Restoration of Wood Support for the Old Depreciated Icons

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Abstract: - The paper aims to analyze some methods and procedures used in our days to restoration old and small icons. For this purpose, three relevant technical studies have been analyzed since each restored icon has a unique design and for which different interventions are used. Also, there are presented the working methods and the materials used in each case, highlighting the innovative and original side of each type of restoration. Classical materials such as Paraloid B72 or Regalrez 1126 are used individually or combined to fill in all insect holes. For the same purpose, light lamellar wood materials were also used. The damaged wood material was replaced with new wood material of balsa (*Ochroma lagopus*) which has a density close to that of fragile wood, with an outline that follows the degraded contour of the small rays and the corresponding canvases. For curved supports, modern curvature reduction methods have been used up to the limit of supportability. As a general conclusion of the paper, it can be said that each type of restoration is different, requiring the use of a certain innovative method and different technological materials.

Key-Words: - church icons; restoration; wood support; conservation; fragile wood; insect hole.

1 Introduction

Old icons represent objects of national or world heritage with a material value, but also a less tangible value, immaterial one [1]. The restoration of wood-based icons can be interpreted as a complex of actions, materials and techniques aimed to recovering lost properties of the heritage objects, restoring steady state in terms of structural stability and of clarity of the pictorial message, whether they are only partially preserved. In practice, it means consolidation and stabilization interventions aimed to recovering, improving and restoring the structure to extend the life of these art objects. The restoration of church icons has two distinct stages, namely the restoration of wood support and the restoration of the painting layer, both of which having the same importance for the complete recovery of the cultural object.

Generally, wood support is physically and biologically degraded due to improper storage conditions (usually high humidity and lack of ventilation). Among the main degradations found on the wood supports it can be evidenced the mould, insect holes and galleries, rot, material losses, cracks, deformations and more (Fig. 1).

The consolidation of the fragile wooden support of the icons, as an integrated and important part of their restoration, represents a complex action in a logical technological succession, whose main purpose is the restoration as close as possible to the initial state of physic-mechanical properties of a support that has been severely affected by physical and biological degradation.

Fig 1. Deep degradation of wooden support of icons

Among the restoration operations it can mention: the general visual analysis of the object to determine its state; chemical and physical analysis, wood excavation to determine the degree of degradation and its extension; cleaning and removing all damaged parts; highlighting and mapping all damages; establishing a restoration plan (materials, soldering mode, strengthening support and not only); performing the process of effective restoration of wood structure; pictorial message identification and pictorial restoration, final preservations.

Restoration technology contains some minimal operations, as follows:

- The heritage object receives an inventory number at the entrance to the restoration workplace, with its identification data (about the object and owner) and a restoration sheet are opened;
- Detailed examination of the icon to determine the degree of degradation and fragility of used materials (object history and other prior restoration technologies). In this phase weighing, classical or laser cleaning [2] of improper elements and eliminating degraded parts are done;
- The method of restoration, materials, wood species and more other details are established;
- The wood support is restored by completing the spaces where is no material, by filling the insect holes, straightening the possible deformations and stabilizing the support against possible future deformations. At this stage both old and newly introduced wood material can be treated against further degradations;
- After identifying the degraded part, it can use an wooden material with the same density as those previously used;
- Painting restoration;
- Cleaning and removing the parts in the wooden support of icon;
- Introducing some hidden elements of restoration identification (working firm, restorer);
- Exposing the restored object into a safe environment, or in a place which does not allow the possibility of subsequent rapid degradations.

Sakuno and Schniewind [3] show the importance of the quality of consolidation materials commonly used during restoration and states that investigations and measurements have been made on their shear resistance. Moreover, some authors [4-7] investigated the use of composite materials from cellulose powder and Paraloid B72, to increase mechanical properties while other authors used only Paraloid B72 on old wood [8]. The type of consolidators that could be used and their properties have been thoroughly analyzed by Sakuno and Schniewind [3]; they specifically addressed the damaged wood hardening by impregnation with thermoplastic resins. They also show that prior to the emergence of synthetic resins, as consolidation materials, the animal glue, melted wax, oil or natural resins were used, of course, each of these materials having their advantages and disadvantages. The applied treatment will not protect the wood material from further deterioration, but it will slow the deterioration process and will give to the heritage object a longer life so that a new treatment can be applied in the future if necessary [9]. These researchers said that the effectiveness of a consolidation treatment depended fundamentally on the amount of consolidator remained in the object. Also it depended of penetration depth, distribution uniformity and obviously the mechanical properties of the polymer type solidifier.

Deng et al [10] shows the importance of electronic tomography in analyzing the degree of degradation of the wooden support. This method allows an analysis of the internal wood structure even on the sub-microscopic scale. Scan Electron Microscopy (SEM) was used by other authors [11] in order to see the filling of the wood cells with the consolidation material. Pavlidis et al [12] shows the importance of 3D digital scanning of the heritage object. Even if the pattern applies to large and complex objects, the method can also be used for small icons to identify the outline of fracture or degradation (rot). Espinola [13] analyzed Russian icons from different points of view regarding conservation and restoration. Wood species commonly used as initial support and as restoration wood such as Lime, Pine, Spruce and Larch have been highlighted. It is also shown that wood is often coated or impregnated with resins or oils to withstand at water penetration and obviously at his degradation. To reduce moisture absorption in Russian icons, another method was used, such as the superficial burning of wood and then coating it with the basic layers of the painting. This method was later removed from the technologies of improving the wood support used at icons.

The objective of the study will be highlighted in three technical studies, observing the novelty elements and the way to reduce or remove wood curvature as well as the way of completing of the losses pieces of wood. The solutions for holes occlusion and insect galleries, strengthening or completing the fragile support will be also analyzed.

2 Method and Materials

Paraloid B72 is a material widely used by conservatives and restorers around the world. This adhesive was also used in our technical studies from the present paper as a product which consisting of two copolymers - ethyl methacrylate and acrylate methyl. Paraloid B72 is a thermoplastic resin which is soluble in acetone, ethanol, toluene, xylene, ethyl acetate, butyl and not only. It has an apparent density at 25°C of 1.15 g/cm^3, the glazing temperature of 40°C, the auto-ignition temperature of 393°C. Another material used in our technical studies analysed for restoration the icons is Regalrez 1126 – a saturated cyclic hydrocarbon like wax and paraffin. It is an aliphatic resin with a low molecular weight (density at 21°C of 0.097 kg/l, glazing temperature of 65°C. It is soluble in most aliphatic, aromatic and chlorinated hydrocarbons, ketenes and esters, but insoluble in alcohols. According to the tests carried out in the paper, it was found that the simultaneous mixing of the two substances (Paraloid B72 dissolved in toluene and ethyl acetate and Regalrez 1126 give great dimensional stability to the wood support of the heritage object.

For preventive or curative chemical cleaning, in the case of fungal attacks, Biotin R treatment was applied in organic solvents such as White spirit. For xylophages' insect attack, treatment with Per Xil 10 was applied. In mixed cases, both treatments were applied sequentially, the objects being packed in polyethylene film in order to reduce the oxygen. This treatment was repeated 7-14 days.

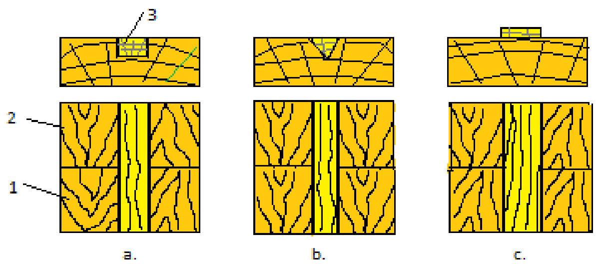

Fig 2. Wood consolidation processes applied on the back of the icon: a- with rectangular wedge and a groove of U type; b-with triangular wedge and a groove of V type; c- with rectangular slat, without groove

Mechanical milling in the form of V at different angles (22°, 30°, 45°) or in U form with the opening between sides of 12 to 25mm (Fig. 2) was used as consolidation procedures. These two types of milling can also be combined in a mixed intervention when cracks are irregular, randomly inclined inside the wood and insertion of a single baguette does not provide sufficient mechanical strength on both sides or when xylophages attack is so intense that the bonding surfaces need to be larger.

Usually, these additions are made with healthy wood of the same type as the structure, but when the structure is too fragile, the lightest wood species such as balsa wood (with a density of about 160 kg/m^3 at 10% moisture content) are used. Also, it can be used the heat treated wood [14] with a degree of degradation that does not affect the overall structure of the icon. When the panels which composing the heritage object are cracked and have reduced losses by milling of the application grooves, the structure can be reinforced by a usually technique, using of the butterflies or the boats. In practice, due to the fact that the icon wood of icons is fragile, getting the butterfly shape can further influence the state of the cultural object. Therefore such intervention is not recommended for these particularly fragile cultural objects. For small icons as our case studies present, it is recommended to use the process from Fig. 2c.

However, when stabilization and consolidation was required, some fragmentary lamellas were introduced into the existing cracks without altering their geometry, without using mechanical interventions (milling). The wand of triangular wood feather type may be long or short. There have also been made consolidations with sawdust or vegetable fibres glue mixtures, with or without reinforcement. Also, temporary short strips from wood were used to stabilization the structure, only needed during restoration process.

The wooden elements used to fill the missing structure had to have the same shape as the one of the degraded icon, a perfect fit being needed. For this, a narrow fret-saw was used. The width of the fret-saw was determined by the curvature radius of the cut profile (Fig. 3).

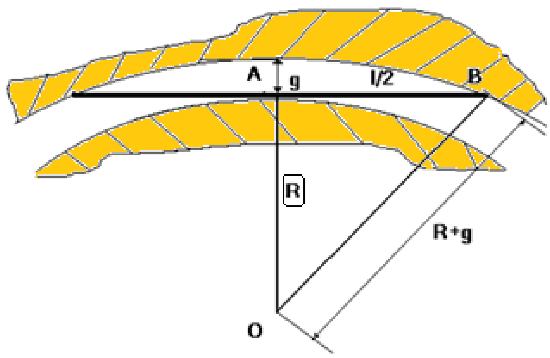

Fig 3. Outline of the correlate the fret-saw width with the curvature radius of the saw: R-the curvature

radius of the profile; l-fret-saw width; g-fret-saw thickness

In this sketch it is used the rectangular triangle OAB, which has the right angle in point A. In this triangle there are the following dimensions: OA=R, AB=l/2 and OB=R+g. If Pythagoras' theorem is applied, the following relationship of the radius of curvature will be obtained:

$$R = \frac{l^2 - 4 \cdot g^2}{8 \cdot g} \tag{1}$$

This equation (1) was used to choose the fret-saw blade. The fret-saw blade of 3 mm width and 0.8 mm thick was used to cut a curvature radius of up to 1.006 mm. Specific chemicals consumption, applied by brush or roller, even if one or more layers were used, was determined with the following relationship:

$$CS = \frac{m_f - m_i}{S} \left[\frac{g}{m^2}\right] \tag{2}$$

Where: m_f – final mass of the icon, in g; mi- initial mass of the icon, in g; S-the flat surface of the icon, in m^2.

Also, for the amount of substance left in wood support after the consolidation treatment was used the following equation:

$$SR = \frac{m_f - m_i}{m_i} \cdot 100\ [\%] \tag{3}$$

The deformability of the wood holder was determined linearly, on several directions of the curvature, by using the following equation:

$$ID = \frac{f}{D} \left[\frac{mm}{m}\right] \tag{4}$$

where: ID - deformability index; f – deformation arrow, in mm; D- dimension of deformation, in m.

3 Results and Discussion

3.1 Technical Study of Broken Icons using Small Pieces of Light Wood for Adding

This technical study analysed a heritage object of icon type with dimensions of approximate 267x335 mm called Assumption of Mary. It is an icon from 18th century. Fig 4 shows the initial and final stages of the icon. The initial icon was found as been broken into two pieces and has many material losses, both in the middle and in the lateral areas. There are a lot of insect holes (of the Anobidae family, *Anobium punctatum*) were observed.

a. b.

Fig. 4. Christian icon - Assumption of Mary - before restoration (a) and after restoration (b)

Breaking the icon into two is due to the lack of the consolidation slats from the back. If the total surface of the panel is about 938 cm^2, the losses on the painted surface have been of approximate 218 cm^2 and on the back side of approximate 183 cm^2.

Analyzing fractures on both sides of the icon, it can be seen that they are not in the same plane, and the degradation area or material loss are irregular. The restoration consisted by additions of small and thin pieces of lamellar wood to the lost area. In addition to good stability of the entire wood support, from 2 by 2 cm on the back of icon there were glued with bone adhesive some thin pieces of balsa wood. The new ensemble was lightweight and stable in size, especially thanks to the transverse slit on the back of the icon. Al these technical methods were used in order to reduce the stress and fix the whole structure.

The fact that on the front area is a non-uniform fractured painting layer, the intermediate piece must fit perfectly into the support. Due to the degradation of the support by xylophages attack, the insertion of the intermediate piece had a high degree of difficulty. This should take over the shape of the fracture so that it does not crush the edges of the paint in layer with variable thicknesses between 0.3-

2.1 mm. In other words, it was not enough to copy the 2D fracture form but required a 3D shape, as other authors have noted [12].

For the side where no consolidations have been done, approximate 978 g respectively 1000 ml of Paraloid B72 was used to closes insect holes (Fig. 5).

a b

Fig 5. Consolidation treatments by injection : a.Per Xil 10 and Rexil; b. Paraloid B72

After other interventions and weighing at 60 days, practically it has remained 130 g compared to the panel which had an initial weight of 1380 g. During the interventions and treatments, the total weight of the icon reached 2350 g and at the end of restoration it remained 1477g by drying. For approximate 1431cm^2, 100 g of solid mass were used and resulted 0.0677 g/cm^2. As a conclusion of the chemical treatment we consider that, after the treatment, the permeability was reduced [15], increasing its dimensional stability. As results of numerous old restoration interventions, the wood support had significant degradations, cracks, fractures with detachment of material. These have led to extensive losses of wood and it has been necessary to develop specific methods for each restored object. The interventions aimed to restoring the fractured areas, completing the losses wood support and painting from the middle part of the heritage object structure. It has been found that injection, dripping, brushing have a surface-consolidation character, the penetration into the depth of the wood cells and the filling of the vessels being relatively low. In order to bring about an obvious effect in improving the mechanical strength, the injection or brushing should be carried out in a considerable number of repetitions, the viscosity of the solution and the type of solvent being extremely important.

However the residual solid substance must not exceed 30% of the mass of the affected panel otherwise the support will be too much loaded. Also, the reversibility of each treatment must be taken into account [9]. After double treatment with Regalrez and Paraloid, a significant advantage of mechanical strength was observed. Although there were no advantages in terms of resistance to photo-oxidation or colour changes, poplar samples treated with Paraloid B72 and Regalrez showed a significant reduction in porosity (6 ± 2%), with a slight value lower for spruce samples.

For samples treated only with Regalrez, porosity was insignificant in both species (0 ± 2% for spruce, 2 ± 2% for poplar). The results obtained through treatment with Regalrez may be due to its lower molecular weight. This tends to penetrate deeper into the cell wall leaving the overall porosity unchanged. Instead, Paraloid B72 with a higher molecular weight, may tend to penetrate deeper the cell lumen and therefore decrease porosity. This phenomenon also occurs in the case of double (mixed) treatment.

3.2 Technical Study of Broken Icons using Small Pieces of Light Wood for Adding

This technical study was analysed on the icon named Saint Nicholas, from 17-th century. The initial and final stage of the icon can be seen in Fig. 6. The wooden panel of the icon used as a support for the painting layer was curved and was made up of two glued boards, this being the main reason for breaking into two pieces. Those two pieces had fractures on both sides and large losses of painting and wood support. The icon with a mass of approximately 3600 g, had also an advanced fragility (degradation) both at the wood support and painting layer.

Different xylophage's attacks on the two parts, cracks of different depths and inclinations, produced dimensional destabilization of the wood and aggravated the conservation status of the icon. Moreover, there were paintings loss of about 25% of the surface and about 35% of the support mass. Under these conditions of degradation and fragility of the wood support, it was chosen balsa wood for additions due to its low density of about 160 kg/m^3. The density of balsa wood was appropriate to the density of depreciated support.

The innovative character of these consolidations consists in all sequential operation of restoration. First of all, to secure the two boards of the icon there were used small pieces of wood, glued on behind them (Fig 6.d). After that, lamellar parts were inserted in the gaps, they followed the degraded contour of the icon, cut with narrow blades of about 2-3 mm (for curvature rays of 1-2 mm), according to the relation (1). Each of three lamellar parts was realized outside. These were geometrized and equalized in order to return to the original position. Positioning the consolidation lamella for panel reconstruction had an oversize length to fit the bending radius of the original panel.

Fig 6. Restoration of *Saint Nicholas I* icon from 17-th century

The interventions were highly complex and the process was conducted over approximate 2 years.

Table 1. Losses and Completions to the restoration of the Saint Nicholas I icon

Parameters	**Value**
Total weight of panel estimated without degradation	7117 g
Estimated weight of the panel, with new wood, at the entrance to the restoration	5460 g
The hypothetical weight of lime wood additions	1657 g
Mass loss caused by biological attack (M_{Ai}- M_i) *(M_{Ai}- M_i= 5460-3988= 1472)*	1472 g
Panel weight at the entrance to the restoration	3988 g
Weight of Balsa additions	689 g
Final weight after restoration	4677 g
Initial thickness	27,75 mm
Dimensions	895 × 615 mm
Surface of the whole icon	5475,49 cm^2
The newly added surface (balsa wood additions)	1275,32 cm^2
Volume of additions	4143.75 cm^3

The choose of balsa wood, as a species with a low density, was justified in this case (used also in the other case) by the fact that a fragile panel with fractures and intense xylophages attacks, with losses of approximate 40% from the initial mass, would have meant that the consolidation material to become an additional risk factor and an unjustified stress to the art object by its own mass, but especially by the possible tensions [16]. To stabilize and consolidate the panel, brushing up and injections were performed with Paraloid B72 in concentrations of 6-12%, soluble in Ethyl Acetate and Toluene 1:1 [18]. They were introduced approximate 1000 ml solution, of which: 500 ml 6% and 500 ml 12%. The total solid mass of Paraloid B72 was 90 g.

3.3 Technical Study about Reduction or Eliminating the Curvature and Deformation

For this purpose it is used a *Saint Nicholas* icon from 18-th century. The essential degradations of the wood support (Fig 7) consisted of extended xylophages' attack of approx. 120-150 flight holes/dm^2, fracture and detachment of the boards. It is worth mentioning the loss of approximately 40%

of the support and about 30% of the painted layer, but also a deep bending of the panel. With fracture into two parts of board, they curved and twisted independently and differently. When these were restored in a single panel, a concave curvature resulted with an arrow of 39.21 mm to 53.40 mm on a width of about 500 mm, i.e. an average curvature of 92.61 mm/m determined by Eq. 4.

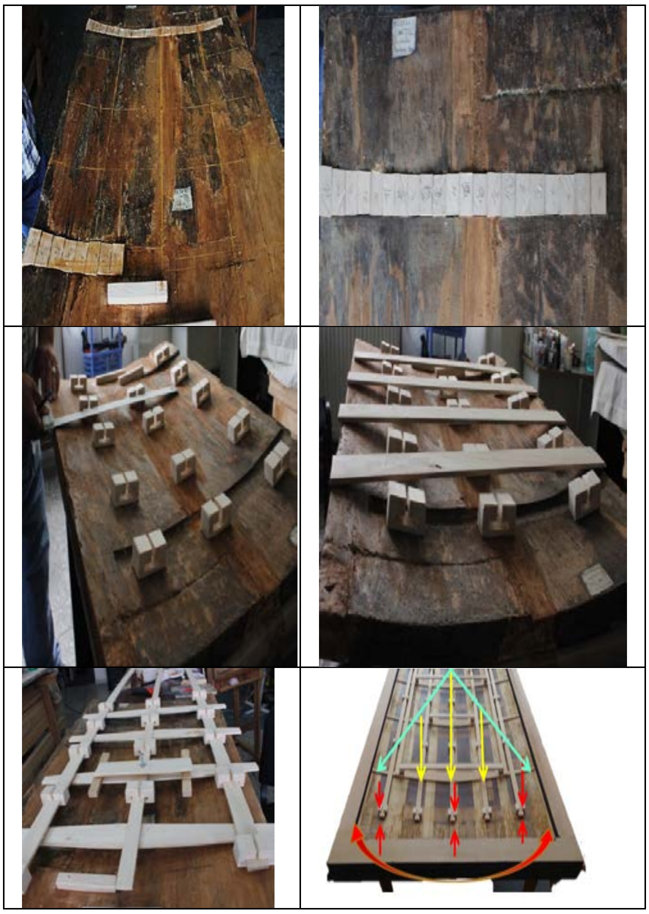

Fig 7. Restoration of *Saint Nicholas II* icon from 18-th century

The restoration consisted in stabilizing the structure of each independent piece, improving the structure and consolidation with balsa wood in order to recover the natural curvature. It has been taken into account that the rheological properties of wood are influenced by wooden specie and density [17]. In order to stop the deformation of the wood support, an elastic frame was made to limit the curvature in width direction. These must be rigorously calculated so that the effect is not contrary to expectations and the result does not lead to cracking of the panel or damage the painting. Another role of these elastic frames was also the possibility to exposing the painting with maximum readability and no additional devices in order to restore the painting layer. To achieve this elastic frame, it was taken into account that this panel is fragile and deformed.

The concept of elastic frames has taken into account the reversibility of wood material deformations and their applicability. The possibilities of subsequent adjustment of the tensioning lamellas in order to preserve the initial curvature of the panel were also analyzed. From the point of complexity besides the usual part of filling the insect’s holes, and cracks, the restoration of the initial curvature was the most difficult problem of restoration. If initially the maximum bend arrow was 53.40 mm, after the geometry and the flatness were restored, a maximum arrow of 29.89 mm was reached under the protection of weak steam treatments on the opposite face.

The bending strength of the lamella in the frame had values ranged between 58-65 N on outer areas and 39 N on median area. The tensile strength of the blades in the frame assembled had values 12-30 N. Curvature radius of the blades at 12 months after assembly had a maximum arrow of 11.89 mm and a minimum arrow of 4.61 mm. The blades were made of poplar and have a width of 40.04 mm and a thickness of 5.45 mm. The slats in which the blades were assembled have had the following dimensions: length of 65±0.5 mm, width of 30±0.5 mm and height 25±0.5mm. Even if each tightening of the support was carried out under the protection of a steam jet to ensure plasticisation of the support, at one point the painted surface seemed to become degrade. At that time, the straightening of the wood support was stopped. Therefore, with the beneficiary’s agreement, the bending reduction of the support was stopped at 7 mm on the width of about 50 mm, i.e. at 14 mm/m, if the Eq. 4 was used.

4 Conclusions

The restoration of wood-support icons as heritage object involves special techniques and actions of flatness and consolidation of wood support, replacement of extremely damaged parts, filling of holes and insect galleries. As have been observed in the all technical studies presented in the paper, all these actions are different from one icon to another.

Replacing of larger degraded parts with new wood requires a correlation between the density of the new and of the old wood. This condition is essential for obtaining durable objects. The lack of this correlation may lead to the occurrence of cracks or affect the whole structure of the patrimony object. For example, cracks with thicknesses over 1 mm have been re-build using solid wood feathers made of the same species or of a species that has a similar density to that of the fragile support. The cracks, holes and galleries of insects smaller than 1 mm were filled with Regalez 1126 and Paraloid B72. Last technical study highlights the fact that there are cases where it is preferable to keep a slight curvature of the holder to the expense of a perfect flatness. The last purpose is to preserve the original painting and its wood support structure.

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