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Do Silicon-Based Products Respond to Conservation Purposes?

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Abstract

Silicon-based protectives and consolidants have been present in the field of conservation of porous building materials since the early 1900's. It was only until the 1960's that these products were frequently used on cultural property. Since then, chemical manufacturers have released products satisfying the needs of the industry as a means of maintenance for civil buildings. Even though the conservation community utilizes these products a great deal, a small number of manufacturers have paid attention to this market's needs; thus, around the 1980's restorers and conservators were forced to "discover" which product might fit their conservational needs. Concurrently, conservation scientists dedicated research to understanding the chemical and physical characteristics of these materials in relation to their destined use in conservation. The present work will consider some relevant aspects related to technical information supplied by the manufacturers/suppliers, application methodologies, durability, and chemical affinity with the material treated, efficacy, costs and marketing failure. A representative number of case studies will be discussed to represent a variety of requirements for conservation problems depending on the materials, surface structure, degradation phenomena and environmental condition.

1 Introduction

The use of silicon-based products in the field of restoration, both for the consolidation and protection of stone materials can be traced back to the early years of the twentieth century [1], but one can only really speak of its more widespread adoption since the 1960s [2]. Furthermore, it is necessary to add that although the use of these products has been gradual and uninterrupted, this has however been the result of an extremely slow process. One of the main obstacles has been the well-known fact that the majority of available products were not produced specifically for use in the cultural heritage sector, but imported from other sectors of application and, as a result, have made it necessary for conservators and conservation scientists to have to carry out new studies, experimental tests and appropriate adjustments.

The growing interest of the conservation world in these new materials is clearly evident if one examines the numerous experiments carried out in this field. The majority of articles dealing with problems of alteration and deterioration in stone materials and the relative proposals of solutions using this or that product as they become available on the market clearly demonstrate this fact [3].

Unfortunately, if one carries out a critical analysis of these publications, it will show that in the majority of cases conservation professionals have worked in isolation with respect to the world of the synthesis and industrial production of Si-organic compounds. It must be noted that this dichotomy between the world of conservation and industry is not limited to the early years of development of these products, but has continued right up to the present day.

2 A useful parallel

During the brief period of recent history of conservation, much attention has been paid to the new technologies, both in relation to diagnostic studies (aimed at understanding the alteration processes of materials) and to proposals for restoration and conservation treatments with new materials [4].

In the former case, still today there is a perfect integration between the developers of instrumental analysis systems for diagnosis and conservation professionals perhaps because of the diverse nature of the product itself. A scientific instrument, in fact, would almost never be subjected to a planning process involving marketing studies. Scientific apparatus due to their intrinsic characteristic of advanced technological development are not designed for a large market but are compensated for this commercially negative aspect by the high cost of acquisition and customer support.

In the specific case of new products for conservation of industrial production, there appears to be little interest on the part of the industrial world in a user who has complex technical requirements, pays meticulous attention to the efficacy of the product, and who, above all, represents little commercial potential in the form of product consumption.

3 Industry and restoration

Can the sad lack of dialogue between the niche requirements of the conservation world and those of large-scale production/distribution only be attributed to the industrial sector? Very often, it must be noted, that those responsible for restoration work sites are obliged to perform immediate treatment operations and conservation scientists, having to adapt themselves to this cycle of contingent needs, have found themselves in the majority of cases involved in evaluating the efficiency of materials available within the complex casuistry of a restoration process, rather than searching for new solutions.

Fortunately this situation is gradually changing and we are beginning to see a positive reversal of tendencies within a new hoped-for scenario of collaboration between producers and users. To take an actual example, it was remarkable to note the presence of specialists from the production sector with treatments targeted at conservation problems at the recent International Congress on Deterioration and Conservation of Stone held in Stockholm [5] in 2004 and similarly, during the last meeting of Hydrophobe III in 2001 [6, 7], although it is not by chance that the majority of works refer to maintenance problems in concrete and reinforced concrete structures.

4 Some comments on the conservation community

Within the framework of this new scenario, it is indispensable to point out the necessities of the sector both with reference to the diverse materials to be treated, and to the types of alteration of these same materials, and with reference to problems of compatibility, efficacy, durability and the aesthetic impact of the treatments.

When we refer to materials to be treated, we generally mean all those materials for construction that come under the heading of porous building materials, but at the same time this does not exclude other materials such as historical glass and metal artifacts. The necessity to carry out protective conservation treatments on extensive glass surfaces or bronze sculptures exposed to the urban environment [8] is no less significant than the treatment of architectonic surfaces.

Faced with the diverse nature of the materials considered, even though we limit ourselves to the field of stone materials, the compatibility of consolidant and protective products with the support to be treated is of primary importance. The low chemical affinity of silicon-based consolidants with materials of a calcareous nature is, for example, well known.

Each stone material then presents an individual picture of alteration and natural deterioration closely linked to its own nature and interaction with the environment, and here the overall picture of parameters to take into consideration in the selection of a conservation treatment becomes much more complex. Can processes of disintegration, exfoliation and pulverization of a stone material always be effectively resolved with a consolidant treatment? In that case, can the significant presence of salts in the deteriorated material be reconciled with the use of a silicon-based consolidant? How do these salts interact with the chemism of the selected product?

Similarly, if we consider instead the aspects linked to the protective treatments of surfaces, we wonder how durable these products are? What will their aesthetic impact be? How much will they alter the porosity system? How much will they influence the permeability?

One cannot claim that answers have never been given to these questions, but we are always dealing with individual cases, specific studies, carried out exclusively in the conservation laboratory, thanks to which, after a series of tests on some samples prepared ad hoc, an attempt is made to forecast the behaviour of this or that product in situ.

Certainly the large number of restoration treatments that have resorted to using consolidant or protective products, have not benefited from the results of preventive studies and, where these have been carried out, they always refer to specific monuments and it is surely unrealistic to think that these results can be adopted for common use. Current practice in selecting a protective product, for example, has been that of adopting a product that has been used on other occasions with positive results, but this method has led as a consequence to the indiscriminate use of a limited number of products more or less known commercially, on diverse types of support. There are also numerous cases of applications of the same product in vastly different climatic zones [9] and often no account is taken of the purity of solvents and proportion of active ingredients in the products. In too many cases, it is exclusively economic criteria that have prevailed.

If the state of things in the conservation sector is what has just been described, it is evident that an appropriate policy is lacking in this area. Proof of this perverse cycle is in the still current lack of selection procedures for materials, which should match the characteristics of the product with the peculiarities of the conservation problem to find a solution.

5 Some comments on the manufacturing community

Research scientists in industry are particularly involved in the formulation of products with large-scale applications and the field of application of silicon-based products effectively covers a huge variety of different needs. These range from the semiconductors sector to that of the automobile industry, textiles, household products, personal care and healthcare; the sector closest to the field of conservation is represented by construction and architecture.

Also in the case of this specific sector, the technical data that accompanies both the products for general use as well as those with specific properties, is not detailed enough and in the majority of cases its style is more commercial than technical. None of them appear to make reference to applications in historic architecture and only on rare occasions we find citations like historic lighthouse preservation [10] or preservation of monuments [11].

The immense range of products on the market and the general nature of the technical data relating to their application create considerable confusion for the user when selecting a product for conservation purposes. Some examples of the latter are apparent just by looking at some of the most commonly used terms to describe a product such as: water-based, water-borne, solvent free; and hydrorepellent, hydrophobic agent, water repellent; or coating, protective coating, consolidant, impregnation agent; or pre-polymerized, pre-hydrolyzed and others, to name but a few. Almost always there is no possibility of establishing any direct contact with the research and development department of the manufacturer. Given this situation, the suppliers become the exclusive interlocutors of conservators and architects, thereby eliminating the possibility of any direct feedback between the latter and the R&D sectors of the industry.

On the other hand, while this situation persists, all the manufacturing companies do not economize on providing assistance for the so-called tailor-made product solutions and application know-how. There is no doubt that this takes place, but who wonders what the economic entity of the product has to be to warrant a project-specific service?

6 Some emblematic case studies

It does not help anyone by giving such a negative picture of the situation and positive examples both in terms of results and in fruitful technical collaboration do exist. One of these is that of the restoration of the entire monumental complex of the Campidoglio [12] in Rome, which commenced in 1994 with the restoration of Palazzo dei Conservatori and Palazzo Nuovo,

and concluded with that of the facade of Palazzo Senatorio [13], also thanks to the commitment of the manufacturer (Rhone Poulenc) [14]. The latter, in combining technical as well as financial support played a key role in this project. The technical choices as well as the materials adopted [15] on this work site are an excellent example of successful synergic collaboration between technology, know-how and research or, between the product expert and the specially appointed scientific committee.

Naturally, in an operation of this nature, the prestige derived from restoring a monument of such importance is evident, although this is a sector which is open not only to favourable comment but also very often to severe criticism.

This was a case where the situation effectively presented few problems. But the picture is very different when confronted with more complex cases. The examples discussed below, that of Teatro di Marcello [16] and the Basilica di S. Maria Antiqua [17] in the Roman Forum express situations of the latter type.

In 1998/99, as part of the restoration programme for Teatro di Marcello, the external wall surface was treated with Wacker 290 L. Work site requirements (erection of scaffolding and work deadlines) made it necessary to carry out the protective treatment in two phases: the first on a series of arches and subsequently on a second series of arches. Despite having always used the same product, this division into phases led as a consequence to using two separate lots of the protective, delivered at different times. Unfortunately, only during the concluding stages of the work was a certain dissonance observed between the first series of arches treated and the second. Random colour reflectance measurements then confirmed this inconsistency. In anticipation of the problem worsening with the exposure to light, attempts at accelerated ageing were carried out directly on site using UV radiation.

Despite all the limitations of the case (exposure time, radiant energy, test area not sufficiently representative), the surveys carried out did not predict any further aggravation of the problem [18]; a problem that fortunately today has been completely resolved by the homogenizing effect of time. Up to here all is well, and part of the responsibility of this inconvenience must certainly be attributed to the lack of prudence in the procedures adopted by the restoration firm, however accepted practice in these cases would demand the immediate control of the detailed technical specifications of both lots of protective as is customary for all types of chemicals. But which technical specifications? Those supplied by the technical data sheets? And with what standard methodologies? Because it is precisely here where the main fault lies.

A second case that we believe worth citing is that relating to the restoration of the severely deteriorated surfaces of the pictorial cycle of S. Maria Antiqua. Here it was a case of carrying out a so-called pre-consolidation given the necessity of performing a subsequent operation to reduce the salts present in a layer made up of very weak and fragile mortars, with a high content of water-soluble salts and high moisture content.

The aim of this study was to select the right product for the consolidation treatment, capable of improving cohesion and adhesion of the mortars. Once this consolidating effect had been satisfactorily achieved, it would then be possible to proceed with the process of extracting salts.

Obviously as a first step some of the more significant references to this particular problem were consulted [19]. Despite the considerable amount of research that has been conducted, there has been very little effort to pull it all together and produce a clear statement. We arrived therefore at the conclusion that a peculiar situation such as that of S. Maria Antiqua required specific experimental investigation

Several silane-based products, silica sols and acrylic emulsions have been tested on specifically prepared mortar samples, with a mineralogical composition and poor mechanical behaviour similar to the original mortars, enriched with a mixture of water soluble salts.

The consolidant materials selected for this research were supposed to have characteristics that would make them suitable for use as pre-consolidants (i.e. to strengthen the plaster surfaces before the operation of extracting soluble salts), so that the treated surface remained hydrophilic with open porosity to permit the transport of water (and saline solutions) to its interior.

This study took one year to complete. However, even though encouraging results were achieved (although not entirely decisive), it must be pointed out yet again that “yes”, these will be useful for the conservation of the mural paintings at S. Maria Antiqua, but we do not know how useful they can also be for all the other hypogean or partially buried sites with analogous conservation problems. Also in this case, on account of contingent needs, it was not possible to systematically evaluate individual interactions such as, for example: the interaction between the original material and the consolidant; the influence of growing percentages of moisture content, the influence of varying quantities of soluble salts and of various mixtures of salts, the durability of the treatment under diverse environmental conditions and the efficacy of different methods of extracting salts following pre-consolidation. We are convinced that only experimentation conducted with this spirit can lead to the formulation of mathematical models of the phenomena with the consequent possibility of forecasting behaviour on the basis of the variables in play.

7 Conclusion

Within the framework of this scenario, certain indispensable priorities emerge:

- Indicate the requirements (misuse of silicon-based products)
- Make direct contact (i.e. dialogue) with the manufacturers (lack of communication)
- Define guidelines for the selection of products (choice-making parameters)
- Tailor-made product solutions (specialized applications)
- Detailed procedure and conditions for application.

Although the development of new materials for conservation is both time-consuming and expensive, chemical manufacturing companies will only truly be able to satisfy the needs of cultural heritage if they take the specific concerns of conservation scientists seriously into consideration. It is essential that manufacturers consider the possibility of exchanging data on the formulation of products and, at the same time, are willing to share their results with us.

Of course, on our side there are still many things that we do not understand deep down and if we are able to communicate these things clearly, only then will manufacturers really be able to recognize and appreciate the specific needs for conservation and count themselves among the leading protagonists in the protection of cultural heritage worldwide.

8 Notes and references

[1] 1918-1926 A.P. Laurie acquires several patents for ethyl silicate as a stone consolidant.

[2] 1968-1980 Development of several commercial products such as Wacker H and OH, Tegovakon V and T, RC70, RC80, RC90.

[3] See bibliographical references collected in: E. Borrelli, M.L. Santarelli, Silicates in conservation, (CD-ROM distributed on request), ICCROM June 2002, Rome.

[4] One of the most significant examples was the “International Colloquium on Methods of evaluating products for the conservation of porous building materials in monuments”, Rome, 19 - 21 June 1995.

[5] H. Geich, Wacker-Chemie GmbH, Wacker silicones, Recent developments in protecting gacades with silicones, in: Proceedings of the 10th international congress on deterioration and conservation of stone, Stockholm, June 27 - July 2, 2004 / ICOMOS Sweden, 2004

[6] H. Geich, Wacker-Chemie, Silicones Division, Germany: Protecting Concrete with Cream - Practical aspects, in Hydrophobe III, Third International Conference on Surface Technology with Water repellent Agents, Hannover, 2001.

[7] K. Weissenbach and B. Stanke, Degussa AG, Germany: Antigraffiti and Easy-to-clean properties on porous mineral surfaces are achieved by using waterborne fluoroalkylsilane systems, ibidem

[8] As clearly emerged during the last Workshop on Silicon-based Products in the Sphere of Cultural Heritage held in April 29 - 30, 2004, ICCROM, Rome, Italy

[9] The restoration of the temples of Angkor Wat, in Cambodia, for example raised the problem of emergency consolidation vs. time in extreme environmental conditions

[10] Dow Corning® brand silicone construction products.

[11] “Monuments require project-specific services. Remmers has become the market leader in Europe with tailor-made product solutions and application know-how” and “The branch plant in Bad Düben is also the home of the Institute for Monument Preservation, an advanced level training centre for all aspects of monument preservation”

[12] The famous square realized on a Michelangelo project (1563)

[13] See: La facciata del Palazzo Senatorio in Campidoglio: momenti di un grande restauro a Roma, M. E. Tittoni, (ed.), Rhône-Poulenc, Ospedaletto (Pisa): Pacini Editore, 1995 and Il Palazzo dei Conservatori e il Palazzo Nuovo in Campidoglio: momenti di un grande restauro, M. E Tittoni, (ed.) / Pouchain, Italy, Ospedaletto: Pacini, 1997

[14] Now Rhodia Silicones

[15] Rhodorsil RC70 for plaster, RC80 for marble and travertine, Silirain 50 for lime paint, Rhodorsil RTW 1600 as sealant

[16] Begun by Caesar, it was completed (17 B.C.) by Augustus.The latter dedicated it to his nephew Marcello (13 B.C.),

[17] Built on the pre-existing structures of an architectural complex of the Domitianus period (81-96 AD), in the North-West slopes of Palatine Hill it was sacred to the Holy Virgin in the first half of the 6th centuryand then rediscovered at the beginning of the 20th century, during archaeological excavations in the NW sector of the Roman Forum.

[18] E. Borrelli, P. Ferrantelli, Teatro di Marcello: Misure di colore dopo il restauro 1998/99. Prove di invecchiamento in situ, ICCROM, Rome, 2000, (unpaginated vol.)

[19] A. Miquel, P. Bromblet, V. Vergès-Belmin, L. Binda, E. De Witte, H. De Clerq, R. Van Hees, H. Brocken, Experimental study on the compatibility of a polysiloxane treatment with a substrate loaded with sodium sulphate: influence of the physical properties of the substrates on the salt content limit, in: International journal for restoration of buildings and monuments / Internationale Zeitschrift für Bauinstandsetzen und Baudenkmalpflege, 2002