THE PRAETORIAN GATES IN AOSTA. EMERGENCY, RESTORATION WORK AND DIAGNOSTICS

L. APPOLONIA°, E. PECCHIONI*, S. MIGLIORINI°
° Soprintendenza per i Beni Culturali e Ambientali, Aosta
* Univ. Firenze, Dipartimento di Scienze della Terra, Firenze

Abstract
The needs of the various disciplines that deal with conservation come face to face during the planning of restoration work. We can easily apply the principle of « every action causes a reaction » to the conservation sector. Diagnostics can become an excellent means of solving doubts concerning ways of operating. There are often several possibilities, but we have deemed it utmost to stress the importance of conservation and of a possible future complete recovery of the monument's material even despite its historic image. The present case shows how the analytical data has unequivocally pointed to the type of treatment to be carried out. The acquisition and study of previous work and its influence on the monument's conservation are described below and help us to understand how thinking must not be tried to stereotypes which sometimes do not correspond to reality.

1. INTRODUCTION

When evaluating conservation priorities for a monument, the planning side of the restoration work should be of great import. Information about the materials and decay causes take on an importance which increases according to the general situation in which the monument stands. The monuments in the roman town Augusta Prætoria (now called Aosta) have different characteristics in the present urban structure of the city. Two of the three most valuable monuments are now extirpated by the direct contact with daily traffic. The third, that is the Prætorian Gate, once the city's main access point for both people and goods, is still in active use.

The type of considerations to be made and work to be carried out on the various monuments have a different value according to the present use made of the monuments ; thus in the case of the Prætorian Gate this forces us to make quick, specific choices. The present state of conservation of the restoration work carried out in the 1930's has allowed us to evaluate both the materials used and the environmental conditions during the last 60 years, and consequently restoration procedures that could be adopted today.

2. THE MONUMENT

The Prætorian Gate is made up of two arches each with three barrel-vaults, the widest being the central one. The arches have a north-south direction with a medieval tower to the north and buildings to the south. The tower to the north is outcome of making the Roman structure higher, whilst to the south the present buildings are more or less the same size as the original ones. The pavement level has changed as the road level was raised by about 3 metres. An excavation carried out in the 1930's to south in order to show the original size, has created a ditch with particular microclimatic problems which will be dealt with further on when describing alterations. The present road situation consists in a controlled-traffic area : the traffic being mostly pedestrian except for the vehicles which are necessary to the trading activities present in the two roads that lead to the Prætorian Gate. This is so mainly for the central barrel-vault whilst the one to the north is only used by pedestrians and the one to the south cannot be used because of the above mentioned ditch.

3. THE MATERIALS

Pudding-stone blocks were used to build three of the four sides of the arches and the barrel-vaults, whilst the eastern side of the city's entrance arch is made up of travertin blocks which are at present only partly covered by the marble slabs which decorated them. The grey veined marble called Aymaville Bardiglio, after the locality where it is quarried, is surmounted by a frieze made of white marble from Carrara [1] as the isotopic tests have shown. The pudding-stone is a conglomerate of fluvial origin [2], the aggregate being quite irregular and not homogeneous. The travertin also comes from the same region even if the breccia aspect and the typology of the included fragments makes one think of a coastal deposit rather than a valley bed quarry [2].

4. THE CONSERVATION STATE

The monument is still part of the city's road system as described above ; thus, considering its use, its conservation state is of great importance. The most worrying aspects regard the falling of small fragments and the pudding-stone pebbles let loose by the conglomerate binder. The fact that the monument is used by pedestrians, even if not in great numbers, is worrying as their safety must be guarenteed.

The stone's brittleness is caused by various degradation situations summed together. As was expected, the surfaces are partially washed away and partially covered by black dust deposits. Nevertheless we believe that these two factors are not sufficient to explain the type of decay present. The most damaged surfaces are without doubt the pudding-stone ones, whilst the bardiglio with exfoliation due to the schistose phases with black incrustation in the most covered parts is in a less « dangerous » situation. As the travertin surfaces are only covered by a superficial black deposit they appear to be without doubt the soundest.

It seem evident that the most important conservation problems are thus only relevant to the parts made of pudding-stone.

The environmental conditions where the arches are to be found differ in exposure and vary according to the area. We also have to consider the fact that early century conservation work has in part modified the exposure of some sides and the air mass movement around the structures. The alpine climate is characterized as having little humidity, a great difference in temperature between day and night and between the sun-exposed areas and the ones in the shade. This situation creates considerable thermic gradients on the stones' surface, for example in months such as February an increase in surface temperature of about 35 °C due to exposure to direct sunlight was registered in a few hours and it was noted that passing shadows can make the temperature fall as much as 10 °C [2] in a few minutes. Only the upper parts of the monument facing east are exposed to direct sunlight even if only partially and limitedly both in summer and in the early hours of the day. The parts facing westward have a more diffused irradiation and above all for the most westerly arch, almost complete. The irradiation received by the little square between the two arches is limited to its upper parts and only in summer. The superficial thermic gradients are quite high due to poor atmospheric absorption caused by the city's low air humidity and high altitude (586 metres above sea level). We can deduce the superficial irradiation valuation, seen in figure 1, from specific tests carried out on the same material taken from the city's Roman theatre which is only 50 metres away from the Prætorian Gate. From these tests it is evident that the material is sufficiently refractory to limit superheating penetration to 2 or 3 cms in depth from the surface.

The constant presence of wind especially in summer is another important factor. The currents blow from west to east following the valley's course, therefore penetrating the gate's arches as a result of accelerations due to the Venturi effect [3].

These valuations as a whole show that the upper layers are continuously exposed to varied dilatometric stress, to stress caused by water erosion, water absorption and subsequent quick evaporation and to stress caused by more or less evident erosion due to quite fast moving air currents which are often rich in sand or dust.

Other more circumscribed, particular problems are caused by the excavation to the south of the monument. This excavation has caused the formation of a damp area because the ditch receives little sunlight and is surrounded by alluvial soil. This situation coincides with abundant biological outcrops above all on the eastern arch's barrel-vault which is more sheltered from air mass movements.

The eastern arch's state of conservation has worsened because of a lead covering used in the 1930's which should have protected the arch's upper part from direct exposure to atmospheric agents. However the result has undermined the original aim since the covering has settled on the surface's unevenness creating cavities where rainwater accumulates and from here filters through to the underlying part. Continuous water erosion has created grooves which have in time weakened the materials reducing their bulk and thus their physical contribution to the monument's structure. This problem is quite serious in the western arch's central barrel-vault and can be seen by directly observing the large cavities present and the efflorescences caused by recurrent salt migrations.

The atmospheric pollution is mostly made up of airborne particles and dust present because of the location's dry climate. This helps to contrast the rainfall's pH as the carbonate rich dust contrasts the gaseous pollution's acid effect. The SO_2 and NO_x content present in the valley bottom because of heating or combustion is limited and thus not deemed as having played an important role in the stone's decay. The superficial chromatic changes due to the oxidation of the large amount of iron present in the material, can be attribute to the O_3 presence. We believe that this alteration is quite recent and not reported in past records. There is no analytical data at present to corroborate this theory reached by exclusion after having also carried out specific biological tests [5] whose results were negative [6]. The oxidation presence can have a worsening effect when evaluating the monument's superficial decay, given the danger of a phenomenon that anticipates a variation in bulk for the internal parts of the material. The reticular structure which gives the monument its solidity can thus subsequently collapse.

The absence of drainage systems for rainwater or for animals' biological saline refuse causes other decay situations limited to the areas of the monument directly effected by treading. Loss of material from the ashlars and the consequent reduction of the present monument base are in fact evident..

Since the alpine climate in winter is subject to a considerable temperature range above and below 0 °C, the materials' freeze resistance was the last factor to be considered, even if it is not the least important. Considering the obvious cryoscopic reduction caused by the salt present, even if in small quantities, and the relevant thermic « protection » given by the urban microclimate, we believe that the freeze resistance has a decidedly smaller influence than that which might theoretically be supposed and is most probably only relevant to the parts which already cohere weakly.

5 THE MATERIALS' BEHAVIOUR

Assessing the level of decay and the environmental characteristics mentioned above, led us to consider some characteristics of the stone's behaviour ; the type of interaction present with water, be it in the liquid or steam state, in particular. The main physical characteristics were water (liquid and steam) absorption and deabsorption, porosity and, above all, the behaviour and movement of liquids inside the material. At the moment research which aims to better understand how to reduce these phenomena with the help of water-proofing systems which can be applied to the surface, are being carried out. Tests [7] in specifically prepared samples have thus been done. The pudding-stone was paid particular attention as its surface is in a worst state of conservation.

The results have shown and quantized the extreme water absorption rate (figure 1) from which we can deduce the pudding-stone's extreme saturation rate and the subsequent dehydration rate. Other than saline mobility on the inner part of the surface, this phenomenon can also cause mechanical problems due to the liquids' movement.

Figure 1. Medium-coarse grain pudding-stone capillary absorption. Note how the first measuring point at only 5 min, has almost already reached the absorption plateau.

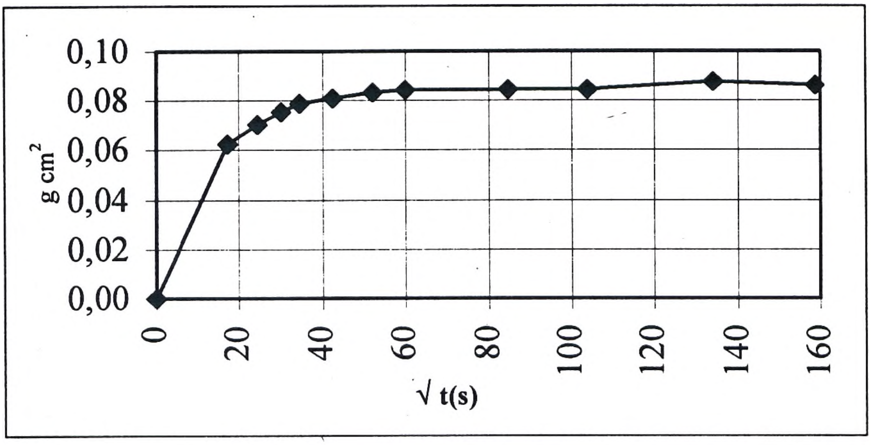
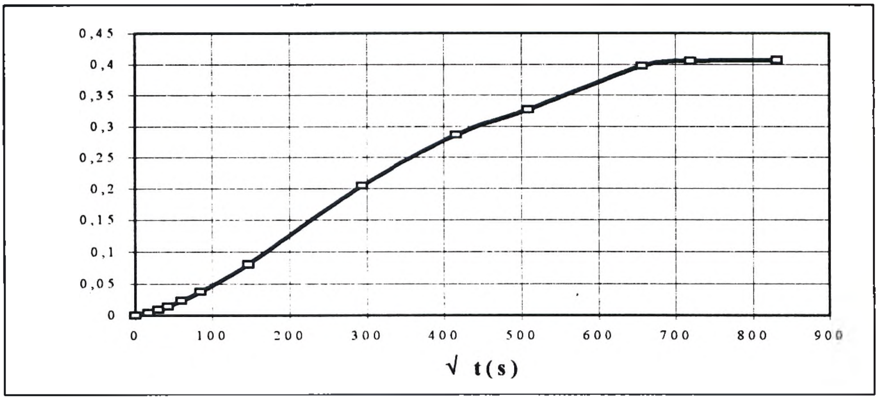


Figure 2. Water deabsorption as steam by the medium-coarse grain pudding stone.



6. RESTORATION WORK CARRIED OUT IN THE 1930's.

As mentioned above, the work carried out in the 1930's has proven to be quite suitable as far as the choice of materials is concerned. Studying these materials can supply useful information for the planning of the present conservation phase. During the 1930's restoration work the monument underwent a radical transformation with respect to the appearance it had assumed during the Middle Ages. The demolition of some adjacent houses carried out with the intent of recovering the original Roman aspect has influenced the air mass movement around the surfaces and this has in turn directly influenced the state of conservation.

A medieval chapel with a communication trench that permitted reaching the top of the eastern arch that faces out from the city walls, was built. Both the chapel and the communication trench connected to in were destroyed during the restoration work whilst some windows were rebuilt to recover the original aspect deduced from the remaining Roman ruins.

An archaeological excavation that restored the original road level was carried out to the south but at the same time this excavation created an area which has quite a stagnant high-humidity microclimate with consequent biological outcrops. This work greatly influenced the monument's original structure and in some cases several surfaces which had been tampered with by the medieval constructions, were restored. Surveying the monument showed that this integration work was done according to the principle of mimetic reintegration both in the cracks between the ashlars and in the reconstruction of whole parts of some blocks. The state of conservation of this integration work and of the seals is decidedly good as is the state of conservation of the stone that is in direct contact with the integration work.

The western arch does not seem to have undergone any conservation work in this period and the original materials have remained exactly the same with very little integration. Some maintenance work carried out more recently was limited to laying some coping on the lower parts of the holes left after the houses were demolished. The most drastic work done on this part was covering the upper part with lead. This type of covering has drawbacks which we have already alluded to during our considerations on the state of conservation.

It is thus evident that the present study, whose aim is planning the recovery work, is interested in understanding the influence of the changes in the atmospheric phenomena surrounding the monument but also in studying the integration materials used, above all in the eastern arch. The state of conservation and perfect camouflage shown by them guarentee their reliability and they must thus be considered excellent comparison data.

7. THE MATERIALS USED IN THE 1930's.

Mortars samples were taken to study the materials used as seals during the various restoration phases over the past years.

The sampling concerned both the mortars used to fill the cracks between the stone blocks and part of the mortars used to protect the flat surfaces. When taking the samples we noticed that the mortars were quite hard and compact and this made it necessary to use tools normally employed for heavy building work. The hardness of the materials, the fragments' aspect, the period in which they were used, led us to suppose that cement products were used to make up the mortars.

The tests carried out by mineralogical-petrographic and chemical characterization of the mortars and of the raw materials used to make them up, as well as closely examining their conservation state, were therefore aimed at verifying this hypotheses.

The mineralogical tests carried out using X-ray diffractometry (PHILIPS PW 1830 diffractometer, Cu tube and Ni anticathode) showed the same make-up in all the samples. In fact, the mortars are made up of quartz, calcite, mica, chlorite, feldspar, amphibole, pyroxene, chrysotile and gypsum traces. Traces of thenardite and tobermorite have also been found on all the samples.

The petrographic thin section tests showed an aggregate of heterogeneous dimensions that go from 50-80 μ to several centimetres in size. This aggregate is made up of quartz fragments, calcite, pyroxene, mica, amphibole, metamorphic rock fragments, granite, schist, limeschist, gneiss, pyroxenite etc.. The binder has a calcitic make-up and is of brownish colour with darker spots and shades. The binder/aggregate ratio is around 1 : 3. The porosity is average with slight variations from sample to sample, the shape is round and regular.
It is possible to think from these results that the mortars present typical cement mortar characteristics such as the presence of tobermorite and of a brown coloured binder of a fine consistency seen through the microscope. However we do realise that this evidence is not enough to be certain of the above . The problem of characterizing old cement is still one of the most controversial points and very difficult to solve finding, in this case, a coherent development remaining connected to the petrographer's personal experience.
Other research was carried out with the intent of better understanding the interaction level between the mortars and underlying stone. Water absorption and deabsorption tests, both in the liquid and steam state, were carried out with the intent of comparing them with tests carried out on stone materials. Unfortunately the difficulties encountered when taking mortar samples conditioned the collecting and the specimens thus obtained proved to be unsuitable for comparison for absorption in the liquid state. The methodology is simples for the steam state and we therefore obtained the two curves relative to the average absorption and deabsorption values (fig. 3 and 4).
The comparison between these curves and the stone ones (fig. 2) shows that the mortars are more hygroscopic and that the ratio of water absorbed in the steam state can even be ten times more. This result did not seem negligible but, however, it did not permit us to draw any conclusions (if we exclude that fact that pudding-stone is a durable material) both because of the lack of information present concerning this in literature and because of, as already stated, the stone's good state of conservation when in contact with the above mentioned mortars.

8. THE RESTORATION PROJECT.

8.1. The realisation principles

We think it appropriate, before discussing the planning, to premise the general consideration that all restoration work exercises quite a strong action on a monument's reality and all restoration work must be considered so.
Our reference point is not only the monument but also its role as part of a city. The customary question to answer is : do we want to save the monument or its historical image ? This question imposed itself during the planning phase when the needs expounded by the technical staff (chemist, physicists, geologists, restorers) scarsely met with the monument's present reality.

Figure 3. The water as steam absorption percentage (weight/weight) by the mortars used in the 1930's. We can note the high percentage of steam absorbed compared to the original material (fig. 2). The fact that the

mortar's surface is quite irregular and therefore difficult to evaluate must be borne in mind.

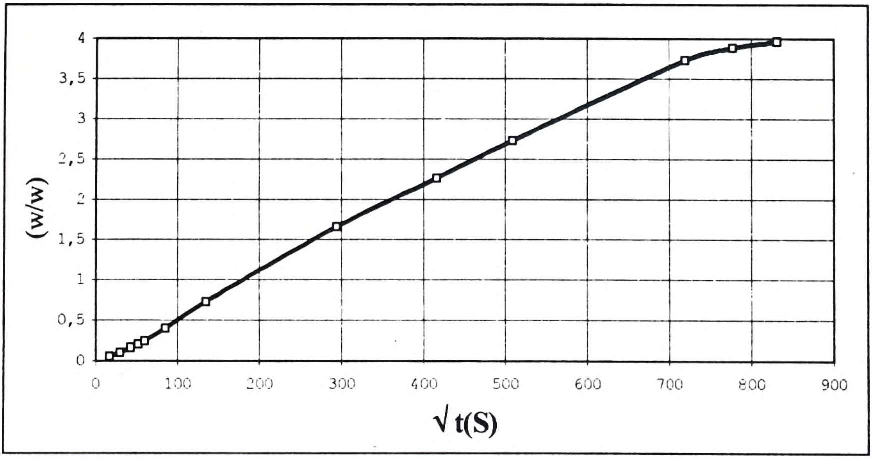
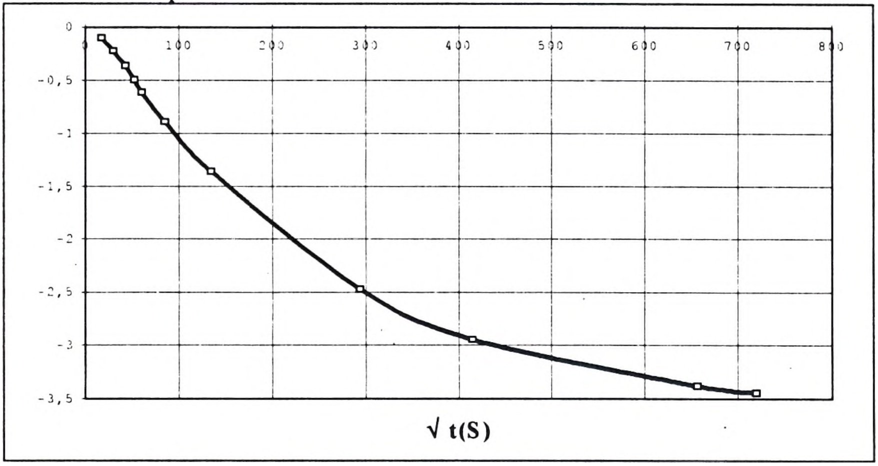


Figure 4. The water as steam deabsorption ratio for the mortars used in the 1930's. We can see that the deasorption speed is only slightly higher than the absorption one.



8.2. The methods and materials

The planning part of the work was divided into two phases. The first being immediate work to secure the stones which are more likely to fall, and therefore more dangerous for traffic, as well as observing the decay phenomena present on the surfaces more attentively.

The second concerned complete restoration work using the information obtained from the diagnostic and first phases.

As with all restoration the operative phases can be divided into four main parts : preconsolidation, cleaning, consolidation and protection. The first part, generically called preconsolidation, involves both the surfaces and the unstuck parts which are to be reintegrated using mortars which have been suitably prepared both as far as the grading, the colour and the binder/aggregate ratio are concerned. The more external parts will be perfected in the final consolidation phase instead.

The stone's high hygroscopicity and dishomogeneity had to be carefully considered for the cleaning phase. Traditional methods using water or basic solutions seemed hazardous because they would not allow enough control over the area which they would affect. Water penetration can in fact cause disintegration phenomena in areas inside the stone undermining the stone's integrity . The scarce amount of carbonate binder present in the stone suggested using dry cleaning methods. At present we have chosen cleaning methods using microsanders and continuously carrying out readings with a videomicroscope before and after cleaning [8], in order to have controlled dirt removal.

We believed that the use of traditional water repellents to protect the surfaces would have been quite complicated for the same reason stated above concerning the lack of understanding of the movement of fluids inside the stone. The impossibility of estimating correctly the resin distribution on the surfaces or in the hollows on the materials to be protected, is an unknown factor which could cause a lack protection effectiveness with some interaction problems between the stone and the water repellent. The research regarding this is still being carried out [9], but the first results have not given us enough guarentees as to the validity of this type of work.

The integration phases were based on analytical data. We can state from the mineralogical petrographic tests that the integration materials used in the 1930's all come from the city of Aosta and its surroundings. The aggregate is made up of variable sized pebbles taken from rivers. The travertin limestone frequently found in all the region was probably used as binder. The results however seem to point to the use of cement material. Proof of this is the thenardite and tobermorite presence (typical compounds found in cement mortars), the binder's evident darker colour, and the round shaped regular porosity (seen in thin section). Despite this the mortars cohere and are in a good state of conservation.

Therefore as far as integrating the gaps or filling the cracks is concerned, the results show little damage due the cement presence and the stone's resistance to contact with such products. We do not deem considering the use of cement as reintegration material appropriate, but the fact of having understood how the use of cement mortars is possible and not dangerous. Care will have to be assessed considering both the stone's gradation with which it will come into contact with and the choice of local grit.

The reflection on the type of consolidation or « protection » led to a series of considerations reported below. We must take into account the fact that surface consolidation work using the methods available to us, is thought to be uncertain. This is so for two reasons : first, there is the problem of the stone's structural dishomogeneity and from this stems incorrect work valuations ; second, the type of decay present on the surfaces is limited to one at most two centimetres in depth, after which the stone appears to be sound and strong. The risk involved in creating several reticular structures of various size is a sealing effect on the present porosity and with this a possible change in interaction characteristics between the stone and the environment. However, an ethyl silicate which resembles the rock's silicate chemism will be used where it is deemed absolutely necessary.

8.3. The proposal

The decay phenomena valuation as a whole and the analytical data led to a debate within the departments designated for the monument's protection. The operative sector's proposal, after the data had been presented, consisted in three possible ways of intervening definitively : heavy, medium and light.

The water absorption data, the salinety present, the iron's superficial oxidation phenomenon and the wind passage factors were all assessed according to their potential and dangerousness.

The heavy « method » consists in using resins and other materials useful in giving complete continuity to the materials that have undergone changes. The advantage is that the monument's aesthetic aspect would not be altered even if the use of resins and protective materials can give rise to superficial chromatic changes. The disadvantage is not being able to predict the behaviour and type of interaction that would be created as the new structure would differ from the present and would have different conservation problems which are not easily foreseen and which would need a precise, feasible maintenance project.

The medium « method » is limited to using integration materials but it would influence the architecture as it foresees creating suitable coverings. The advantage would be that the materials/stone interaction would be limited thus postponing it to possible scientific developments in the future. The negative side is aesthetic as this type of work would alter the monument's historic aspect. Moreover we must also consider the fact that the following problems capillary ascent, biological growth, wind effects and dust particle deposit brought by aerosol would not be sufficiently reduced.

The light « method » (to be considered light only as far as the stone is concerned as it is quite drastic for the site) is the one which takes the technical sectors' perplexities into account most. Perplexities which have already been partly expressed in the descriptions in preceeding chapters.

We began formulating the work method starting from the following belief that restoration work can only be considered « perfect » if the factors which are causes of decay are all eliminated. In this specific case this would mean eliminating direct contact with rain, wind, capillary ascent and the oxidizing environment which surrounds the monument. The direct contact with water is, according to us, the main decay factor to be reduced. It is in fact water which carries the polluting elements, which creates internal migratory flux due to the evaporation speed favoured by wind, which in turn favours the oxidation reactions. The only way of avoiding all of this is to cover the area extensively.

The planning phase therefore takes on a fairly fascinating aspect as far as the architectural side of the work is concerned. This type of choice would also allow a complete excavation around the gate creating an active archaeological area within the urban traffic. We could therefore achieve a small urban archaeological salon with suspended passages. The extensive covering would allow a greater control over the air flow. Enlargening the open excavation area would reduce the biological growth phenomenon to be found at present.

It is obvious that this is not a system to be proposed for all the world's monuments but it can give new stimulus to planning in the urban-archaeological sector. Conservation can be a reason for debate but also for proposing a new evolutionary boundary so that our age does not limit itself to conservation but can also propose and build for the future.

9. BIBLIOGRAPHY

1. MIRTI P., ACETO M. APPOLONIA L., BORTOLASO G., On the provenance of white marbles from roman buildings in the town of Aosta (Italy), Science & Technology, in press
2. APPOLONIA L., VAUDAN D., DE LEO S., Proceeding "8th International Congress on Deterioration and Conservation of Stone", 30.9-4.10 1996, Berlin, 1097-1108
3. PULGA S., internal report
4. SAGGESE M., Microclimatic gauging analysis, internal report
5. REALINI M., SORLINI C., Le macchie rosse del marmo apuano, in La Certosa di Pavia - passato e presente nella facciata della Chiesa. Ed. CNR, 1988, 253-261
6. PINNA D., internal report
7. AA.VV., Raccomandazioni NORMAL, Assorbimento d'acqua per capillarità - Coefficiente di assorbimento capillare, 11/85, ed. ICR-CNR
8. FRATINI F., MANGANELLI DEL FÁ C., PECCHIONI E., RADDI G., Effetti di pulitura su superfici marmoree : valutazione mediante analisi microscopica, in Proceeding "Scienza e Beni Culturali: la Pulitura della Superfici", 1995, 531-538
9. BORGIA G.C., NMR analysis on materials from the Roman Theatre in Aosta, internal report