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PROBLEMS AND SOLUTIONS OF CLASSICAL AND INNOVATIVE INTERVENTIONS ON CULTURAL OBJECTS WITH WOOD SUPPORTS

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Abstract:

Consolidation interventions aim at recovering, improving and restoring physical and mechanical properties of wood, a complexed set of actions developed in a technological succession to extend the life of objects that are, in fact, cultural objects, art objects, a national or world cultural heritage, that have been severely affected by physical, chemical and biological degradation.

Our study has taken into account a rich bibliography, including theoretical and practical observations of some specialists from this country and abroad, researches and answers to a series of restoration activities carried out by the author and especially the answers given by these interventions. Our goal is to achieve growth in terms of mechanical strength of the panels affecting the damaged wood, which has losses of anatomical elements (cohesion).

The restoration of patrimony assets implies the approach of techniques and materials in accordance with the state of degradation, the type of artefact, and especially the choice of how to exploit and subsequently expose it. In order for wood to be consolidated, it is necessary to introduce liquid and/or gas materials and/or substances into its microstructure. Transport and penetration into wood is conditioned by a property called "permeability" and the consolidation (the support, the painting layer, or the whole of the work) must be regarded as an important part of the restoration process.

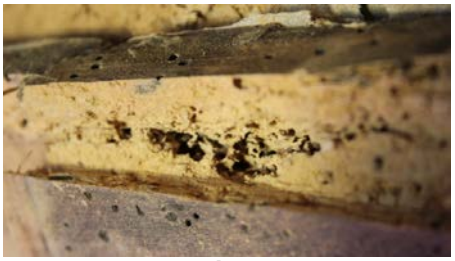
Key words**:** *building; heritage restoration; composite stabilization; conservation; impregnation.*

INTRODUCTION

Wood is a natural material and as such it is predisposed to degradation, especially when insects and fungi come into contact with it, causing significant changes to the basic properties. Damage can be so severe that it endangers the continued existence of the object. Humidity, heat, light, are major degradation factors of the wood structure; also, another factor to consider is the essence of the timber.

Restoring wood means knowing the properties and characteristics, the techniques and technologies that are based on engineering studies of wood. A complementary approach to the two professions is that, in wood engineering, the main objective was to apply treatments and technologies on new healthy wood as standards to improve some properties. Restoration treatments are applied to a wooden panel subjected to biological degradation, with chemical changes, and losses in physical and mechanical properties. In practical terms, on a brittle support, which has reached a powdery state, where the anatomical elements of wood are almost entirely destroyed – Fig. 1 a, b, c, d.

a



b.

c. d.

Fig. 1.
Fragmented support:
a, b c, d – Massive loss of anatomical elements of wood caused by a xylophage attack.

We recommend the use of science and technology engineering, and transferring their results to improve or restore the structure, the physical and mechanical properties of degraded wood found in support of their cultural heritage assets.

Technical and technological developments allow us today to benefit from advanced technologies, multidisciplinary investigation systems, computer programs or the use of numerically controlled CNC machines.

All these technologies and materials that can be applied to degraded supports are, however, subordinated to regulations and the principles of conservation and restoration of patrimony objects. Therefore, there needs to be a catalogue of materials and established treatments, which yield known results and others, which have less satisfactory results, when their evolution and behaviour are known after the treatments have been performed; the findings and measurements of scientific experts are included in disseminated articles and presentations in restoration conferences – their advantages are shown, but most importantly, the drawbacks of these treatments are elucidated (Wang 1985, Crisci et al. 2010, Ionescu 2016).

OBJECTIVES

The use of compounds close to the anatomical, physicochemical and mechanical structure of the constituent wood in order to allow for: the restoration of the physico-mechanical properties of wood, in our case, affected by the biological attack, the reconstruction of anatomical elements of the support, in order to prolong the life of the patrimony assets.

Increasing the mechanical strength of affected wood panels, which suffered loss of anatomical elements.

The development of a product and / or intervention process on wood support, fragmented by biotic and abiotic factors.

HISTORY

Consolidation interventions aim at recovering, improving and rebuilding the properties to extend the life of objects, which are in fact cultural goods, art objects, a national or world cultural heritage.

Wood consolidation is a complex technological succession; the main purpose of which is partial restoration to achieve, as close as possible the natural state of the physical and mechanical properties of a support, that has been severely affected by physical and biological degradation (Ionescu 2016).

A common material used on a large scale by specialists in conservation is **Paraloid B72** consisting of two copolymers - methyl methacrylate and ethyl acrylate, produced by Röhm and Haas in 1935. Paraloid B72 is a thermoplastic resin soluble in acetone, ethanol, toluene, xylene, ethyl acetate, butyl etc.

In our research, we found that strengthening interventions considered as “manual”, like injection, dripping, brushing, remain only at surface level or shallow in terms of depth of penetration into the wood cells, filling is relatively low. In order to bring about an obvious effect in improving the mechanical strength, injection or brushing must be carried out in a considerable number of repetitions and the viscosity of the solution and the type of solvent are very important.

It is known that in hardwood, because of the complex structure “fluid flow is more difficult” (Siau et al.1984); permeability is an important factor affecting the retention of liquid in comparison with the pressure and viscosity. Intercellular voids in the wood structure will result in retention of treatment solutions.

The polarity of the solvent stream affects the penetrating flow. The wood is more permeable to non-polar than to polar solvents (Wang Schniewind 1985). Non-polar viscosity allows deep penetration, and high polarity solutions cause swelling in wood.

After evaporation of the solvent, the polymers reinforce the structure. The most common treatment used to strengthen the wood are acrylic polymers (Paraloid B72). The solvent chosen must be appropriate to: dissolve the polymer, penetrate into the wood, and to not cause colour reactions with components of wood and deterioration of pictorial layers. Another important parameter is the degree of swelling of the wood, as a result of interaction with the solvent. Also, the choice of solvent, toxicity, explosiveness and flammability must all be taken into consideration (Aurerson 2000 cited by Mankovski 2015). For example, according to a study by Paciorek (1993) the greatest degree of saturation of the timber was obtained by using Paraloid dissolved in methanol, however, due to swelling, it could not be applied for practical conservation. Therefore, the most commonly used solvent is toluene. Paraloid solution B72 with a low polymer concentration penetrates the wood best, but for efficiency it requires repeated impregnation. High saturation causes a reduced penetration of the solvent in the depth of the timber (Schniewind 1990, Wang and Schniewind 1985, Schniewind and Eastman 1994). In their research, determined the content of polymer in the samples of damaged wood impregnated with 20% Paraloid B72 in toluene, and it was found that there is polymer at a depth of less than 7mm, in about 10% of the timber vessels. Better supersaturation was obtained by dissolving the Paraloid in acetone (Mankowski et al. 2015). Acetone causes dimensional instability of the wood and its use in the restoration should be judiciously observed.

MATERIALS, PROPERTIES AND USES

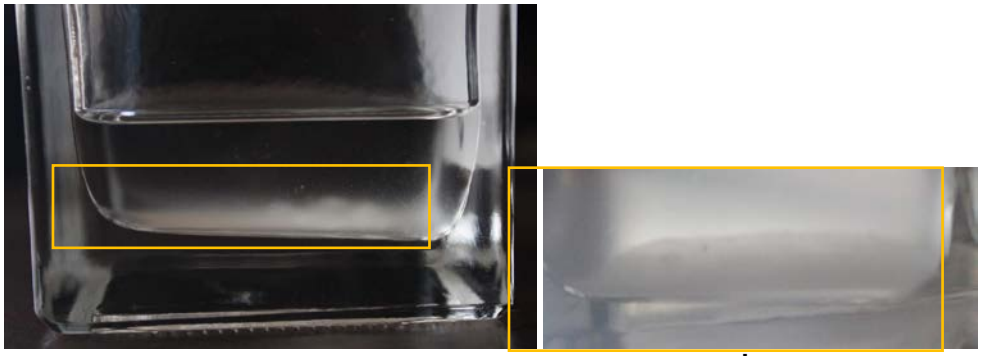
Strengthening damaged wood by impregnation with soluble thermoplastic resin is considered the most promising method because of the physical and mechanical properties, as well as the reversibility compared with thermosetting synthetic resins (Wang and Schniewind 1985). In fact, Timar (2011), specifies that the original synthetic polymer solvent that was set in the timber remains soluble.

The degree of impregnation will depend on: the building material, the solvent used, the concentration and the viscosity of the solution, the permeability of the wood material to be reinforced, the technique used (brush, injection, immersion, vacuum impregnation etc.) and other treatment parameters such as time and temperature (Wang and Schniewind 1985, Unger and Unger 1994, Unger et al. 2001, Timar 2003, Formakalidis 2006, Timar 2010).

Higher concentration solutions store more resin and will give more resistance. However, for practical applications, where large objects or low permeability panels have to be consolidated, full penetration is not easy to achieve. Absorption can be increased either by increasing the pressure difference, applying positive pressure after vacuum treatment (which would require more elaborate equipment), or by reducing the viscosity of the treatment solution. The latter can also be achieved by reducing the concentration, which is to some extent counterproductive, as it reduces retention. The choice of solvent and the concentration becomes one, which cannot be done in absolute terms, but must be adapted to the particular requirements and conditions of the subject to be treated (Schniewind and Wang 1985).

A similar conclusion we obtained in our *"Scientific study about the determination of masses of active substance needed for treatment of wooden panels degraded by xylophage attack"* (Ionescu 2016*)* where we presented measurements and determinations of their masses, of the solvent, of Paraloid B72 at various concentrations and the panel on which it occurred. The parameter measured was the necessary and acceptable quantity of non-volatile, active substance required to strengthen the restored panel. Over the course of 3 years, we started a study that took into account the required amounts of the builder (Paraloid B72) and the solvent type with different polarities from non-polar (e.g. Toluene, Xylene) to medium polarity (ethyl acetate, butyl acetate, acetone), which have a different volatility. Our findings, as in accordance with those of Schniewind (1990) and Mankowski (2015) tell us that solutions with high polarity can cause swelling of the wood and the penetration depth of solutions with high viscosity is more difficult.

Another material used for restoration, is **Regalrez 1126** - a saturated cyclic hydrocarbon similar to wax and paraffin (Crisci et al. 2010). According to the tests made by us, it was found that the mixture of the two substances simultaneously (Regalrez 1126 and Paraloid B72) can produce a crystallization, resulting in a suspension, which makes it difficult for injection, that could lead to a negative effect on the expected outcome. It is recommended that the steps are to be done differently. Our conclusion was the application of the two independent substances, at an interval of drying of at least 8 hours (Fig. 2a, b).



a. b.

Fig. 2.
Particles in suspension:
a - deposits; b – detail.

The efficiency of a consolidation treatment will ultimately depend on the amount of consolidate remaining in the material/object (consolidate retention), the depth of penetration and the uniformity of its distribution, all of which can be aggregated under the term of degree of impregnation (Timar et al. 2011), which is otherwise found new in these techniques.

Taking into account the concentration and the solvent volatility, permeability is reduced the more the anatomical elements of wood are degraded by a xylophages and fungal attack, and where flight holes are clogged, blocked by the wood sawdust produced by chewing insects.

In general, the permeability is higher in the heartwood than the sapwood, and it is also much higher than that in the longitudinal direction of the crossbar. Permeability is the most important factor affecting retention, compared to pressure and viscosity (Wang and Schniewind 1985).

TREATMENT, METHODS, EFFICIENCY

Where we have shown that the effectiveness of the treatments by injection, brushing or dipping (where possible) can be reduced by many factors, then, to increase the effectiveness of the treatment, it must be repeated. A much more effective measure is vacuum-pressure consolidation. A clear example, in addition to the one shown in our study (Table 1, 2), is shown in the study of Golez et al. (n. d.), where a panel of wood before the impregnation weighs 1000g, and immediately after impregnation weighs 2380g. After conditioning and stabilizing, the weighed object reaches 1370g. The increase in weight was due to impregnation with the consolidate solution. By using gravimetric methods in our researches carried out during the years 2014-2016, so far, on a number of 24 wooden objects, we made determinations of the fragments entered in the restoration, compared to the mass of new panels (determination with conventional masses of new wood), the mass of solvents and the active substance (Paraloid B72), the mass of the impregnated wood, at various stages and with various concentrations, and then the final mass of the restored object. Our study shows that the masses of panels were determined before, during, and after the final stabilization, and quantities were found that each time approached the mass of the panel on which it had intervened or even surpassed, and that at the end of the intervention, the remaining mass, fluctuated between 18.4% and 60%.

Table 1

Determination of masses of residual substance required for the consolidation of wooden panels

Name of the icon Inv. No. Essence	**Mass stage 1**	**Stage 3 final mass**	**Remaining substance mass**	**Required mass for consolidating (percent)**
Baptism of the Lord 761 walnut panel	882	1095	213	24.15%
The welcoming 762 lime panel	638	806	168	26.33%
Dying of the Saint Mother 763 walnut panel	521	835	314	60.27%
The Transfiguration 766	732	934	202	27.59%

Name of the icon Inv. No. Essence	Mass stage 1	Stage 3 final mass	Remaining substance mass	Required mass for consolidating (percent)
lime panel				
Descent to Hell 774 lime panel	216	533	317	46.76%

Table 2

Mass determination during restorations

Inv. No.	Initial dimens-ions (mm)	Healthy wood mass (g)	Panel mass T0	Mass after excavation	Consolidation stage I B72.	Stage II B72 12%	Stage III B72 20%	Final mass after approx. 60 days
760	415 x 345	1889	1380	-	1412	1479	1510	1477
764	415 x 345	1889	1270	-	1753	1848	1968	1748
768	332 x 240	1051	738	573	831 Adding td. & c. B72 6+12%	949	880	770
771	320 x 270	1140	970	846	1146 Adding td. & c. B72 6+12%	1243	1278	1001
775	320 x 120	506	277	161	351 Adding td. & c. B72 6+12%	379	426	388

EXPERIMENTAL STUDIES, DISSEMINATION

We believe that the efforts of internationally recognized specialists, chemists, biologists, physicists, engineers, restorers, teachers, etc., who have valuable contributions to research and dissemination, and extensive and beneficial results in the field of conservation and restoration of heritage objects, must be further analysed and applied to our own research, in order to improve the techniques and materials used for the salvation of works of art.

When substances and solutions introduced into wood do not have the expected effect, when the mechanical strength of the support is diminished, and the valuable painting layer is in danger of irreparable loss, practical radical interventions called “prosthesis” are imposed (Ionescu 2014).

The structural and dimensional restorations are made through the use of fragments of wood, from the back to the front painting, to create a structure for stability by removing the strongly degraded base, and the panel then geometrized with the new wood elements, so that the contractions and swelling of the wood produces minimal impact on the painting layer, but also on the support in general (Ionescu 2014).

Composite materials resulting from the stratification of wooden planks as the horizontal axis and the vertical thickness, can be addressed as treatments and techniques to restore wood by the very fact of the arrangement of the blades, taking into account anisotropy and the tendency for natural bending, to form both the width and especially the thickness of the alternating layers. However, the joining lines of the materials must not be overlapped, in order to reduce internal stress and dimensional variations (Ionescu 2016). Our research has shown that this way of putting into practice some of the fragments required for addition, arranged in such a method, have resulted in the development of practical techniques. The old and degraded wood as well as the new wood brought in as additions, results in a more stable material with low dimensional variations, which gives the painting increased stability; tensions caused by wood play are reduced. We can find and practice with new materials, plywood etc., but only where we do not have layers perpendicular or angled fins attached.

Following numerous interventions of restoration, the support showed significant deterioration, cracking, fracturing, detachment, or worse, where degradation led to great losses; this guided us to develop concepts for interventions to restore on the traces of fracturing by additions (Fig 3.a,b,c) when the fracture and loss of support of the painting layer was between the two areas.

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a. b. c.

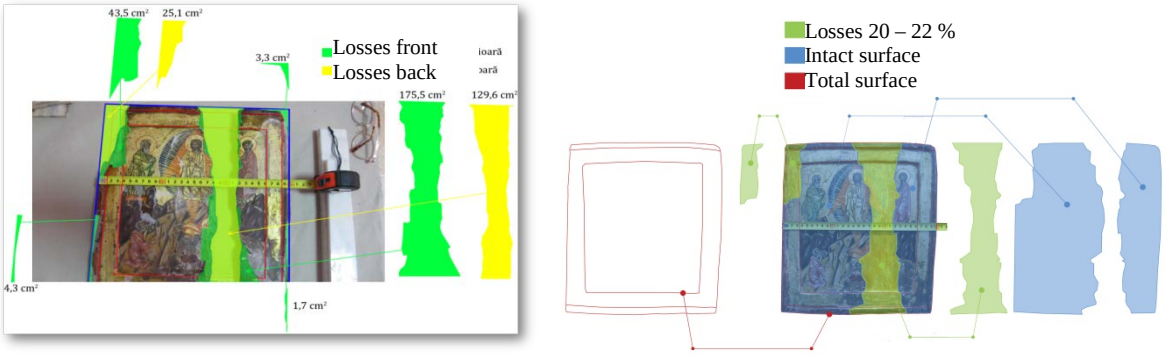
Fig. 3.
Icon 766: a - before the restoration; b - back before reloading; c - after restoration.

Observing the fractures from the pictorial layer, on the one hand, and from the back, on the other hand, it can be seen that they are not in the same plane, and the shape is irregular due to fracturing and loss. Our restoration intervention was carried out by adding composite material (wood) for the reduction or cancellation of the panel tensions.

On the front, there is a paint layer, which required special attention, due to the fact that the cradle was to be merged into the particularly rundown support caused by the xylophages attack. The painting showed evidence of fracturing, this imposed making tracings of the irregular contours, the two fragments were detached, and the intermediate piece was to take the shape of the fracture so as not to press the edges of the paint layer, which showed variable thickness between 0.3-2.1mm., these measurements representing the paint layer, primer and the rest of the wood. Basically, it was not enough to copy the 2D fracture track, but it required a 3D approach.

Note that it is possible that this panel was originally constituted from two panels, although the reduced panel dimensions (about 267x335mm) did not require this, especially since the similar icons of the same group were made up of a single slab.

Our hypothesis on this type of degradation and fracture, with detachment and fragmentary loss of the median area, was generated by the very probable sticking together of two wood floors which, with aging adhesive and detachment, continued the progressive degradation of both fragments, causing the loss of important areas. If the panel surface constituent is about 894,4cm^2, then the losses on the painted surface measure approximately 228.3 m^2, and losses to the reverse side approximately 183.1cm^2 (Fig 4a,b).



a. b.

Fig. 4.
Graphical representation of support losses:
a - differential marking of loss seen from the front and from the back
b - graphic representation of additions - front view.

RECONSTRUCTION BY FOLLOWING THE LINE OF FRACTURE

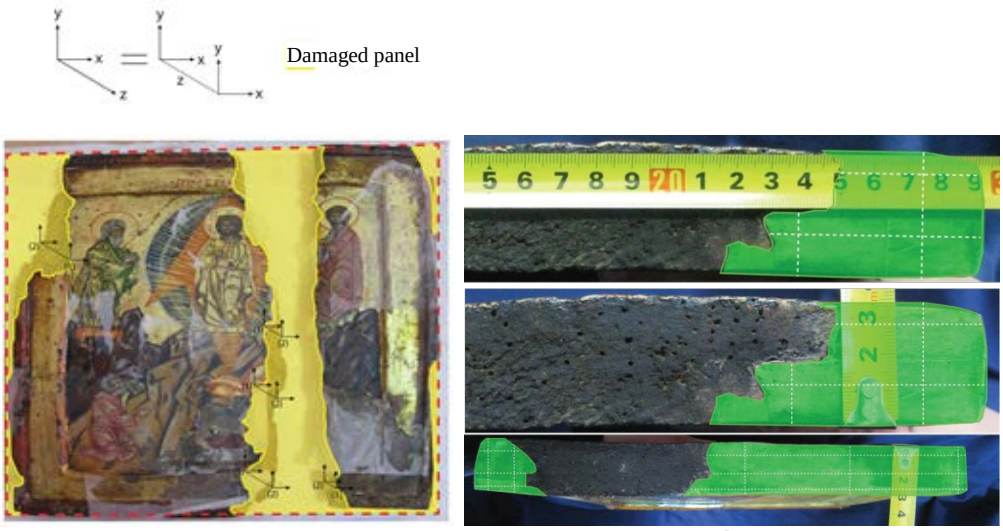
This intervention has generated a series of researches and studies, which have been crowned with recording and registering with OSIM (Office of Patents and Trades) of a “Method of consolidation - restoration and monitoring of wooden heritage objects” (Ionescu and Lunguleasa 2017).

The invention (Ionescu and Lunguleasa 2017) relates to a process for the restoration and protection of national and international heritage objects with wood supports. In its realization, it starts from the observation and determination of the conservation status, with the loss of the physical-mechanical properties, of the wooden support, of the carved and/or painted polychrome wood, of the patrimony objects that are undergoing the restoration intervention. Also, the present invention is used to limit the risk of falsification, theft, illegal exports, paintings, icons etc., which can easily be transported or replaced, or by changing the identity of the owner.

The problem solved by the invention is to provide 1. a method of restoring the wood substrate sheet that have areas with a high degree of degradation, loss of support and fracturing, and 2. protecting them against theft or forgery.

1. The restoration of the wood substrate sheet objects by reconstituting traces of the fracturing of the wood substrate, where the sheet objects are in a state of degradation (Fig. 5a,b):

a. Reconstruction is done by physical and mathematical determinations of gauge dimensions.
b. By comparative measurements of the object itself or similar objects belonging to the same production, time, author etc.
c. By recomposing the drawing represented by the iconographic theme or the scene.
d. 3D tomographic scan of the fractured detached object and loss.
e. Transfer of the imaging result into a numerical control machine (CNC) program.
f. Making the missing piece on the machine in coordinates, on the traces of fracture, and incorporating a three-dimensional prosthesis, to reconstitute the shape and the gauge.
g. Bonding of old and new components with vinyl polyacetate materials that are reversible.
h. Showing the geometry of the patrimony object with respect to the flatness or curves in the cutting plans to which the heritage object was subjected in its life cycle, from the origins to the moment of the interventions.



a. ***b.***

Fig. 5.
Reconstitution on fractures.

2. Protecting and monitoring of heritage objects by implementing an identification chip.

One of the main advantages of the current invention resulted from implanting heritage objects of particular value with an identification chip, which are then ranked in a legal form, fund or treasury. The implementation of a microchip on patrimony objects is done to limit the risk of theft mainly by illegal exports of paintings, icons, etc., which can easily be transported, changing the identity or the owner. The procedure consists of the implantation in a certain area, which is well determined and known at national and international level by specialists from the competent institutions, who have the obligation and possibility to easily check, research, scan or identify patrimony objects that have the general characteristics of art objects. This application may be for the benefit of collectors, auction houses, the customs, etc., and allows easy identification of stolen or incorrectly catalogued items. The chip is loaded with the identification data of the patrimony object, the represented theme, owner, date, year of restoration, style etc., to conserve the authenticity, and other interventions that are governed by the principles of restoration and specialized legislation in force.

CONCLUSION

In conclusion, restoration interventions include the integration and use of classical or innovative materials or techniques and is a long-term process, whose results are quantifiable over long periods of time, precisely by determining the influences or behaviour of materials both individually as well as in the combination of interventions. Therefore, we note that the dissemination of studies, the implementation or the development of researches by restorers, based on extensive and valuable bibliographic documentation, may be the basis for superior restoration processes that will benefit the patrimony objects in order to recover and save objects of art and of national or world cultural values. The purpose of using new, advanced techniques and state-of-the-art materials, is subordinated to limiting or stopping degradation, restoring or re-establishing the lost physical and mechanical properties for art objects on wooden panels, that have been degraded over the centuries, but surprising, whose pictorial layer of a special value, was kept inversely proportional to the support losses. That is why the knowledge of materials and their behavior over time is necessary, not only at the level of workshops or schools, but all the more so at the international level, through the understanding and application of materials and solutions that were produced by the centres or laboratories of cultural, European or world institutions, whose best practices are based on research of interdisciplinary high-level scientific laboratories.

REFERENCES

Crisci GM, la Russa MF, Malagodi M, Ruffolo SA (2010) Consolidating properties of Regalrez 1126 and Paraloid B72 applied to wood, in Journal of Cultural Heritage 11(3):304-308 https://www.researchgate.net/publication/248546319_Consolidating_properties_of_Regalrez_1126_and_Paraloid_B72_applied_to_wood

GOLEŽ M, Škrlep L, Čretnik J, MAUKO A, http://en.restavratorstvo-vitez.si/vacuum-consolidation/, extracted in February 2017

Ionescu CȘ (2016) Scientific study on the determination of masses of active substance necessary for the treatment of wooden panels degraded by xylophage attack. Communication session at the Ethnographic Museum of Transylvania, Cluj.

Ionescu CȘ (2014) The problem of stabilizing and strengthening the structure of a wooden support of some Orthodox icons, sec. XVII-XVIII. Case Study, Mega, Drobeta Turnu Severin, pp. 95-118.

Ionescu CȘ (2016) Wood consolidation. Restoration interventions on cultural goods, whose support is wood and which is affected by the biological-fungicidal or xylophagic attack, have reached the verge of collapse, Drobeta XXVI, Mega, Drobeta Turnu Severin, pp. 161-169.

Mańkowski P, Kozakiewicz P, Krzosek S (2015) Retention of polymer in lime wood impregnated with Paraloid B-72 solution in butyl acetate, Department of Wood Science and Wood Preservation, Faculty of Wood Technology, Warsaw University of Life Sciences – SGGW, 159 Nowoursynowska St., 02-776 Warsaw. Annals of Warsaw University of Life Sciences – SGGW Forestry and Wood Technology № 92, 2015: 263-267 (Ann. WULS - SGGW, For. and Wood Technol. 92, 2015) https://www.google.ro/search?q=Piotr+MANKOWSKI%2C+Pawel+KOZAKIEWICZ%2C+Slawomir+KRZOSEK%2C+Reten%C8%9Bia+de+polimer+%C3%AEn+lemnul+de+tei+impregnat+cu+Paraloid+B72%2Csolu%C8%9Bie+%C3%AEn+acetat+de+butil.&oq=Piotr+MANKOWSKI%2C+Pawel+KOZAKIEWICZ%2C+Slawomir+KRZOSEK%2C+Reten%C8%9Bia+de+polimer+%C3%AEn+lemnul+de+tei+impregnat+cu+Paraloid+B72%2Csolu%C8%9Bie+%C3%AEn+acetat+de+butil.&aqs=chrome..69i57.1003j0j4&sourceid=chrome&ie=UTF-8#q=Piotr+MANKOWSKI%2C+Pawel+KOZAKIEWICZ%2C+Slawomir+KRZOSEK%2C

Schniewind AP, Eastman PY (1992) Consolidate distribution in deteriorated wood treated with soluble resins, New York http://www.wag-aic.org/1992/WAG_92_schniewind.pdf published in JAIC 1994, Volume 33(3)/2:247-255) http://cool.conservation-us.org/jaic/articles/jaic33-03-002.html

Siau JF, Davidson RW, Meyer JA, Skaar C (1984) Transport Processes in Wood. Springer-Verlag Berlin and Heidelberg GmbH & Co. KG Berlin.

Timar MC, Tuduce Trăistaru AA, Porojan M, Gurău L (2010) An investigation of consolidates penetration in wood, part 1, PRO LIGNO, Vol. 6(4):13-27.

Timar MC, Tuduce Trăistaru AA, Pațachia S, Croitoru C (2011) Experimental investigation of the penetration of wood consolidate products Part 2: FTIR spectroscopy, in PRO LIGNO, Vol. 7(1):25-38.

Wang Y, Schniewind AP (1985) Consolidation of deteriorated wood with soluble resins JAIC volume 24(2-3):77-91https://translate.google.ro/translate?hl=ro&sl=en&u=http://cool.conservation-us.org/jaic/articles/jaic24-02-003.html&prev=search