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The conservation of a wooden Graeco-Roman coffin box

Technical paper

Y. Zidan[1], T. Handoussa[2], H. Hosni[3], N. M. N. El Hadidi[1]

1. Conservation Dept. Faculty of Archaeology, Cairo University, Giza, Egypt
2. Egyptology Dept. Faculty of Archaeology, Cairo University, Giza, Egypt
3. The Herbarium, Botany Dept. Faculty of Science, Cairo University, Giza, Egypt

*Corresponding author: nelhadidi@excite.com

Abstract

This paper describes the treatment and conservation of an Egyptian wooden coffin box dating back to ca. 1st century. The treatment procedures entailed cleaning, removal of dust and sand, securing severely damaged wooden fragments and damaged resin as well as the use of a suitable gap filler. Studies included wood and microbiological identification.

1. Introduction

In 1931, the first Egyptian University excavations were carried out in Touna El Gebel, at the funerary monument of Padykam, scribe of the town Khemenou (*Hermoupolis Magna)*. Inside the tomb three wooden coffins were found, one of which belonged to his father Dhouty - Iou. In 1932 and 1941 the inscribed text on the back of this coffin box, which consisted of 5 vertical columns was transcribed and translated, but nothing was mentioned about the wood species and the state of the wood itself.[1,2]

In 1994, work started on this coffin box, which was exhibited at the Faculty of Archaeology Museum, Cairo University and registered under the number 852. It was evident from the beginning that some of the hieroglyphs, especially in the lower foot area of the coffin box had vanished due to the deterioration of the wood. By comparing what had been published in 1932 and 1941 one clearly notices the loss of some letters or symbols. In addition to that there seem to be some slight differences in some of the letters and symbols, in comparison to what had been published in the past, but that is beyond the scope of this paper.

In this paper we concentrated on the identification of wood, wood deterioration and suitable treatment methods. Owing to the fragile state of this coffin box, it was very difficult to move it to the laboratory, and treatment had to be carried out *in situ.*

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wooden coffin, microbiological deterioration, softwood, gap fillers

2. Materials and Methods

2.1 Documentation

Visual examination and documentation was carried out in order to understand the condition of the object; it's method of manufacture and deterioration. The condition of the coffin box was recorded in detail and cracks in each part were carefully recorded. This technique produced clear documentation of the condition in all parts of the coffin box.

2.2 Description and Condition of the Coffin box

The coffin box was carved out of one tree trunk, and 5 vertical rows of hieroglyphs were inscribed at the back. Traces of white colour or gesso were evident in the inscriptions. It did not contain any wooden dowels or pegs, but mortise openings (chiseled rectangular holes) were evident along the upper surface of the sides of the box, where the lid must have been secured in the past. The length of the coffin box is 189 cm; the width 40 cm and the height approximately 22 cm. The inside of the coffin box was carved for the mummy to fit in. Ancient black resin covered the area that was underneath the mummy.

The wood samples that were taken from the coffin box were desiccated and brittle; therefore it was not possible to carry out standard techniques of sampling and optical microscopy, or to make thin-sections in order to identify wood. The only solution was to prepare the samples for scanning electron microscopy, by fixing small pieces of appropriate size on stubs with double-sided cellophane tape. The samples were sputter coated with gold and observed with a Joel T200 SEM.

The wood was identified as Cypress wood (*Cupressus sempervirens)* (Figures 1-3). It is important to note here that this type of wood has been rarely documented in ancient coffins, and even today this species is not used commonly as a timber product, but it may have been of some local importance in some countries[3] and has been identified in some ancient Egyptian objects[4]. *Cupressus* is distinguished microscopically from most other conifers by abundant parenchyma, ray cells with pitted horizontal walls and smooth vertical walls and cupressoid cross-field pits, circular shape of the tracheids as seen in transverse section and by the frequently observed biserate rays.[5,6]

In most cases local wood was used to make coffins, by gathering small pieces of wood together. To cover all the wood joints, the ancient Egyptian carpenter would cover the wood with a gesso layer.[7-9] In cases where imported wood had a fine texture and was used for making coffins or

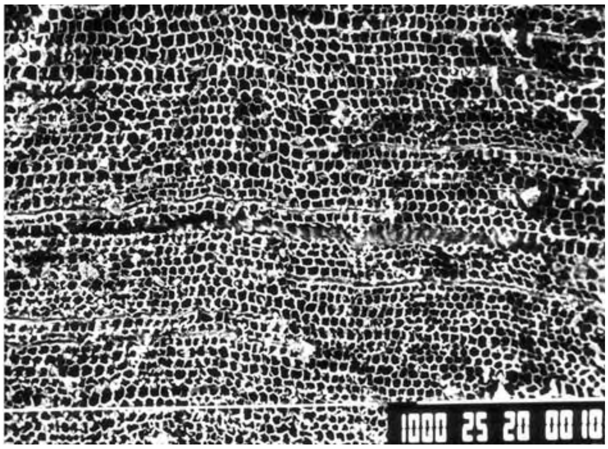

Figure 1. Cross section in Cypress wood taken from the inner surface of the coffin "foot area". Tracheids partially degraded SEM micrograph bar 1000µm.

Figure 2. Cross section in Cypress wood taken from the inner surface of the coffin "head area", the inner cavity of the quadrangular tracheids (somewhat circular shape) are occupied with dense fungal mycelium. A fungal spore is shown in the inner cavity of the tracheid. SEM micrograph bar 10µm.

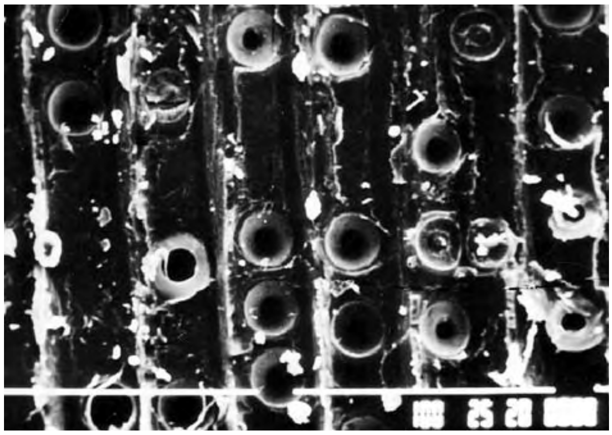

Figure 3. Transverse section in Cypress wood taken from the foot area, showing tracheids and bordered pits, foreign particles and traces of hyphae. SEM micrograph bar 100µm.

other wooden objects, there was no need to cover the wood with a gesso layer. In the case of the coffin box we are discussing, only the inscribed letters were filled with å white filling, of which traces were still evident. An analysis of this material, however, was not done due to the small amount that was available.

Scanning electron microscopy showed there was clear evidence of microbiological attack. Microbiological investigations indicated that the coffin box was infested with the following fungi: *Paecilomyces variotii; Penicillium aurantiogriseum; Aspergillus niger; Aspergillus flavus; Aspergillus terreus; Emericella nidulans; Mucor racemosus.*

These fungi were found in various parts of the coffin box, and their growth rate varied from one part to the other, as can be seen in Table 1. The wood was also infested with the gram positive bacteria *Micrococcus tetragenus.*

These microbiological results revealed only what fungi are currently in or on the wood and all are likely common molds that could easily be isolated from any object or even samples of dust. Comparing these results with microbiological studies done on other materials at the same museum, confirmed this fact.[10]

The diffuse decay appears to have been caused by a brown rot fungus while the coffin was in the tomb for almost 20 centuries, which may be difficult to prove now. The loss of the inscriptions from 1932 to present is likely due to fragmentation of the exceedingly weak and decayed wood and not by current modern microbial decay. Since different types of decay each have unique morphological characteristics, SEM observations of transverse sections can easily differentiate brown rot from soft rot or other forms of decay. It is not uncommon for severely decayed ancient wood with brown rot to fragment and have continued deterioration over time while in storage (even with very careful handling). Small wood chips could be easily blown away and the brittle wooden outer layer would be easily scratched. This confirmed the very fragile nature of the deteriorated wood and losses over time are probably from the severely degraded condition of the wood – not from modern fungi and bacteria found in the object

Sample no.	Sample taken from	Identified fungi	Growth rate
1	outer surface - foot part which contains a desiccated wood knot	Paecilomyces variotii	++++
		Penicillium aurantiogriseum	+++
		Aspergillus niger	+
2	outer surface - left side	Paecilomyces variotii	++++
		Penicillium aurantiogriseum	++++
		Aspergillus niger	+
3	outer surface - right side	Emericella nidulans	++++
4	outer surface - foot part	Paecilomyces variotii	++++
		Aspergillus flavus	+++
		Mucor racemosus	++
		Penicillium aurantiogriseum	+++
		Aspergillus terreus	+
5	inside the coffin box - foot part	no fungi	-
6	inside the coffin box - head part	no fungi	-

- no growth; + weak growth; ++ average growth; +++ over average growth; ++++ excessive growth

Table 1. The distribution and growth rate of the fungi.

It may be presumed that the ancient decay played a major role in the physical and mechanical deterioration of the coffin box, i.e. small cracks all over the wood, warping of some desiccated parts and loss of many parts.

No insect damage was found in the coffin box, although it is important to note here that the second coffin that had been found in the same tomb suffered from an old insect infestation. The second coffin that had been made of local hardwoods, had been totally decayed by wood borers in the right side of the foot area, and deterioration of the right foot of the mummy that had been found in that coffin was clearly evident.

3. Treatment Plan

3.1 Cleaning

As this coffin had never been treated before, it was important to begin with mechanical cleaning. Sand, dust and straw were found inside every crack. To remove these particles it was important to use only fine brushes. But sometimes that was not enough, as these particles would quickly slip back into the cracks, therefore a small photographic blow brush was found to be more useful, as it would blow out the particles, which were hidden inside the cracks. Anything stronger would either blow away small wood chips or scratch the brittle wooden outer layer. This process was time consuming, but it gave the best mechanical cleaning results. Smoothly polished parts were easily cleaned with charcoal erasers. Mechanical cleaning was proceeded by chemical cleaning, in order to remove the remaining fungal mycelium. Cotton wool swabs immersed in one of the following solutions were used for that purpose:

1. distilled water
2. distilled water and methanol 3:1
3. distilled water and methanol 1:1
4. distilled water and ethanol 1:1
5. methanol

Best results were obtained by using solutions no.2 or 5.

3.2 Consolidation

Consolidation of this coffin box depended mainly on the use of gap fillers, which were chosen after several tests. Multiple tests were carried out to select a suitable gap filler, which was required to be reversible, exhibit minimal shrinkage, easy to carve, strong - yet weaker than the wood, whenever possible, exhibit good adhesive properties, easy to handle and to produce an acceptable surface texture that may easily be coloured. Due to

Resins
animal glue 35%
epoxy
polyvinyl acetate
paraloid B-72
hydroxy propyl cellulose
carboxy methyl cellulose sodium salt (CMC)
methyl cellulose
Fillers
sawdust, from pine wood
beeswax and rosin (5:1)
shredded filter paper (for chemical filtration)
shredded papyrus stems, taken from fresh papyrus stems.

Table 2. Selected resins and fillers.

the minimal availability of data about gap fillers used for conservation of archaeological wood and their evaluation, various compositions of resins and fillers were mixed and tested empirically and subjectively. The choice of resins depended on literature and availability in Egypt. Chosen resins and fillers are shown in Table 2.

After mixing several resins and fillers together (with different amounts and concentrations), the following fillers and resins were eliminated, because they gave unsuitable results: animal glue, beeswax and rosin, epoxy, polyvinyl acetate, hydroxy propyl cellulose.

Gap filler	Composition	Viscosity (in poise)	Density of dry filler in g/cm3
A	300 cm3 distilled water, 40 g sawdust, 20 g shredded papyrus, 12 g CMC sodium salt	218 p (at 30 rpm)	0.3203
B	300 cm3 distilled water, 40 g sawdust, 20 g shredded paper, 12 g CMC sodium salt	355 p (at 100 rpm)	0.3741
C	300 cm3 distilled water, 40 g sawdust, 20 g shredded papyrus, 6 g CMC sodium salt	238 p (at 30 rpm)	0.3498
D	300 cm3 distilled water, 40 g sawdust, 20 g shredded paper, 6 g CMC sodium salt	213.9 p (at 100 rpm)	0.4211
E	300 cm3 distilled water, 40 g sawdust, 20 g shredded papyrus, 12 g MC	2313 p (at 12 rpm)	0.3520
F	300 cm3 distilled water, 40 g sawdust, 20 g shredded paper, 12 g MC	185.2 p (at 100 rpm)	0.3603
G	300 cm3 distilled water, 40 g sawdust, 20 g shredded papyrus, 6 g MC	1340 p (at 12 rpm)	0.3854
H	300 cm3 distilled water, 40 g sawdust, 20 g shredded paper, 6 g MC	243 p (at 100 rpm)	0.4495

Table 3. Composition of 8 samples, their viscosity and density after drying.

Sample	Compressive Strength (N)	Compressive Displacement (mm)	Tension Strength (N)	Elongation (mm)
A	52	2.56	22	8.80
B	32 - 44	3.68 - 6.52	299	11.90
C	34 - 44	4.62 - 5.40	11	13.46
D	59 - 142	3.46 - 3.88	180	14.32
E	119 - 274	7.34 - 8.54	43	11.56
F	49 -108	3.94 - 5.42	64	38.54
G	92 - 218	6.52 - 9.10	21	8.88
H	51 - 105	1.76 - 4.08	75	13.46

Table 4. The compressive force and depression of the 8 samples (cubes) and the average tension force and elongation of the 8 samples (thin plates).

The remaining fillers and resins were then mixed together. Viscosity of the mixture was measured by using a Viscometer RI:I:M; (Rheology International); spindle no.7. The results are shown in Table 3.

These samples were then placed in specially made moulds and left to dry. After drying, the 1cm^3 cubes were tested in order to try to evaluate their mechanical properties, the force was measured in Newton with a Chatillon Force measurement apparatus (model ET 1100 at 30 mm/sec.). A sample of the same mixture was poured into thin balsa wood frames. Thin plates of the gap filler were obtained (5 cm × 5 cm × 0.2 cm). The elongation of these gap filler plates was measured using the same apparatus.

All 8 samples were also placed in an oven with a glass door, so that light could penetrate the samples. The oven was set at 68°C for 5 weeks. These accelerated aging conditions have been found to give a fair representation of the actual long term behavior of materials inside the museum.[11]

4. Results

Choice of appropriate gap filler for the conservation of the coffin box depended on the results obtained. Density of gap filler samples was within the average range of the density of coniferous woods. Gap fillers that had either a very high or very low viscosity had to be eliminated because of the difficulty of handling during treatment. As for the other results obtained, it was evident that sample D had a relatively elastic tensile stability with respect to a relatively high tensile strength, contrary to sample B, which had a very high tensile capacity. Sample D showed the best capability to handle the compressive stresses superimposed.

From the previously mentioned experiments the most suitable gap filler was chosen. It was fillet D, composed of sawdust, filter paper (2:1) and carboxymethylcellulose sodium salt (2%). While it would be desired to determine some properties of the ancient wood, this was not possible due to the destructive nature of the tests.

Figure 4. Part of the coffin box, showing the degree of decay, where wood has cracked into cubicle pieces, where little to no integrity remained in the wood.

Figure 5. The use of a gap filler in the previously shown part of the coffin box, during treatment.

This filler did not have a high viscosity, was easy to shape and its density was close to the density of Cypress wood. Its colour showed the least colour change during the accelerated heat aging.

5. Conservation of the Coffin Box

The small missing parts and cracks in the coffin were carefully filled with the chosen filler and left to dry. In areas were the missing pieces were bigger than 5 cm, the dent was first filled with a small layer of gap filler. Small pieces of balsa wood were then placed in the dent and covered with more filler, until the outer surface reached the expected level. It was easy to use fine sandpaper on the dry outer surface of the gap filler, in order to obtain a smooth finish similar to the ancient wood surface. At the end of the whole process the outer paste layer was coloured using water colours, which helped cover the pale colour of the newly introduced material (Figures 4-7 show the 3 stages of conservation).

Inner parts of the coffin were fixed in place by using fine strips of Japanese tissue paper, in order to prevent small pieces from falling off. The strips were glued to the outer wood surface using 2% methyl cellulose. Afterwards they were coloured with water colours (figure 8).

6. Discussion

During the examination of the coffin box various unexpected results were obtained. The coffin box was extremely deteriorated, and in some areas the wood would simply crumble when touched or held between the fingers. In the past, it was believed that the coffin box had been made out of local wood that does not resist microbiological decay. The anatomical features of the samples taken from different parts of the coffin box all proved that the wooden tree trunk, out of which the coffin box had been carved, was a cypress tree. This wood had

Figure 6. Before treatment

Figure 7. During treatment

Figure 8. During treatment of inner parts using Japanese tissue paper

Figure 9. After treatment.

been rarely used in the manufacture of wooden coffins, and was documented only in a few recent references.[12,13] It has been reported that 6 coffins had been made out of this imported wood. There is no doubt of course that by studying and identifying the immense number of ancient Egyptian coffins found in museums all over the world, the actual number of coffins made from cypress could be much larger. What had been recorded in the Cataloge Generale of the Egyptian Museum in Cairo in the first two decades of the twentieth century will certainly have to be changed, especially because most of the wood was classified as sycamore.

The microbiological examination showed some interesting results. In various references wood decaying fungi are divided into brown rot, white rot etc. Blanchette et. al.[14,15] confirm that both brown and soft rot were encountered in some archaeological wood examined from ancient Egypt. Here, SEM observations indicate that the decay is not caused by a soft rot fungus, as no cavities can be seen in the cell walls. The decay appears to be caused by a brown rot fungus. All indications are that this decay was caused by a brown rot fungus while the coffin was in the tomb. The fungi isolated from the wood are common mold fungi that can be found frequently on any substrate. Eaton et. al.[16] and Zabel et. al.[17] consider the *Aspergillus sp.; Paecilomyces sp.* and *Penicillium sp.* moulds of minor danger compared to other wood decaying fungi. These fungi stain wood, and that was evident on the outer surface of the coffin box.

Mucor sp. is considered a primary saprophytic fungus with a fast growth rate, but by comparing the microbiological results obtained with the microbiological studies done in Egypt it was interesting to note that both, *Aspergillus flavus* and *Emericella nidulans* are major cellulolytic fungi found in Egyptian soil. They both produce exo-β-1,4-glucanase, endo-β-1,4-glucanase, which decompose cellulose. The first enzyme is responsible for the initial attack of more highly ordered forms of native cellulose. The latter completes the degradation to the short-chains, cellobiose.

Although these fungi can produce cellulase enzymes that does not indicate they can degrade lignified wood or are responsible for the decay found in the coffin. They may cause some soft rot attack under very extreme conditions over a very long period of time. If they were to attack the cypress coffin, the wood cells would have a Type 1 soft rot – with cavities formed in the cell walls. This is easy to observe in degraded wood under SEM, but in our case these cavities were not evident. The extensive, diffuse attack found in the coffin and the large losses of strength associated with this decay indicates it is caused by a brown rot fungus, which is clearly seen in Figures 1-3, and was noted during treatment of wood. With such a long period of time in storage, the brown rot fungus would not be able to be isolated from the wood.

As for the bacteria that were found on this coffin box, namely gram - positive *Micrococcus tetragenus,* tests proved that they grew on blood agar, but their growth stopped on Sabouraud's agar after 4 days.[18] Further research needs to be done in order to study the colonisation sequence of microbes on wood and their effect.

It was surprising to see that the inside of the coffin box, which was covered with an ancient resin, and in which the mummy had been placed, showed no fungal growth in any of the two parts that were examined.

Due to the results obtained from the microbial study of the coffin box, the authors were keen to undergo further studies on the chemical composition of the wood. That was one of the reasons why they decided to use gap fillers for the stabilization of the falling and crumbling parts. Any chemical consolidation would not only be irreversible, but it would also change the physical and mechanical properties of the wood. Further chemical composition studies would also be impossible.

The choice of the gap filler depended on both recent literature in addition to tests carried out. Hatchfield[19] discussed the use of glass microspheres in Acryloid B-72 as a gap filler for water sensitive materials, where large voids and unsupported surface pieces required a strong, lightweight fill material which would not affect water-sensitive gesso or painted surfaces, and not be absorbed into porous materials. Storch[20] mentioned in his introduction the various gap fillers that had been used for treating different cases in wood, but he used room temperature vulcanizing (RTV) silicone resin as flexible gap filler for restoring structural integrity to the components of a wooden architectural object. Watkinson and Brown[21] mentioned the use of two different fill materials, which showed different properties. Each of the two fillers was used according to the state of the part of the coffin which was being treated. Both Watkinson and Brown[21] and Narkiss and Wellman[22] consolidated ancient Egyptian coffins. Watkinson and Brown used Paraloid B-72 to fill the flight holes that had been caused by an insect infestation and Narkiss and Wellman used Poly Vinyl Acetate to consolidate flaking gesso layers, but both these cases are completely different from the coffin that was being treated here. The coffin has been stable for the last 10 years since it was last treated, and it is being monitored in case of change.

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