MECHANICAL STRENGTH PARAMETERS ON POLYESTER FABRICS. TREATMENT APPLIED IN SUPPORT OF LARGE CANVAS PAINTING : "THE EXPULSION OF THE MERCHANTS FROM THE TEMPLE" BY ARTIST SAVERIO LILLO. (1734-1796)

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ABSTRACT: *The twentieth century significantly facilitated the involvement analysis of the works from a more complex view, with the development of industry and science. Interdisciplinary studies became inextricably linked to the growing field of conservation and restoration understanding the conservative properties of the materials applied on paintings conservation.*
Since then when the conservators began to consider the application of synthetic fibers on support reinforcement on canvas paintings. Pictorial interventions, pursuing the purpose that it was none other than textile reinforcement systems, are safer and stable than those that had been done up in the time.
Throughout the decades of the eighties and nineties, there was a great progress in this area, developing the application of new synthetic fabrics such as the so called non woven fabrics, polyester fibers, polyamides and others.
These fibers were analyzed jointly by conservators and scientist evaluating the pros and
cons of each, always emphasizing the assumptions of minimum intervention and maximum reversibility, obtaining minimum contribution of stress in the work.
This article discusses the use of tissues in the intervention of strengthening the textile support and how their study has allowed the development of new materials and methodologies in this area, showing how such use in a painting on canvas large format "The expulsion of the merchants from the temple" by Saverio Lillo. (1734-1796)

KEYWORDS: synthetic fibers, mechanical behaviour, painting support reinforcements, Saverio Lillo, oil painting restoration, scientific examinations

1. INTRODUCTION

From the end of sixties and early seventies, began to carry out the first tests of synthetic Fabrics on polyester, polyamide and glass fibers used to the reinforcement support operations on canvas paintings. These studies allowed knowing better long-term conservative properties of materials. Established since then the parameters should have a good fabric in the conduct of general reinforcement of the paintings, stressing its dimensional stability, toughness, flexibility, recovery, future conservation… and of course its affordability.

The aim was to get reinforcements systems more secure and stable than they had been used before. These new materials emerged as an alternative to organic fabrics used so far. Was A. G. Roche with Hedley who described in the eighties, the physical properties that should have a *good fabric* to be used with optimal guaranties on general reinforcements on canvas painting.

Consequently, C. With D.Young Hibberd extended Hedley studies, and in 1999 published his research about the influence of certain factors that determine the structural properties of tissue.

Along with other researchers, analyzed the isotropic behaviour of textiles and dimensional stability in all axes as one of the key terms to consider before selecting a good fabric reinforcement.

2. PHYSICAL AND CHEMICAL PROPERTIES OF SYNTHETIC FIBERS 100%POLYESTER

The search for synthetic fabrics to paintings reinforcements was developed from the seventies. Since then they, begun testing polyester fibers for use on reinforce support textile on canvas paintings.

Initially these tissues were manufactured by the *British house Power weave 440* and studied by G. Hedley, whose papers in the Conference of ICOM, 1975, presented the first studies on the implementation of these fibers in general called *sail-cloth*. These canvases were used in the field of navigation and their fundamental properties that made them suitable for use in its light scrim with optimal rigidity and elasticity, high mechanical strength, good response to abrasion, good isotropic behaviour, and dimensional stability in all axes.

Also, be quoted as main advantage compared to the fabrics that the conservators had used up to now, its great stability to humidity and the attack of moisture.

In the 1980s Hedley, C. G. Vickers and Alain Roche continued their studies and test on the properties of these fibers, and published the positive results, who established comparative studies between reinforcements made using linen and polyester. Any type of fabric, shows a high stability and mechanical behavior to the inherent movements of the canvases, and has very good resistance properties to humidity and oxidative environments[1] . In this way, the tests of peeling showed such as polyester could be a good alternative in comparison with the results obtained by natural fibers such as flax.

The main reason of their behavior comes determined by the composition of the polymers obtained by polycondensation of dicarboxylic acid and diolein. These kinds of fabrics are made from polyethylene terephthalate multifilament high strength, and are easily manipulated.

The main properties of these fibers differ greatly from those of a conventional fabric, because their manufacture has different kind of traditional textiles. That makes each filament shrink irreversibly, resulting in a more compact tissue, stable and waterproof, while maintaining its flexibility, which makes it an ideal fabric for the performance properties of the scrim. As reference, we can able to indicate that in 65% of relative humidity, these fibers absorb 0,4% of water, in front of 12% retained by the flax.

It has been tested dimensional stability of polyester fibers and their resistance to environmental acid contaminants, with experiments in immersion solutions of sulphuric acid, studying their stability up to 1000 hours aging, obtaining very positive results of their chemical and physical aging.

It has also been studied their mechanical behaviour, being more stable to abrasion than other natural fibers like linen and cotton, and even having greater resistance than other synthetic type, such as Kevlar and polypropylene fibers (polyamide). In terms of rheological properties, the polyester has a resilience of the deformations of 40%, compared to 16% of flax.

3. EXPERIMENTAL: SUBSTANCES AND TYPES OF JOINTS TESTED

Our study was focused on the mechanical analysis of two types of fabrics distributed by the company CTS (SPAIN). Both manufactured with composition 100% polyester, but with different density and thickness. Belonging one to them of 19x19 threads/cm^2, and the other 23 x26 threads/cm^2. The selection of this type of tissue was determined by previous studies with results about its high resistance to air pollutants, toughness and good elastic recovery strain.

In order to establish comparative strength and / or applicability to wild-type fibers were tested also natural cellulosic fibers, explicitly flax fabric (20 x 13 threads/cm^2).

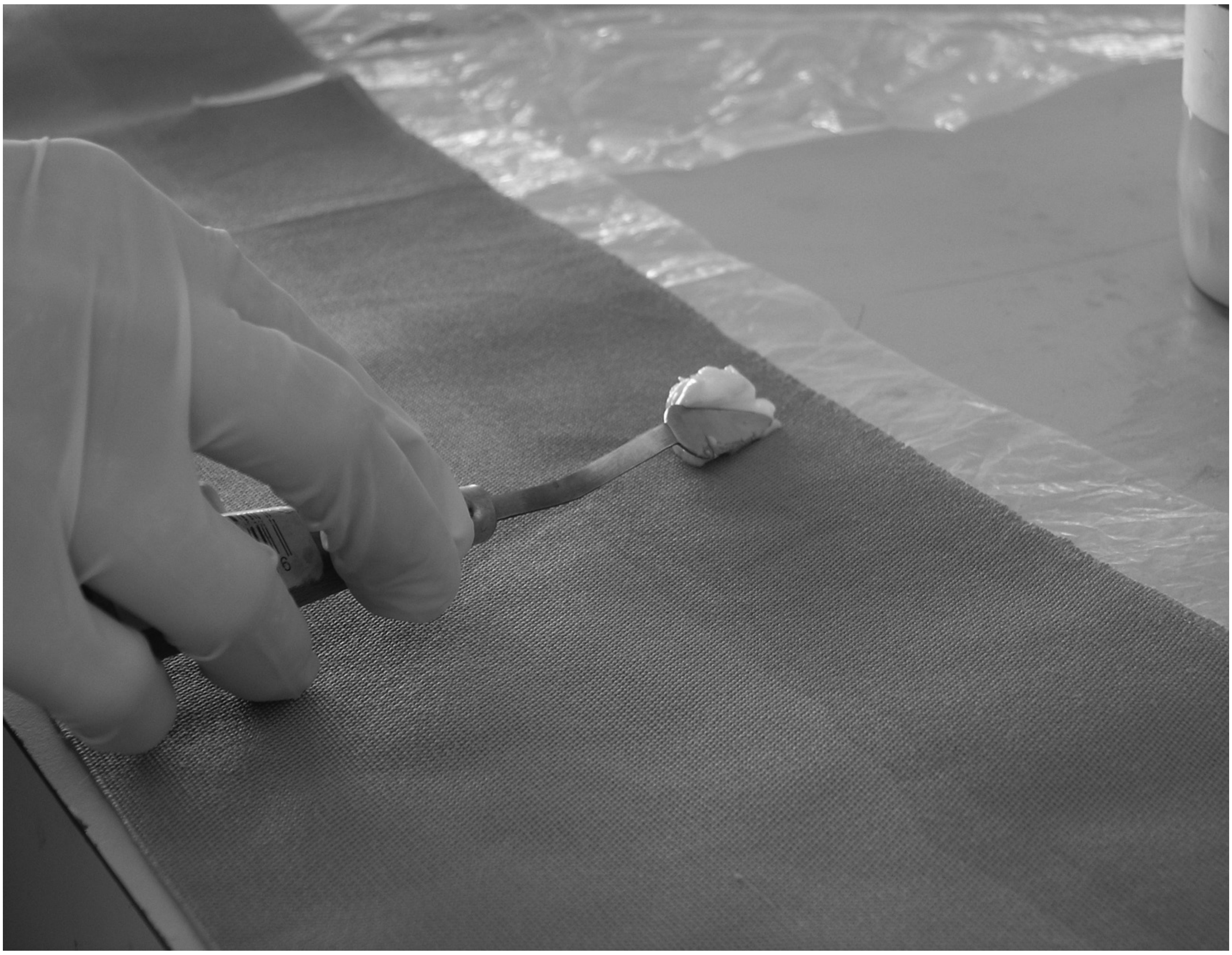


Figure. 1. Analytical test with polyester fabrics

We attended different aspects from adhesives tested, among them: good adhesive properties, stable structure and good durability over time. Other pursued parameters were, compatibility with the original canvases materials, good applicability and easy reversibility.

The test established comparative heat sealing adhesives based Eva (Beva-371®/ diluted in white spirit), and contact adhesives (Plextol B-500® thickened with xylene), to enable us to obtained conclusions between the suitability of each material and method.

EVA thermoplastic adhesive (Beva-371®) was diluted in xylene at a rate 75% -25%, and warmed in a water bath until it reaches the melting point of the substance. Subsequently, the application was made by rolling the fabric in the direction of the weft and warp alternately. We applied a total of two layers, with an interval of 12 hours between coats to allow proper formation of the sealing film.

By focusing our studies on treatments perimeter of the textile support, the provision of textile reinforced adhesive and its treatment make the design of adhesive bonding is known as *overlapped union*. This type of joint is performed between two substrates together, to form overlapping each other. This particular type of adhesion is used in perimeter reinforcements on canvas paintings called strip lining.

After establishing a set of testing protocols, prepared in identical form the samples with the purpose of reproducing the exact form of working later with the work. The comparative conclusions could settle down among the results obtained with each one of the analyzed materials, such as the amount of adhesive cure times, pressure etc ... The environmental conditions of the sampling were of a constant temperature of 25ºC and a relative humidity of 45%.

We prepared 50 tests of 100% polyester fabrics. 25 samples for each type of polyester (described above) steeped in hot-melt adhesive of the study. And 25 samples from the same fabrics were used for studies about contact adhesive or cold seals.

Overlapping type and adhesive joints have been described in the previous paragraph. Half of them were subjected to accelerated aging, in order to make comparisons between the behaviour of the materials to short and long term.

On carrying out shear tests of standard specimens, were used peeling following the Spanish standard (NPC 53538). All sampling were subject to accelerated aging in the chamber, climatic aging (DYKOMETAL) for 72 hours. Where the samples were affected by sharp changes in humidity and temperature, the following periods marked by other researchers, studied the deformation and strength parameters of textile fibers.

The samples were subjected to 4 continuous cycles of 30 ', start with an average temperature of 20 º and 65% RH, which was sharply declining and ascending cycle to cycle during the scheduled time.

4. TRACTION DETACHMENT RESISTANCE

The tests made in the stripping Texturimeter-TA-XT2i provide us the information about the characteristics and behaviour of an adhesive bond between two substrates. The test is to measure the force required to separate two materials off at 180 º[2].

To assess the reversibility of the interventions, hot melt adhesives were regenerated to reach its glass transition temperature (Tg), by applying heat using an infrared lamp for 15 seconds, reaching the surface temperature is approximately 50 degrees (measured with an infrared thermometer). In the case of the tack-melt, the samples were subjected to vapors of acetone, once regenerated were placed in the testing machine with a continuous speed of 0.1 m / min.

The average temperature in the place of trial was 25 º C with a relative humidity of 50%.The final result values obtained were the mean of five samples of the same type of test on each adhesive bond.

4.1 Breaking Strength

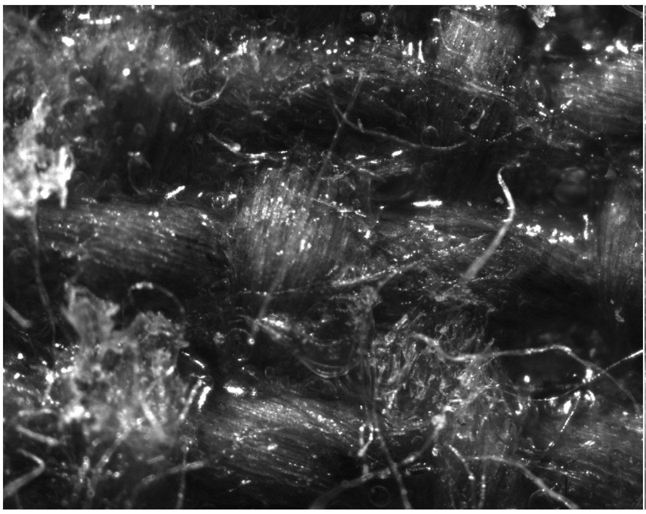
The shear test determines the mechanical properties of a material by applying tensile forces up to the rupture. This test is the maximum voltage that holds up a sign along its major axis at a constant speed[3].

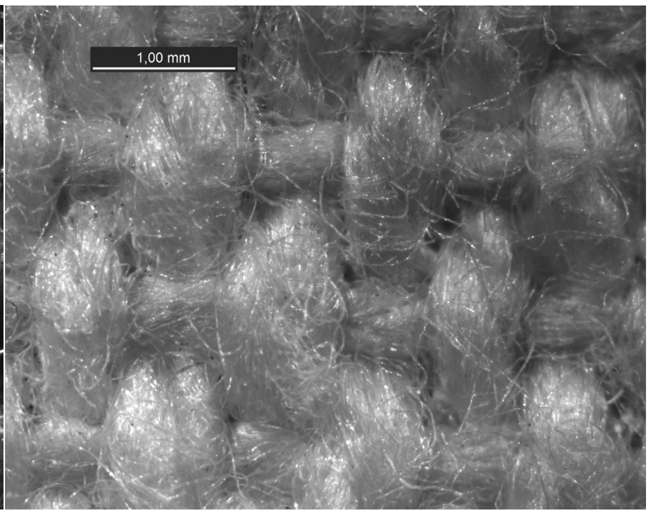
After measuring the thickness and width of the specimens using a calliper to calculate its area, were placed plucked from the jaws by the testing machine at the top and bottom, and proceeded to perform the test at a speed of separation of 50mm/min until the tensile strength. As in the previous case, there were averages of five repetitions of the same trial, with which to obtain media data, that enable us to establish some margins of error.

4.2 Conclusions About Adhesion/Mechanical Test

On testing and studying the quality and physical-mechanical response of bonded joints, were obtained the following results:

• 100% polyester fabrics 19x19 thread /cm^2 (Trevira), were used in reinforcements by binding to overlap. Their suffer a maximum tension of 5.72 N, lower than that achieved by linen 20x13 thread /cm2, reaching 8.96 N.





Figures. 2 y 3. Flax (left) and Polyester (right) fabrics after peel test

• From the standpoint of reversibility, the linen fabrics create stronger attachment points, and retain more adhesive causing failure of the original substrate, compared with 100% polyester fabrics, which show mostly adhesive failure favouring separation between substrates.

• Strengthening 19x19 thread /cm2 100% polyester (Trevira), was used as reinforcement on lap joints with contact adhesives, it showed a break-up time in 11seconds. Being lower, when was impregnated with a thermoplastic adhesive, the time breaking down to 4 seconds.

• Flax fabric 20x13 thread /cm2 adhered with contact adhesive undergoes a maximum voltage of 16,97N/mm opposite to 100% polyester fabrics 23x26 thread /cm2 that did not exceed to 5,2N/mm.

5. RESTORATION OF THE PAINTING "THE EXPULSION OF THE MERCHANTS FROM THE TEMPLE" BY SAVERIO LILLO (1734-1796)

The restoration of this painting created a series of objective difficulties and problems, compounded by the approximate preliminary assessment of the state of preservation of the work, carried out by the client, and by the lack of means. The working technique, inspired by Minimal Intervention methodology, was made possible by the general condition of the painting and the auxiliary support and was applied simultaneously to the obverse and reverse sides of the work, hence avoiding exposure to excessive dynamic stress.

The work, signed and dated - XAVERIUS LILLO A' RUFFANO P. 1767 -, (Figure. 1) is situated in the Church of the Natività della Beata Vergine Maria in Ruffano, in the Province of Lecce. It is part of a pictorial cycle executed from 1765 onwards by the artist Francesco Saverio Donato Lillo (Ruffano 1734-1796). (De Bernart and Cazzato, 1997: 46). The painting depicts a passage from the Gospel According to Matthew, the Expulsion of the Merchants from the Temple, which the artist has located in a lavish setting, enlivened by the many Figures set against a classical architectural backdrop.

The "Expulsion of the Merchants from the Temple" has been on the church facade since its execution, occupying an area measuring 44 m^2. The lower edge follows the line of the 17th Century wooden polychrome portal. The painting is bounded on either side by two pilasters, which prevent its being moved forwards, and furthermore the presence of the portal makes it impossible for the painting to be moved downwards. The canvas had been fixed to the wall by three L-shaped hooks and an equal number of two-holed brackets and fixed to the top of the frame with forged nails. In order to reduce the weight on the upper hooks and ensure the painting's adhesion to the back wall, another six identical supports had been affixed to the two lower edges. The central part of the painting, which delineates the top of the portal, was not supported in any way.

5.1. Technique and scientific research

The fabric used by the artist is a particularly dense, 11x11 cm^2 canvas weave. The entire support was constructed by putting fourteen strips together vertically, seamed along the selvedge with a similar thread to the canvas one, with the weft running horizontally and the warp vertically. The width of the strips ranged between 63

Figure. 4. S. Lillo, "The expulsion of the merchants from the temple" (1767) before restoration

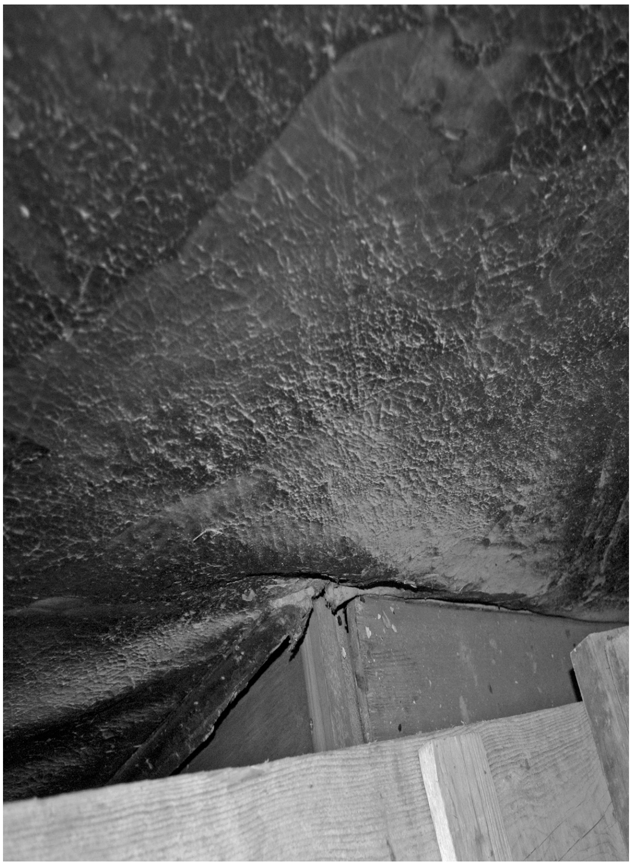


Figure. 5. Deposits of dust detail and paint distortions

Figure. 6. Right angle detail: damage and deformation of the wok. Diagonal mark from the original stretcher

and 69 cm, apart from one piece measuring 31 cm; the latter was assembled from four pieces of differing lengths, held together by three horizontal open-edged seams.

The canvas displays the typical signs of oil paintings: the ground layer has risen to the surface in small lumps or appears to be flattened, characterised by craquelure marks, some more significant inpainting and spots of paint and glue.

Scientific investigations allowed to characterize constituent materials and to verify the executive technique.

Analytical investigations were carried out on cross and thin/ petrographycal sections by optical microscopy with visible light and ultraviolet light. Some samples of paint layers were examined by staining tests (Masschelein-Kleiner, 1986: 185-189) and observations in environmental scanning electron microscopy (ESEM) supplied with chemical analyses by means of X-ray spectrometry in energy dispersal (EDS) and Fourier's transform infrared spectroscopy (FT-IR).

The work is an oil painting on a linen canvas; flax fibers were identified through microscopic observation of either diagnostic sections. In longitudinal section they look like a bamboo reed because of the trasversal dislocations, often X-shaped, while in cross section they appear polygonal to round with a very small and defined lumen (Pinna et al., 2009: 42-43).

The preparatory layer has a brown colour; it is between 200 and 500 µm thick and is formed by a micritic clay matrix where calcareous and silicate fragments, little iron oxide and hydroxide (yellow and red ochre), carbon black and orpiment (Arsenic trisulfide) are spread. FT-IR analyses verified that a lipidic compound was present.

The chromatic tones are generally achieved through a double pictorial layer; the former can be defined as a ground layer more rich in binding medium and with a darker colour; the latter, more rich in pigments, having a lighter colour. Only the red tones seem to be constituted by a single layer.

5.2. State of preservation

The support was found to be slack and deformed, demonstrating the typical undulations caused by overweight and inadequate restraints.

The worst areas of sagging and deformation were found along the edges and predominantly along the lower members of the stretcher, particularly in the centre, above the portal (Figure. 3).

The greatest damage was observed on the top edge, by the right-hand corner (Figure. 4); approximately 170 cm of the canvas having come away from the stretcher, and its own weight had caused it to become deformed and sag roughly 3 cm down from the upper edge. It may have been detached in order to repair a large lateral tear, patched on the verso with a double piece of canvas and fixed to the recto with many iron nails. The oxidisation of the nails, together with the powerful traction, had broken up the fabric, causing it to come away. The painted surface had suffered some lifting that could not be ascribed to repositioning on the support. A significant area of swirling craquelure is still visible in the centre of the area, probably caused by the same traumatic event that caused the tear on the edge.

The margins of the canvas had been strip lined and glued to the original support with flour paste. Several fabric patches had been applied to the verso. The side strips and patches had been carried

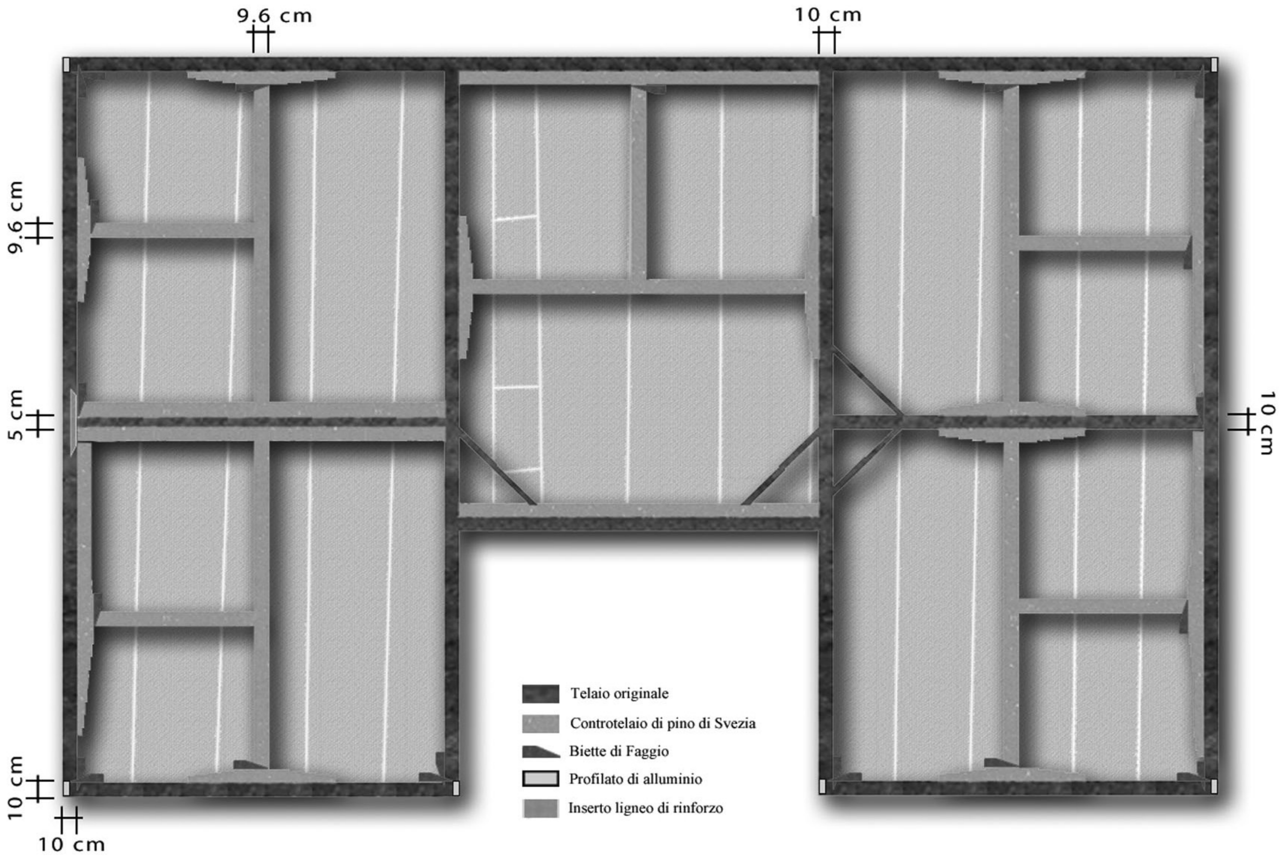


Figure. 7. Stretcher graphic reconstruction after the carpentry work

out with different degrees of precision and resistance: the patches appeared to be well secured to the support, while almost all the strips on the margins had become detached. The way in which the patches had been applied was also strange, arranged diagonally to the weft of the canvas. Because of the way they had been positioned, it was clear that they had been applied to alleviate the deformations and impressions left by the original stretcher.

6. INTERVENTION METHODOLOGY

As anticipated, the size of the painting, its shape and the difficulties in moving it, together with the unfeasibility of bringing in special, expensive equipment to move it safely, suggested that handling should be kept to a minimum. However, inspired by the work carried out to the Dro Crucifixion (TN) by Cesmar7, the decision was made to work vertically, allowing easy access to both the verso and the recto of the painting. The intervention was therefore put together by assessing the conservation needs of the canvas in relation to the adequacy of the stretcher. Following a careful examination of its state of preservation and mechanical characteristics, it was deemed possible to restore full function to the stretcher, by talking off the diagonal cross-members and constructing an internal auxiliary stretcher in order to make expansion easier and ensure better structural resistance.

6.1. Operational phases

The existing front scaffolding was used for moving the painting. The top member of the stretcher was hooked onto three pulleys with ropes, enabling the painting to be lowered to ground level and then moved approximately one meter away from the wall. Later scaffolding was erected at the back, in the space left between the masonry and the painting.

The first phase of the intervention consisted of carrying out superficial cleaning of the verso using small bristle and brass brushes, a vacuum cleaner, scalpels and damp sponges.

After a series of tests in order to decide which adhesive should be employed to consolidate the layers of paint and which method to adopt, animal glue was deemed to be the most compatible and effective.

The most complex operation, which was therefore given precedence, involved the top right-hand corner. In order to consolidate the colour, Cyclododecane spray was used: the torn area was faced with Japanese paper and colletta. After assigning two parts of the scaffolding for use as a temporary measure. The support of this portion of the painting was repositioned and drawn using a system of strips and rods, first on the upper margin and then on the edges. The perimetral strips, made of Lipari polyester canvas, were attached to the support with BEVA Film and fixed to the temporary battens with steel thread and adjustable rods. Before consolidating the colour, gentle tightening was carried out, following which the adjacent areas were slightly humidified, and the traction gradually increased.

Within the context of this operation, the margins of the bottom half of the painting were freed from their restraints in order to maximise the stabilisation and flattening of the support as a whole by means of its own weight. During this phase the old perimetral reinforcements and compromised patches were removed, although any viable reinforcements were left in place.

The consolidation of the paint layers was carried out first to the areas damaged by the warping of the support, applying 99.9% alcohol the flakes and in the lacunae as a vehicle for the glue. The operation was made easier by using a moving system of panels on the verso to counter the pressure being exerted. During this operation, the margins of the canvas in the affected areas were tightened by hand and temporarily fixed to the stretcher.

In order to flatten the surfaces affected by cupping, a small portable Low Pressure Board (LPB) (Villani, A.E., 2008: 55-58), was used, which not only provided strong support, but also helped the adhesive to dry. This apparatus has two slender aspirating arms that protrude from the suction chamber, enabling the board to be positioned underneath the stretcher members; the board also has an adjustable metal pedestal for vertical work. In order to prevent marks being made by the holes in the suction board, the following were brought into play: ordinary stiff netting, rather like a mosquito net, and a densely-woven linen sheet, to act as buffers but unyielding ones.

Once a sheet of Melinex film had been placed over the painted surface while it was still damp, all the affected areas were flattened with a slight pressure of the fingertips, followed by repeated tapping whilst the LPB depression system was activated. During this operation, the paint film was gently heated with an iron in order to dry it completely.

The subsequent colour cleaning phase was carried out gradually, to eliminate the uneven use of varnishes, retouching and excessive infilling.

The layers of varnish were puffed up with applications of 99.9% alcohol thickened with Klucel G, subsequently removed with a 94% alcohol rinse. The overpainting and infilling were removed with an emulsion consisting of a mixture of neutral pH Chelating Gel, containing 10% Tween 20 surfectant and 10% Benzylalcohol . This emulsion was also successful in removing residual grime from the paint surface. The emulsion was removed using a mixture of Ligroine and alcohol, followed by a rinse with White Spirit. The cleaning was completed with a scalpel, the effectiveness of which was observed through UV light, in this phase too, the margins of the canvas in the affected areas were drawn by hand and temporarily fixed to the stretcher.

Once the support fabric had achieved good planarity, perimetral strips made of polyester canvas treated with BEVA371 were attached to the edges of the painting, to ensure its stability during the traction leading to its definitive fixing.

The stability and functionality of the stretcher were restored by making the Swedish pine auxiliary stretcher, shaped in such a way as to reduce the overall weight. The six mortise heads were cut in such a way as to be able to insert an aluminium profile geared to containing potential deformations of the joint (Figure. 17). The stretcher was first treated with Perxil10 moth proofing and then protected with a layer of Paraloid B72 diluted 10% with Chloroethene.

Once the painting had been definitively fixed to the stretcher, a paintbrush was used to apply the varnish to the painted surface, temporarily, using Retoucher resin, while awaiting an overall assessment of the equilibrium of the cleaning.

7. CONCLUSIONS

The work is an oil painting on canvas with such pigments, typical of the classic pictorial tradition, as lead white, red and yellow ochre, red lead, cinnabar, massicot, Naples yellow and carbon black. In the green and blue tones Prussian blue, often described as the first synthetic pigment (West FitzHugh, 1997: 191-212) was also employed. It was available to artists since the second half of XVIII century and became extremely popular throughout the two following centuries. Particularly green tones were achieved by a mixture of yellow and blue pigments and not directly using green pigments.

The linen canvas was prepared by applying a brown priming of clayey nature containing traces of carbon black and orpiment with drying oil as a binder.

Results of scientific examination will possibly used as a reference and will be a support to the historical-artistic and stylistic attribution of further paintings.

The painting was restored to its original position, despite the fact that the work was not yet complete; this decision, in which the restorers had absolutely no part, was dictated by religious constraints rather than conservation needs, and will create further problems for the remaining phases of the restoration.

These works will involve infilling, after a series of tests have been carried out on different materials, geared to choosing a resilient and elastic product, suitable for application to the greatest lacunae in particular. Finally, the integration of the painted surface will call for well-chosen and selective decisions, conditioned by the extensiveness of the painted surface and the loss of various elements in several parts of the paint layer.

The mechanical characteristics of the support were restored without too much new material being added, in respect of the equilibriums between the canvas and the surrounding area, altered though they were. The painting, cleaned of the various accretions found on the verso and the recto, regained elasticity and structural stability and the canvas-stretcher system responded well to the measures taken.

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Versión española

TITULO: ***Parámetros de resistencia mecánica de tejidos poliéster aplicados en tratamientos del soporte textil de pinturas sobre lienzo de gran formato: "La cacciata dei mercanti dal Tempio" del artista Saverio Lillo. (1734-1796)***

RESUMEN: *El siglo XX, facilitó sustancialmente el análisis y la intervención de las obras desde un punto de vista más complejo, gracias al desarrollo de la industria y la ciencia. Los estudios interdisciplinares se fueron vinculando cada vez más al campo de la conservación y la restauración, permitiendo conocer mejor las propiedades conservativas de los materiales aplicados a largo plazo, para valorar su aplicabilidad o no en el refuerzo de las pinturas sobre tela.*

Fue en los años 60 cuando comenzó a plantearse la aplicación de fibras artificiales en intervenciones de refuerzo del soporte pictórico, la finalidad que se perseguía no era otra que la de conseguir sistemas de refuerzos textiles más seguros y estables que los que se habían venido realizando hasta el momento.

A lo largo de las décadas de los 80 y 90, se produjo un gran progreso en este área, desarrollándose la aplicación de nuevos tejidos de tipo sintético, como los denominados tejidos sin tejer, fibras de poliéster, poliamidas y un largo etcétera. Estas fibras se analizaron conjuntamente por restauradores y científicos, evaluando los pros y contras de cada una de ellas, destacando siempre las premisas de mínima intervención, máxima reversibilidad y aporte de mínimo estrés en la obra.

En este artículo se analiza el empleo de los tejidos en la intervención de refuerzo del soporte textil y de qué forma su estudio ha permitido el desarrollo de nuevos materiales y metodologías en esta área, mostrando como ejemplo su empleo en una pintura sobre lienzo de gran formato: "La cacciata dei mercanti dal tempio" del artista Saverio Lillo. (1734-1796)

PALABRAS CLAVE: *tejidos sintéticos, comportamiento mecánico, refuerzos del soporte textil, Saverio Lillo, restauración pintura al óleo, testado de materiales*