The Sticking Point: adhesives and consolidants in painting conservation
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Authors : Matteo Rossi Doria, Ezio Buzzegoli, Diane Kunzelman

A working group on consolidation: investigation, research, decision making processes in treating a sensitive painting by Mario Sironi. Results of a 2004-2008 project.

Introduction

This paper briefly describes part of the research efforts and work carried out by a group of Italian professionals, composed of public and private conservators, researchers, and scientists, on the issues of consolidation of the paint layers of canvas paintings.
This project was mainly developed from 2004 to 2008, and much of its contents have been part of the meetings and scientific activity of the Association Cesmar7. Cesmar7 has dedicated two of their international meetings to consolidation issues, precisely the 2006 and 2008 conferences, both held in Milan. The reason for looking into this previously scarcely investigated field of conservation was to finally focus on the complexity of the problem and to start to look at materials, operating a shared comparison of scientific data and actual consolidation practise.
All of the work developed for these occasions, however, found limited possibilities for divulging results and involving the international community.
The post prints of these two conferences, including the English edition of the 2008 proceedings, represent a first in-depth step in seeking to understand the original materials involved, their decay and response to climate conditions, together with the behaviour of consolidants+solvents, their dynamics and diffusion in porous systems and real effectiveness in terms of stopping or slowing damage.
The post prints unite many important contributions. Some of these, as shown in the following list, are, in our opinion, fundamental to build a shared scientific framework for a better understanding of all the various issues involved in consolidation.
- A.Roche, A new way to interpret the concept of adhesion and decohesion: physical-chemical and mechanical aspects
- M.Mecklenburg, Failure mechanism in canvas supported paintings: approaches for developing consolidants protocols
- R.Wolbers, Short term mechanical properties of adhesives: solvents and plasticiser effects
- Stefan Michalski A physical model of the consolidation process, particularly of paintings

On the basis of these fundamental contributions, many other scientists and restorers described different ways to study the problems and to focus on investigation methods and tests, applied to a list of most commonly used consolidants to determine their effectiveness and behaviour in different conditions. Other papers faced the use of Cyclododecane as a provisional consolidant and practical treatments on real works of art.

In this common process our group decided to work on several projects that could be related to the overall scientific scheme. The first step was to try to define what role porosity plays in the decay processes and a correct way to relate this with how consolidating materials may be used in solution.

According to the specific structure of different support+ground+paint layers, we focused on a few cross sections taken from real, untreated paintings, measuring pore size and morphology. The second stage was to cast inert, porous and homogeneous test standards and observe the diffusion, migration and position of many different consolidant mixtures. The final part of our work was to design an appropriate methodology for treating an extremely sensitive and highly porous tempera painting dated 1933 with severe consolidation problems.

Porosity measurements

While seeking the best way to collect a huge number of images of paint layers presenting decohesion, detachments, losses, we immediately recognized the difficulty of precisely describing the enormous amount of variations found, even sometimes within the same painting. Variability and deterioration specific to each case was not useful to approach the problem in a way that enabled scientists to work on real data. The only possibility was to look at cross sections measuring the thickness of the different layers and the size of pores inside the paint matter. SEM-EDS has been widely used to analyze paint films and grounds. Usually, cross sections cast in epoxy resin or with specific treatment to better respond to the needs of analysis, lose the possibility to efficiently permit observation of porosity. Nowadays it is also possible to look at samples without any preparation, which makes it possible to study the morphology of the porous materials, and derive an average measurement of pore size and empty spaces. The differences, as we will see, are very small (a few microns) but quite significant, for relating the data with the consolidation procedures and how diffusion and penetration of the various consolidant solutions has taken place.
We observed several samples coming from untreated paintings, selecting three cross sections where it was possible to readily determine the morphology and "architecture" of the materials' structure and measure the empty spaces.

In sample 1 (oil on canvas, XVII century) we may see that the empty spaces occupy 40 to 50% of the overall dimensions and that the size of pores ranges from 20 to 2 microns. The paint film seems well attached to the ground but with loss of resistance and fractures visible in the ground layer. This sample is also interesting because it gives a clear idea of the displacement of the inert crystals and fillers and the bonding medium and, in this case, also helps us to understand were mould has started to develop.

In sample 2 (oil on canvas, XVIII century) we can have a better view instead of delamination between layers and observe the differences in terms of distribution and size of pores. In fact the structure is less homogeneous compared to sample 1 and it results difficult to define an appropriate average of the dimension of cavities and pores. We can also observe how the fillers are unevenly grained and the degree of disintegration of the ground.

In sample 3 (oil on canvas, lead-zinc white ground, XIX century), porosity is much more homogenous and the size of pores ranges from 5 to 2 microns. Fractures are visible within the ground layers but the structure appears less spongy and more difficult to penetrate.

If we extend the number of measurements and plot them it's possible to think that we can understand, or at least have a reasonable idea, of what is required in terms of consolidation. In fact, in conservation we have often seen over-impregnated structures or, sometimes, lack of cohesion and fragility. The forever unfinished discussions on what are "the needs of the painting" or the "exact amount", the one that is respectful but also effective, can be directed towards an alternative frame of evaluation.

Looking at these few samples, it is clear that if we need to treat an object with consolidants, we will be drastically changing, forever, its behaviour and reactions.
To better understand how consolidants penetrate and distribute inside porous systems, we developed a basic research plan to observe the behaviour of some commonly used materials.
This project developed into the thesis prepared by a young student, Debora Minotti, at the Opificio Pietre Dure in Florence, under the guidance of Ezio Buzzegoli.
The materials used for the reference standards of the porous support were alabastrine gypsum combined with micronized silica in a ratio of 40:7 to increase porosity.
The test standards were shaped in blocks and sticks to respectively observe diffusion by gravity and by rising capillarity, made using a short list of consolidanting materials (hide and sturgeon glue, Aquazol 200, Plexisol P550, Paraloyd F10 and Beva 371).
After treatment the samples were documented using a UV source able to evidence by fluorescence the diffusion and migration of the tested materials.
It was important to see, for example, in what way behaviour of animal glues depends on different concentrations and viscosity, or what happens to Beva 371 if we change the nature of the solvents.
It is clear that the right result, in terms of a deep penetration or, for instance, a superficial distribution of the consolidating material, is a complex combination of many different options. As we can understand from literature and other contributions to this conference it is necessary to keep in mind that the effectiveness of any treatment is the result, in terms of decision making, of a balance between the characteristics of materials chosen (molecular size, adhesion-cohesion power, solubility, glass transition), the nature of the solvent (wetting properties, surface tension, migration, retention, plasticizing effects), and the way the solution is applied (by brush, nebulised, misted, slowing/accelerating evaporation, using low pressure or vacuum devices). The inert test standard demonstrates that small variations of concentration or temperature effect migration-diffusion dynamics, but above all the complex mechanism of evaporation and final position, in the cross section, of any kind of glue or synthetic resins.
If we relate this evidence, not with an inert test but with real paintings and their specificity, it is indeed hard to say “I did the best thing”. Our experiences were significant in revealing how much there is to do to drive testing and research towards a more shared evaluation of what the problems are and to understanding the complexity of the thinking or decision making processes.

The treatment described as follows, carried out on a particularly sensitive painting, is the result, not necessarily “the best”, of a working and thinking group, positively oriented to observe the different options and approaches in science and in practise.
We want to thank a list of colleagues, conservators and scientists that contributed substantially to this project.
Opificio delle Pietre Dure: Ezio Buzzegoli, Diane Kunzelman, Debora Minotti, Luisa Landi, Natalia Cavalca
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Mario Sironi *Le Opere e I Giorni* 1933

This part of the paper reflects our contribution to the 2008 Cesmar7 International Meeting in Milan. At the end of the 2006 Meeting it was decided to develop the project on consolidation with further research and practical treatments done according to an "Open Studio" criteria.
The Sironi painting was a wonderful challenge for each of the various approaches. Because it was so sensitive, due to its specific and extremely delicate technical characteristics (tempera on zinc white ground on canvas), all "traditional" or standardized methodologies risked incurring damage or permanent alteration to the original structure.
It was necessary to find the right material, solvent, method of application capable of counteracting the extreme fragility of great part of the surface.
Following is a schematic presentation of the main issues faced in this project, the research and investigation paths, the practical testing, and, at the end, actual treatment of the painting.

Technical data

Author Mario Sironi (1885-1961)
Le Opere e I Giorni 1933 tempera on canvas cm. 240 x 220
Lined in 1970 (?)
The painting is a "bozzetto", painted as a preliminary project for a large wall painting, designed to decorate the interior of a building for the Triennial exhibition in Milan in 1933, afterwards destroyed. Mario Sironi was a prolific artist and worker, whose long activity was extremely productive.
For many of his complex projects he worked, as a first idea, making large cartoons, mostly on paper and a few times also on canvas.
Scientific investigation:
NIR/False colour Infrared, Xray Fluorescence (XRF), FT-IR Spectrophotometry, HPLC Chromatography
High resolution raking light photography, before and after treatment
Cross section analysis
List of pigments and binding materials
Ground composition
Description of paint layers

State of preservation

The large painting was affected by a general loss of cohesion in the ground layers. The fragility and the amount of flaking and losses were more evident where the thickness and superimposing of the paint layers was greater. The worst problems were concentrated in those areas, such as the figures, containing high concentrations of zinc white. The high definition raking light documentation showed that these phenomena affected more or less 80% of the surface. The craquelure pattern was very minute, with flakes 1 to 3 mm in size.
Probably many of these problems were caused by the decay and reactivity of the original materials, but also the amount of deformation due to the slackness of the painting on its stretcher as well as the hygroscopicity of the painting and lining composite contributed.

Because it was impossible and damaging to unroll the test of the painting we decided to design samples very similar to the original characteristics. That was possible because the painting technique was easy to reply working with the fast drying times of the binding medium(animal glue) and because we had clear information from cross section on the different pigments layering.

The models were realized at the Opificio delle Pietre Dure under the direction and experience of Ezio Buzzegoli.
Using heat sources and climatic chambers it was possible to achieve a model quite similar to the original mostly under the point of view of porosity and change in appearance.

In fact the biggest issue was absolutely the change of optical values and the risk of alteration.
It was decided to measure the colorimetric index on the painting and on the models before any treatment. Careful investigation were carried by Marcello Picollo and Natalia Cavalca(IFAC-CNR Florence) following all the recent recommendation and repeating the measurements several times.
The materials selected for the tests on samples were:
Pure hide bone glue 2-4% in water
Sturgeon glue 2-4% in water
Aquazol 200 5-8% in water
Aquazol 200 5-8% in Acetone
Tylose 1-2% in water
Tylose 1-2% in Etil Alchool
Klucel G 1-2% in water
Klucel G 1-2% in Etil Alchool
Funori
Beva 3,6%(1:10) 4,5%(1:8) in CycloHexane and White Spirit

Other consolidants were not considered for drastic change in appearance (Paraloid B72, Plexisol P550, Akeogard 35, Gelvatol)

All consolidants dissolved in water were giving problems probably because the different pigment layers were causing stains and irregularity.
The ones dissolved in solvents were darkening or yellowing and none if the test were really satisfactory.
We had to reconsidered the list and add other options. We looked at POLIURETANI(?) and FLUORURATI(?) used as surface consolidants in stone conservation. One of them Fluoline HY merchandized by Italian company CTS was giving interesting result in the colorimetric measures. We looked at technical data of the product that were encouraging in test it on our samples. The main positive characteristics were to be stable under UV, no cross-linking, very good water proof properties, big dimension of the polimer(300.000-400.000uma) and soluble in solvent with safe standards(Butilacetate).
The only problem was that we didn’t find any use of this consolidants on paintings.
It was planned in the Open Studio project to test the selected materials at a experimental Peel Test method designed by Simone Tellini pHd from the Department of Mechanism of the Engineering University of Florence.
A software specifically designed was able to produce a graph were it was possible to record the properties of each tested consolidants. Fluoline HY was doubled tested. The first graph described his behaviour only with brush application, the second with the aid of a local pressure during the drying process. This last result demonstrate that there was a big difference in term of manual application of the selected consolidants.

The decision making process was terribly challenging and many times, during the development of this project, we had the feeling that we could get in trouble in the correct evaluation of all data coming from the test and observation. For this reason we involved in our continue discussions Stefan Michalski. His personal experiences and confidence with decision charts and flows drove the group to rationalize the thinking process and document each step and considerations coming from all participants. An incredible and interesting human and professional experience. We started to

point all data and evaluate their positive or negative effect for the correct treatment of the painting. It was evident that any solution was “the best” and the final decision was the result of a balance between different options. We decided that this was a good method in approaching a challenging problem for the following reasons:
- register and evaluate all options in an ordinate and rational process
- set a useful map for anybody has to take similar decisions
- understand were lacks in the project are and include new paths and options
- talk more about concerns, problems, mistakes, failures
- put under discussion our skills and experience and be more transparent in transmitting our knowledge
- positively develop from a subjective semi-intuitive expert choise to a more clear and shared vision

Using this method we focused on two completely different ways to solve the problem:

1) protect the surface with an infusion of Cyclododecane, remove the lining and consolidate the paint layers from the back
2) consolidate from the front without removing the lining

The second option, after many tests with different ways to apply Cyclododecane, seemed to be safer and more controlled.
Finally we arrived at the moment of the treatment. The final step was to define the right way to apply the chosen consolidant and record the result in term of general effectiveness.
The models were used to design the correct method and different application options:
-by brush
-by brush trough an interleaf
-nebulized
-misted
All these methods were evaluated with or without a manual local pressure during the drying process and loss of the solvent part of the consolidants solution.
The source of this local pressure was chosen testing low-pressure(vacuum from the back, Micka plates), silicon-rubber tools and, as final option, finger nails. This last option was the best and it, symbolically, demonstrate that the conservator manual experience is still essential to achieve a good result.
The treatment on the Sironi painting was finally carried out using Fluoline HY in a 3% concentration in Butilacetate applied several times by brush followed by a manual pressure(finger nails) during the fast drying process(5 to 8 minutes). It was evident also that the concentration of the solution on the brush was changing after few strokes. This evidence drove us to reconsider the mean of the “right concentration”. If we want to respect an exact concentration we need to clear our brush ever three or four strokes because the amount of consolidant is concentrating depending on the time application. An interesting issue on the way conservators think to manage the “correct percentage” of any consolidants solution.
The consolidants was applied several times depending on each part of the composition without giving problems of change of refraxion. The fast drying(in 5 minutes was completely invible) times allow to repeat the treatment and go locally were the needs of consolidation were severe. After 5 to 8 applications it was possible to gently push on the surface to flatten the flakes and achieve a very good result. Only one figure, executed with thick zinc white, had to be treated in a different way because Fluoline wasn’t enough strong. This area was wormed up with a infrared lamp and a 10% Beva 371 in Cyclohaxane was applied with small brushes into the cracks and, after complete evaporation, pushed down with an heated spatula.
At the end of the consolidation process it was possible to measure the amount of consolidant used for the treatment. On a surface of more than 5 square meters 1.2 liters of FluolineHY and after complete evaporation of the solvent we calculate that only 35 grams of solid resin were inside the painting.

Colorimetric measures were repeated after the treatment with good results and raking light images taken exactly like the one before demonstrate the effectiveness of the intervention.
The final part of the work was to remount the painting on his stretcher with a double loose lining.
Three year passed since the end of this problematic treatment and the result it’s still very positive also if the climatic conditions are not so good.