic features on the marble surfaces

Macroscopic observation of the marble surface showed different forms of alteration frequently associated with massive salt efflorescences. The following types of alteration have been observed:

- smooth dark grey areas in good condition (type a-fig 6),
- rough whitish grey areas showing a slight erosion without any crystal deposit (type b),
- areas with exfoliation or lamination of thin marble layers which are becoming detached from the substratum and with the formation of salt crystal powdering on the sound substratum (type c).
- red coloured round shaped areas.

4.2.1 Type a: smooth dark grey areas

In order to explain the different types of alteration observed, the crystal structure of a sample of sound material was analyzed by thin and cross section. Sound marble shows a compact structure and no inter-crystalline detachment. Also visible on the external surface is a wax deposit due to maintenance treatment (Fig. 6c).

4.2.2 Type b: slightly eroded surface

Samples taken from slightly eroded areas generally show a colour change from grey to white due to the lower density of the outer marble surface layer (fig. 7). In cross section the presence of some inter-granular micro-cracks is ascribed to the crystallization of sodium chloride: this is the initial phase of decay in which crystals detach from each other and the structure becomes less compact and marble appears brighter (lower density).
Fig. 7. a) whitish slightly eroded surface. b) cross section at ESEM showing micro-cracks at an initial stage. c) cross section at ESEM showing more numerous micro-cracks caused by sodium chloride crystallization. d) X ray map distribution of sulphur showing gypsum on the surface and its penetration inside micro-cracks

The marble surface observed perpendicularly (fig. 8) shows a heterogeneous feature with dark areas (wax presence) alternating with white areas presenting some micro-cracks. The same scale observed from the back which, before sampling, was in contact with the sound substratum, shows many micro-cracks associated with sodium chloride crystals.

Fig. 8. a) sample location. b) external surface of the marble scale (wax is visible in the dark areas). c) back side of the marble scale shows a marked decohesion of grain crystals. d) sodium chloride crystal

4.2.3 Type c. areas with multilayer exfoliation of marble

In order to validate the biological colonization mechanism proposed by previous researchers a sample presenting the exfoliation phenomenon was taken from the same location. Visual macroscopic examination of the thin marble scale enabled six levels of progressive exfoliation to be identified (fig. 9). SEM observation shows the presence of sodium chloride crystals between different scales; these are responsible for the detachment. Microanalysis also emphasizes the presence of potassium chloride and gypsum.

Fig. 9. a) sample location. b) three layers from outside. c) three more layers inwards
By analyzing the single layers we have observed that the different levels alternately feature calcite crystals with marked micro-fissures and small sulphur- and chloride-rich crystals without a regular shape, thus indicating a secondary gypsum formation (Fassina, 1978, 1994, 1995)) together with primary sodium chloride crystals.

5. Conclusions

The same sample was also observed in cross section (about 2 mm thick) and it is possible to distinguish up to eleven discontinuity levels instead of the six observed by the naked eye. This seems to suggest a completely different mechanism of marble decay from the one usually considered for outdoor monuments in the Venetian environment (Fassina, 1993a, 1993b, Sabbioni 1995)). In fact, up to now the generally accepted mechanism of marble decay is the following: severely damage is caused by the different texture of calcite grains which, after a certain time, allows water to penetrate into intergranular spaces, and favours the reaction of acid sulphur-bearing solutions which form gypsum around the grains. This is the starting point from which a progressive attack of calcite marble takes place. Gypsum crystals found in the intergranular spaces can be ascribed to different mechanisms:

i) primary formation due to the penetration of sulphuric acid solution coming from the atmosphere and the subsequent reaction with calcite crystals;

ii) secondary formation due to the penetration of gypsum previously formed in the atmosphere;

iii) gypsum, firstly formed on the surface, can penetrate inside the marble during the wetting phase;
The presence of gypsum crystals inside the marble can cause mechanical stresses inside the pores during the drying phase because crystallization causes expansion. To summarize, the mechanism of marble decay takes place in different steps (Fassina 2002):

i) exposure to natural atmospheric thermal changes leading to a long-term effect of crystal de-cohesion (*physical alteration*);

ii) penetration of sulphur-bearing solution into intergranular spaces (previously formed by thermal changes) and subsequent transformation of calcium carbonate into gypsum (*chemical alteration*);

iii) gypsum crystallization inside the pores due to the drying phase causes expansion and consequently mechanical stresses (*mechanical alteration*).

The first step is very slow and the time-scale for its occurrence is a hundred years. The second and third steps became important from the middle of the last century with an exponential relationship between time and damage effects. The time-scale for damage has been considerably reduced to a few decades.

The mechanism of marble deterioration that we are now proposing for marble artworks located in an indoor environment is more strongly influenced by capillary rising damp and the consequent salt migration of lagoon water than the outdoor influence of atmospheric sulphur-bearing solutions.

The ESEM observations and the microanalysis by EDS suggest that the mechanism of crystal decohesion and the consequent sugaring of calcite structure may have a different pathway which is manifesting as an exfoliation pattern that is generally common for sedimentary stone and follows the sedimentation layers, which are almost (more or less) parallel. Crystal decohesion, which was previously the first step in alteration, progresses forming a discontinuity line more or less parallel to the outside surface, a process that explains the layer exfoliation which is proceeding inwards from the outside layer of marble. We can define the process as multilayer exfoliation.
Fig. 11. The black layer (119 μm thick) on the outside surface is the wax treatment, the first layer is 480 μm thick and all the subsequent layers are about 300 μm. The total thickness is 3 mm.

To explain this unusual mechanism for marble decay it is important to take into account the intimate structure of marble and the process of its formation in geological times. Marble is a metamorphic rock with a granoblastic structure constituted mainly by different calcite grain size (60 a 800 μm), with an isotropic structure. Sometimes in unpure marble some veins, contaminated by silicatic or pyrite minerals, contained calcite crystals, with an isotropic structure, which are extended along a preferential orientation which was in turn generated by the metamorphic process.

These veins are responsible of preferential migration, both vertically and horizontally of lagoon water by capillarity. The source of salt solution is the brick supporting structure which is completely saturated with lagoon water. SEM observation showed a salt accumulation in these layers in a similar way of a sedimentary stone and the final result is an exfoliation process which is taking place at first on the external surface layer and successively is recessing in the internal layers as it clearly visible in fig. 11. The damage features actually observed showed an irregular front of the maximum height of the rising damp due to the orientation of these veins (horizontally or vertically oriented with respect to outside external surface) of the marble blocks of the step.

References


