DIAGNOSIS AND CONSERVATION OF A SCULPTURE CARVED OUT OF PHENOLIC FOAM

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ABSTRACT: *The aim of this work is to present, in a coherent and precise manner, some preventive conservation and treatment processes that were carried out on a sculpture which was created by a living artist who is a firm admirer of new technology.*
This paper summarizes the results of a study on how efficient diverse consolidants and protective coatings are when used as a preventive method on a certain type of material that has not yet been widely studied in the conservation field. Several application techniques were tested to select the best method to better preserve the material.
Results are shown of the conservation process that began with a consolidation phase using a vacuum chamber and an aqueous consolidant. Several studies in which different consolidants were tested were carried out. Finally, a comparison was conducted between different consolidants to determine the advantages and disadvantages of each material.

KEYWORDS: conservation, restoration, preventive methods, consolidation, coatings, contemporary art, phenolic foam

INTRODUCTION

With the constant introduction of new technologies, new materials are ever increasingly being employed as mediums of art. Consequently, artists are experimenting with materials that they previously were unaware of. The result is an eclectic variety of contemporary artwor ks where procedures, techniques and heterogeneous materials are all combined. A follow on effect of this is that the ageing of these new materials and their possible alterations, caused by different types of degradation agents such as physical, chemical, biological and human, are unknown. These degradation processes are therefore under investigation.

Under these new circumstances, the various conservation treatments that are currently in use need to be revised and updated regularly, using new intervention criteria to preserve materials better. It is, however, a fundamental prerequisite to establish a dialogue with the artist before starting any conservation, in order to define which, if any, intervention criteria is relevant. José Romero, the artist whose work is the subject of current research commented that he thought it was "very interesting to start thinking about preventive conservation with this type of work, to establish the resistance and stability of materials, due to their unique make up."

The link that the artist has with the restoration work is significantly important; not only should it be consistent, but it should also guarantee that all restoration tasks are faithful to the plastic idiosyncrasies of the work.

The sculpture under examination was created by the Valencian artist José Romero during 1998-99, while he was living in New York City. The piece, entitled ¨Voces Cautiva¨, consists of 150 small figures carved out of phenolic foam. The approximate dimensions of these figures are: 25-30 cm x 8-10 cm x 4-6 cm (HxWxD).

The pieces were in a relatively poor state of repair, due to the inherent characteristics of the material, as well as damage incurred during transport and handling, whilst they were being prepared for display. The pieces are very friable and in some instances a certain amount of "volumetric loss" in the material was observed.

METHODOLOGY

A. MATERIALS: PHENOLIC FOAM

Phenolic resins (bakelites) are one of the oldest known thermosetting polymers. They were originally synthesized by L. M. Baekeland in 1909 from the reaction between formaldehyde and phenol (1). Today they are still considered a very important polymer, due to their efficiency as electrical insulators, low flammability, high humidity retention and low cost. Phenolic foams are employed in nuclear encasements, acoustic structures for buildings, fire retardant panels in airplanes and bases for floral arrangements. Artists have also experimented with phenolic foams as a new medium for their works. Therefore, it is not surprising to find works in modern and contemporary art museums in which phenolic foams have been employed. However, the reaction of the foam with atmospheric oxygen accelerates its deterioration by making it a more friable material.

Schematic 1 shows the industrial level synthesis reactions of this type of phenolic resin. The phenolic resin in the sculptures that were used for this research belongs to Resol type (2). Two samples of these resin products were analyzed in this project: one was supplied by the artist and was of the same batch used to carve the sculptures, and the other was independently supplied by SMITHERS-OASIS® GERMANY GMBH.

The consolidants used in the study include Paraloid B-82® (methyl methacrylate resin), Plextol B-500® (thermoplastic

Figure 1.- A/B.- Details from the sculptoric group "Voces cautivas" by Valencian artist José Romero, Nueva York, 1998-1999

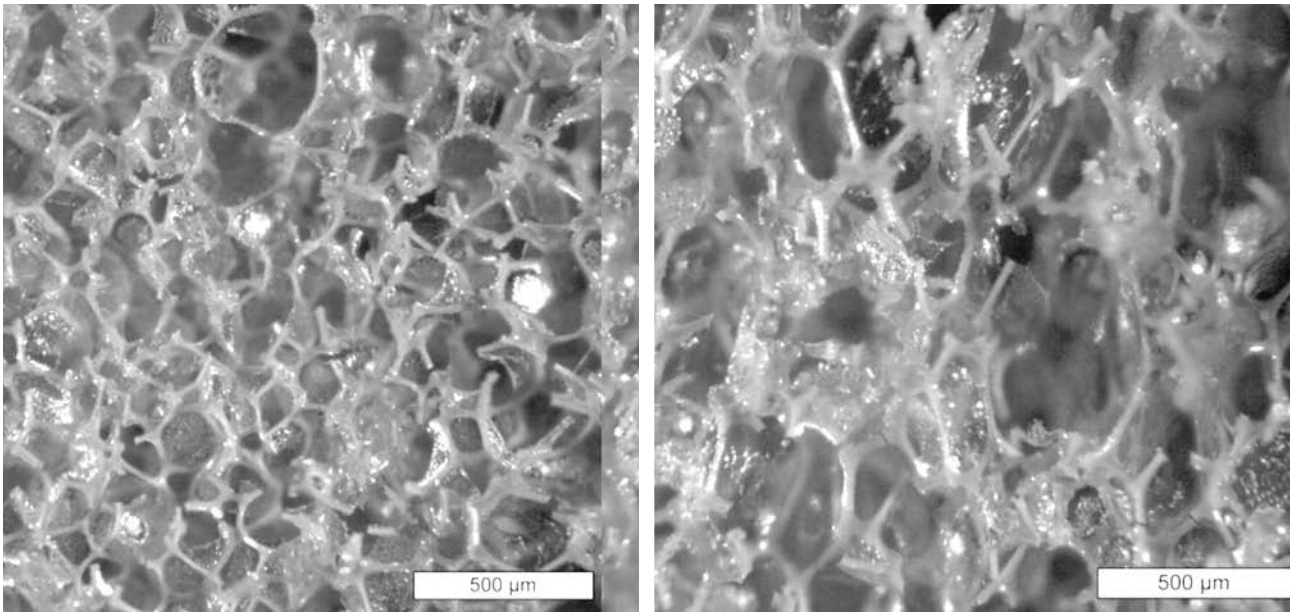


Figure 2.- A/B.- A. Microphotograph of an original phenolic foam sample used by the artist and consolidated with Mowilith SDM-5®. A uniform layer was observed over the entire surface in the sample. B. Microphotograph of a new phenolic foam sample consolidated with Paraloid B-82®. An accumulation of consolidant in the form of white nodules can be observed in the internal structure of the foam

acrylic resin) and Mowilith SDM-5® (vinyl acetate-acrylic ester copolymer) supplied by CTS. The concentrations employed were 5 and 10% (w/w) in distilled water for Plextol B-500® and Mowilith SDM-5®. The Paraloid B-82® was diluted with ethyl alcohol and water using a 9:1 ratio. Partial immersion and vacuum impregnation were the two methods employed.

B. INSTRUMENTS USED

- Struers vacuum impregnation chamber with Epovac, equipped with an Aero-pro Classic air compressor operating at 4.5-6 bar, with the capability of reaching a vacuum of 660 mm Hg.

- Analytical balance by Precisa Instruments, model BJ410 C, ISO 9001.

- Leica GZ6 stereoscopic microscope equipped with a Leica CLS100 cold light source with ringlamp.

- Jeol JSM 3600 scanning electron microscope (SEM) coupled with a Link-Oxford-Isis X-ray microanalysis system. The SEM/EDS was operated at 20 kV with an electron current of 2x10-9 A and a work distance of 15 mm. The samples were coated with gold prior to analysis.

- Vertex 70 Fourier transform infrared spectrophotometer (FTIR) made by Bruker Optics® with a MKII Golden Gate ATR accessory. 32 scans were collected at a resolution of 4 cm-1 and spectra were processed using OPUS/IR software.

- Cromatic coordinates obtained over a uniform surface of the test specimens were measured using a Minolta CM-2600d spectrophotometer. The standard illuminant CIE D65 (daylight, color temperature 6500º K) and a 10º standard observer were employed. Data was recorded with a specular component (SCI) that minimized the influence of surface conditions and with an excluded specular component (SCE) that correlated more to a professional visual evaluation. The area of measurement selected was 3 mm with diffuse measurement geometry of 8 (d/8). The light source consisted of three pulsed Xenon lamps with an integrating sphere of Ø52 coated with BaSO4. The wavelength range and pitch

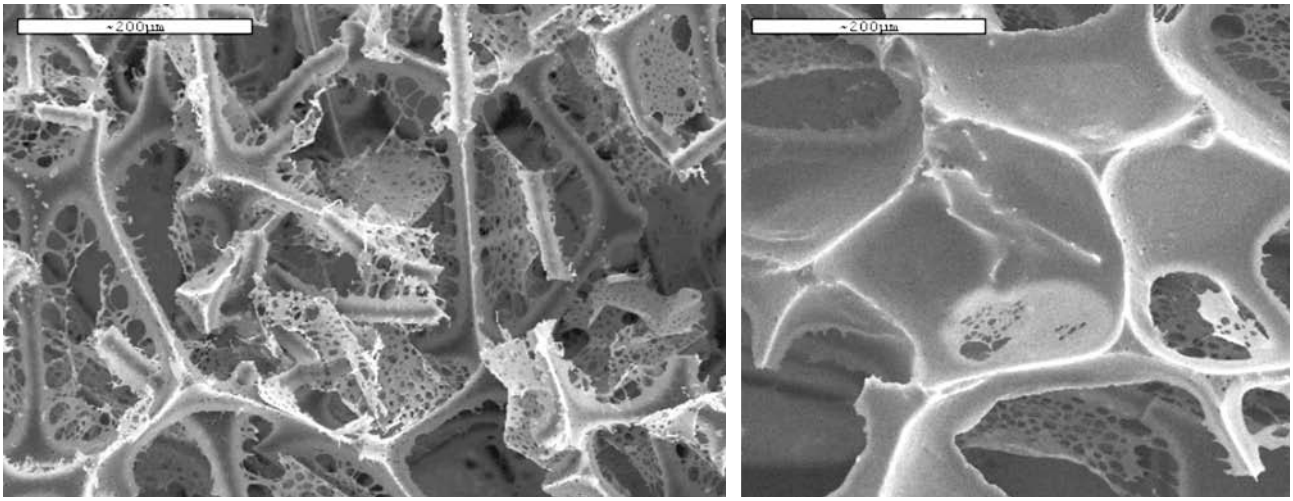


Figure 3.- A/B.- A. Microphotograph using secondary electrons (200µm). Sample showing the internal structure of the foam used by the artist. B. Microphotograph using secondary (200µm). Sample of the internal structure of the foam used by the artist after consolidation with Mowilith SDM-5® (10% in distilled water)

used was 360-740 and 10 nm respectively. The instrument had a reflectance range of 0-175% and a resolution of 0.01%. The standard deviation was 0.1% for spectral reflectance and 0.04% for ΔE*ab (CIE 76) colorimetric values respectively. The CIELAB color space was used due to the fact that it is adequate for secondary source measurements and also due to its uniformity, which makes comparison of results much easier.

C. METHODOLOGY

1. Preparation of test specimens and consolidation methods

Twenty four test specimens with cubic dimensions of about 4 cm^3 were prepared. The first half consisted of new phenolic foam and the other half was prepared using the original phenolic foam employed by the artist. These test specimens were divided into two groups: 12 for partial immersion and 12 for vacuum impregnation.

A description of the consolidants and the application methods tested is presented in Table 1. Each type of phenolic resin was tested against the three types of consolidants, all of differing levels of concentration and this was applied by either immersion or impregnation.

Partial immersion was carried out using the following sequence: 5 minutes of partial immersion up to one quarter of the total height followed by 10 minutes of total immersion.

The vacuum impregnation method procedure was defined after a series of preliminary tests. The method consisted of three phases:
- Extraction of the air from the porous network under vacuum for 5 minutes.
- Impregnation by percolation of the consolidant during 40 minutes at a pressure of 200 mm Hg.
- Impregnation by partial immersion (1/4 of total height) at 200 mm Hg during 15 minutes.

2. Preparation of samples for instrumental analysis

Solid cubic samples of 1cm^3 were extracted from the center of the test specimens and prepared for optical microscopy, SEM/EDX, spectroscopic analysis and FTIR spectroscopy.

Optical microscopy
The reticular structure of the test specimens was examined by stereoscopic microscopy both before and after consolidation so as to compare new and old phenolic foams. The cells presented changes in color and size which is indicative of major or minor absorption of the consolidant. A higher absorption of consolidant was observed in the original foam compared to the newer one. An interesting observation was the formation of a white precipitate on the surface of the test specimen after treatment with Paraloid B-82®. This effect was even more visible at 2 mm below the surface. This build up made the sample more resistant on the surface compared to the rest of the test samples, but deprived it of some of its internal strength. Therefore, it is still important to establish if the 2 mm area is completely impermeable.

Examination by electron microscopy
The conservation treatment was visible after using three consolidants and a thin homogeneous film of a few microns was observed. This thin film saturated the reticular structure without obstructing the pores. Samples treated with Paraloid B-82® did not show any layer resulting from the presence of consolidant. The nodules of the test specimens showed, after X-ray microanalysis, traces of calcium carbonate. However, no significant differences were observed when comparing the two consolidation methods. The consolidant penetrated the porous cavity filling it entirely and, after evaporation of the solvent, the porous reticule became more consistent.

Study of the increase in mass
A summary of consolidant retention values obtained for each test specimen taken over the course of a week is presented in Table 2. These values were obtained by weighing the materials before and after the treatment. A considerable increase in mass was observed in the original phenolic foam samples employed by the artist. This effect was due to the altered internal structure of the material. It is important to mention that test specimens involving Plextol B-500® and Mowilith SDM-5® completed their consolidation process in approximately 4 days while the systems in which Paraloid B-82® was used only required 36 hours.

Spectroscopic IR Analysis
Spectroscopic IR Analysis was used to try to detect the presence of consolidate in the material in question, ie phenolic resin. Three different consolidates of different levels of concentration were compared together with the application method on the new and original foam.

FTIR analysis
Significant amounts of consolidant were detected in the FTIR spectrum of each test specimen. The FTIR spectra of phenolic foams (Figure 4), both untreated and treated with Mowilith SDM-5® (3), shows bands at 1600 and 1440 cm-1 associated with C=C vibrations. The spectrum of the consolidated sample presents a band at 1477 cm-1 which is associated with CH2 vibrations of the phenolic resin. No discernible changes were observed after comparing the FTIR spectra of two consolidation methods.

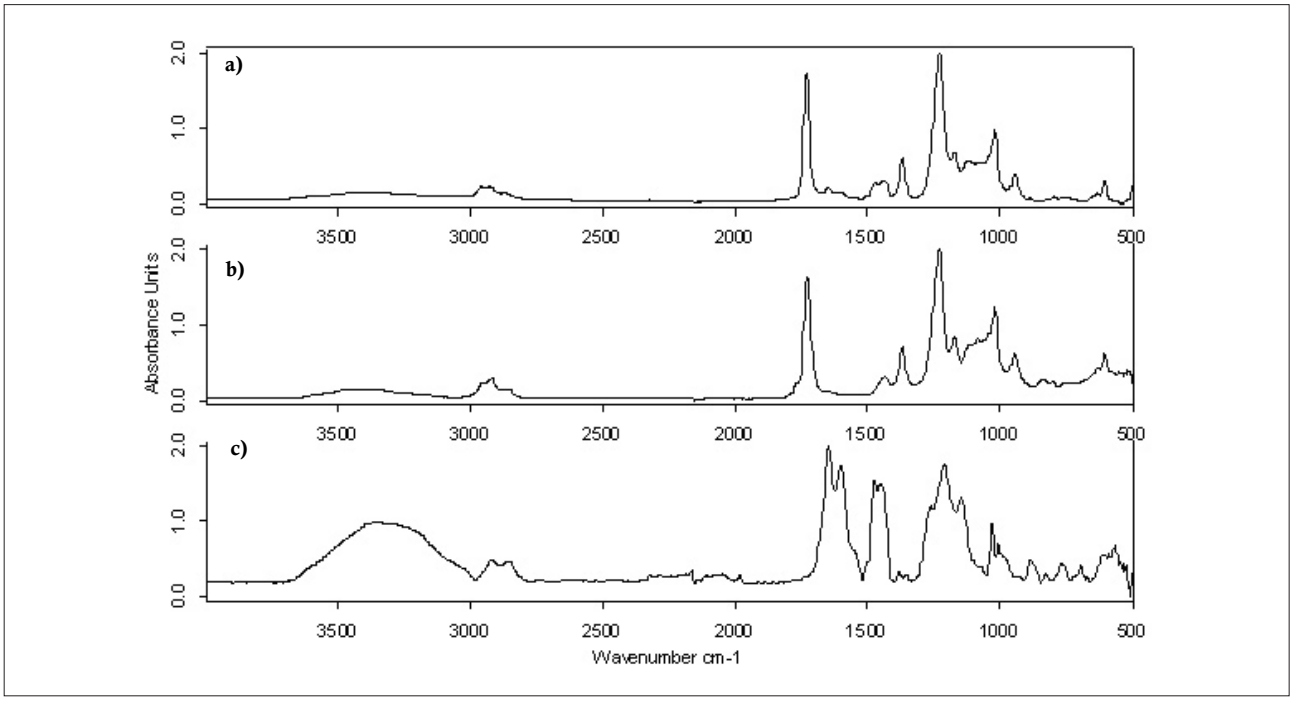


Figure 4. FTIR/ATR spectra of **a)** phenolic foam sample treated with Mowilith SDM-5® (10% in distilled water), **b)** Mowilith SDM-5 resin sample and **c)** sample of phenolic resin before treatment

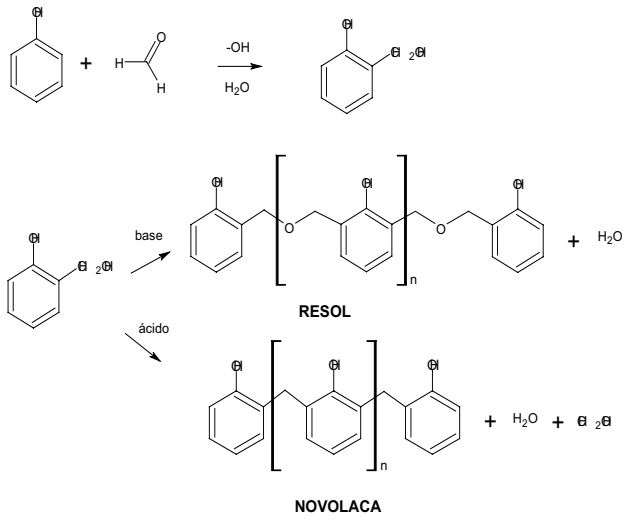
Colorimetric study

The main objective of this study was to determine the chromatic variation observed in the test specimens before and after the consolidation. A summary of the changes observed in the chromatic coordinates (L*, a*, b*) for the two types of foams after consolidation is presented in Table 3. The results show that the samples of the newer foam consolidated with Plextol B 500® and Paraloid B-82® increase their luminosity while the ones treated with Mowilith SDM-5® show the opposite effect. On the other hand, test specimens prepared with original foam treated with Plextol B-500® show a slight incr ease in luminosity when compared to the group treated with Paraloid B-82®. The a* and b* values for the new foam show a tendency towards the green after consolidation, while the original foam has a tendency towards the yellow. Samples 10 and 11 of the original foam treated with Mowilith SDM-5® were the only exception to the previous statement. These samples exhibit similar values (L*, a*, b*) to the ones obtained for the untreated sample.

CONCLUSIONS

Test specimens of both new and original material consolidated with three different types of aqueous solutions allowed an initial evaluation of the intervention process carried out on a real sculpture that was the subject of this study. Both types of foam had a reticular structure of thin walls and open pores although some alterations were observed in the original foam. Test specimens treated with Plextol B-500® and Mowilith SDM-5® in particular, exhibited a more homogeneous distribution and an adequate fixation as shown by major increments in mass after consolidation. On the other hand, test specimens treated with Paraloid B-82® show evidence of a residue consisting of white nodules at approximately 2 mm under the surface of the sample. A thin film of consolidant which increases the internal cohesion of the deteriorated material was observed in all the specimens that were tested. With the exception of Paraloid B-82®, all the systems exhibited a non obtrusive uniform effect in the porous network. On the other hand, the curing time was higher for test

ANNEX



Scheme 1. Synthesis reactions of a phenolic resin from formaldehyde and phenol, followed by the possible reactions to form the novalac and resol types in alkaline and acidic medium respectively. Adapted from Gnauck B and Fründt P, 1991, p.169.

APPLICATION METHOD	PARTIAL IMMERSION FOAM NEW/ORIGINAL		VACUUM IMPREGNATION FOAM NEW/ORIGINAL		SOLVENT
Type of consolidant	Concentration %		Concentration %		
Mowilith SDM-5®	5	10	5	10	Distilled H_2O
Plextol B-500®	5	10	5	10	
Paraloid B-82®	5	10	5	10	H_2O/Ethyl alcohol (1:9)

Table 1. Consolidants and application methods used in the study

TYPE OF CONSOLIDANT/ CONCENTRATION %	REF.	% INCREASE IN MASS	% CONSOLIDANT
PLEXTOL B-500® 5% H_2O.	1 C	506,15	83,50
	5 P	128,33	56,20
	6 P	433,33	81,25
	7 C	531,57	84,16
PLEXTOL B-500 ® 10% H_2O.	2 P	413,69	80,53
	9 P	488,40	83
	17 C	263,51	72,49
	18 C	407,27	80,28
MOWILITH SDM-5® 5% H_2O.	3 P	448,38	81,76
	11 P	882,69	89,82
	13 C	122,38	55,03
	16 C	436,92	81,37
MOWILITH SDM-5® 10% H_2O.	4 C	592,95	85,56
	8 P	973,52	90,68
	10 C	1187,5	92,23
	12 P	1030	91,15
PARALOID B-82® 10% H_2O + Alcohol.	20 P	461,4	82,19
	22 P	295,3	74,7
	23 C	323,07	76,36
	24 C	529,16	84,10
PARALOID B-82® 5% H_2O + Alcohol.	14 P	97,05	49,25
	15 P	138,80	57,05
	19 C	323,07	76,36
	21 C	80,28	44,53

Reference: aged foam	C: impregnation method
Reference: new foam	P: vacuum impregnation method

Table 2. Relative values of increase in mass (%) of the specimens tested with different consolidants and application methods

REFERENCE	ΔL*	Δa*	Δb*
Sample 1	-0.14	-8.41	-3.01
Sample 2	1.19	-8.11	-1.48
Sample 3	-1.75	-4.72	-2.29
Sample 4	2.65	-5.40	-2.55
Sample 5	4.32	-3.38	-1.75
Sample 6	2.95	-5.83	-1.67
Sample 7	2.62	-8.73	-2.25
Sample 8	4.48	-5.97	-3.16
Sample 9	2.19	-6.81	-1.90
Sample 10	0.03	-5.20	-0.13
Sample 11	-0.50	-5.86	-0.99
Sample 12	-2.72	3.53	7.40
Sample 13	-0.92	-2.66	-0.94
Sample 14	4.08	0.78	-2.13
Sample 15	5.26	-6.45	-1.65
Sample 16	1.93	-3.00	-0.42
Sample 17	5.10	-7.51	-2.74
Sample 18	-1.32	-5.12	-0.46
Sample 19	2.57	-4.30	-2.48
Sample 20	2.51	-3.93	22.11
Sample 21	4.79	-0.64	-2.01
Sample 22	0.02	-0.72	-2.34
Sample 23	5.02	-0.04	-1.80
Sample 24	7.14	-3.64	-2.70

Table 3. Increment in the chromatic coordinates (L*, a*, b*) of the samples after consolidation. Sample: immersion method. Sample: vacuum impregnation method

specimens treated with Plextol B-500® and Mowilith SDM-5® compared to the ones treated with Paraloid B-82®. The chromatic changes were not significant and no visually detectable colorimetric responses were observed. Finally, the test specimens showed both tactile stability and an ideal texture after consolidation.

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The authors wish to express their gratitude to Marisa Martínez Bazán for her assistance with the colorimetric measurements.

NOTES

(1) For additional information, see Areizaga et al., 2002, p.371.
(2) Phenolic resins may be classified in two types: novalac and resol, with the Resol type being more common in foams due to their ease of synthesis. Acidic a nd basic catalytic agents are employed for novalac and resol respectively (Gnauck and Fründt P, 1991. p.169).
(3) References for FTIR spectra were consulted in Rout et al., 2003 and Alonso et al., 2005.

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Versión española

TÍTULO: ***Diagnóstico y conservación de una escultura tallada en espuma fenólica***

RESUMEN: *El presente trabajo pretende dar una visión coherente y precisa sobre la propuesta de intervención y proceso conservativo-preventivo llevado a cabo sobre una pieza escultórica de un artista vivo, contemporáneo y claro admirador de las nuevas tecnologías.*
Este trabajo resume los resultados más relevantes de un estudio sobre la eficacia de diversos productos consolidantes y protectivos utilizados como método preventivo en un material hasta ahora poco conocido en el mundo de la Conservación y Restauración de Arte Contemporáneo. Diversas técnicas de impregnación han sido, asimismo, sometidas a estudio con el propósito de seleccionar el método que proporcionara las mayores garantías de conservación del material alterado.
Asimismo, exponemos el resultado del proceso de conservación, que se inició con una fase de consolidación, acometiéndose mediante cámara de vacío y un consolidante acuoso. Previamente, se realizaron diferentes ensayos con distintos consolidantes sobre probetas del mismo material. Por último, se determinaron las ventajas y los inconvenientes entre los diferentes consolidantes ensayados.

PALABRAS CLAVE: *conservación, restauración, métodos preventivos, consolidación, protectivos, arte contemporáneo, espuma fenólica*