# On the Aging of Wood from Cultural Heritage

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Abstract

This paper reviews the research on the aging of wood from cultural heritage, these are, 1) Collection and identification of wood samples from cultural properties and historical buildings, 2) Characterization of the naturally aged wood, and 3) Characterization of the accelerated aging (heat) treated wood and its application to the restoration of the wooden cultural properties.

Wood is aged and degraded under the service of any applications. The subsequent changes of the physical, mechanical and chemical properties of wood proceed very slowly and depend on environmental conditions. Japan preserves a great amount of wooden cultural properties and historical buildings and the precise understanding and characterization on the aging of wood is of critical importance for their conservation and restoration.

Since wood culture and science is an interdisciplinary study being involved with many research fields of Museology, Conservation and restoration science, Archaeology, Material science, and Wood science, the collaboration with the network among the various research fields are essential to promote the research activities.

We started to collect the wooden samples from cultural properties and historical buildings under the support of the Agency for Cultural Affairs of Japan and the collaboration with the related research organizations, such as National Research Institute for Cultural Properties, Nara (NRICP), National Museum of Japanese History (MJH), and Tokyo National

University of Fine Arts (TUFA). The samples are identified the species, then registered at the Xylarium at the Research Inst. for Sustainable Humanosphere, Kyoto University and described with historical, physical, and mechanical properties.

Specimens of hinoki (*Chamaecyparis obtusa* Endl.) aged wood cut out from 8 selected samples were dried and then the physical (density, equilibrium moisture content, color properties, etc.), mechanical (moduli of rupture and elasticity in bending, yield energy), and chemical (chemical components, FT-IR spectroscopy, X-ray diffractometry) properties were evaluated.

As a part of the results from the physical and mechanical properties, the age of the naturally aged wood samples was determined by the dendrochronological dating cross-checked with $^{14}C$ measurements, ranged from 600 to 1700 years and their equilibrium moisture contents were measured. The results showed the wood substances of aged wood were less accessible to moisture and the equilibrium moisture content of the naturally aged wood decreased with an increase of the aging period. The typical stress-strain curves of the aged wood of hinoki samples in the longitudinal direction showed somewhat higher strength and stiffness but less toughness than those of control. It seems that the bending strength in the longitudinal direction of the naturally aged wood samples does not change so much through the aging period over 1600 years, though the values are scattered.

The aging of wood is considered to be a slow thermo-oxidative process caused by oxygen in the air. The hinoki specimens with the highest quality in terms of Buddhist sculptors were subjected to the heat treatment at 90, 120, 150 and 180 C under various treatment times from 0.5 hr to 7 years by normal oven method. Effects of accelerated aging (heat) treatment on the changes of color properties were characterized and the results from the wood under the heat treatment were compared with those from naturally aged wood.

Color was measured by using a spectrophotometer and a spectroscopic imaging system and expressed by the CIELAB color parameters ($L^*$, $a^*$, $b^*$ and $\Delta E^*_{ab}$). Obtained color data were discussed by means of kinetic analysis applying the time-temperature superposition (TTSP) method for accurate analysis. Color changes that occur during naturally aged wood were similar to those during heat treatment for all materials. Color changes

were expressed by decreasing $L^*$, increasing $\Delta E^*_{ab}$, and changes in $a^*$ and $b^*$ characteristic to each material, with increasing treatment duration. Thus, the aged wood was getting darker, redder and more yellow. Measured color data was successfully analyzed with high accuracy. In the temperature range from 90°C to 180°C, the reaction of color changes followed the Arrhenius equation for all materials, which indicated that color changes in this temperature range can be explained by the apparently same reaction mechanism. The heat treated wood controlled under a certain temperature and period was then applied to the restoration of cultural properties.

# In Search of a Balance between Restoration of Cultural Heritage and Tourism Development

Shunsaku Miyagi
Representative Director, Byodoin Temple

Byodoin Temple, located in Uji City 10 miles south of the central part of Kyoto, was founded in 1052 by Fujiwara no Yorimichi, the regent or the chief advisor to the Emperor, as a religious institution of Pure Land Buddhism. Primary concept of the temple was to envision the image and environment of Pure Land on the earth based on the notion that the year was predicted to be the beginning of decadent ages of Dharma, and people tried to mitigate it by building the temple to demonstrate their devotion to Buddhism.

The entire precinct and area vicinity have been designated as a UNSESCO ‘s World Heritage site since 1994 and, around that time, the temple initiated a series of major projects for repair works, conservation and restoration of its cultural heritages, which has been continued over a quarter of century and are summarized as follows. Being based on the scientific research and surveys by the specialists participated from various fields of expertise, most works have been carefully conducted in search of a balance between restoration of cultural heritage and tourism development of the temple itself and the local community.

## 1. Restoration of the original Pure Land garden

Based on extensive archeological excavation and surveys in and around the temple site conducted for over 7 years, the original form and visual images of the pure land garden has been revealed. Restoration works were conducted mostly on the shoreline of the island representing wave-washed beach along the pond on which Phoenix Hall has been set.

## 2. Foundation of the Temple Museum Hoshokan

In order to prepare appropriate environmental conditions for protection and exhibition of the cultural heritages, a new museum was built in the precinct of the temple. According to the results of visual analysis to avoid conflict with historic landscape, the entire architectural volume was set in the hillside of natural topography and visitors circulation system enhances visual experience in the garden.

## 3. Repair of Amitabha statue and ornamental art works

Amitabha, the main statue in the Phoenix Hall, needed intensive care and repair works on its outer surface after having been exposed to the air for several hundreds years. Other statues and ornamental art works also to be repaired include 52 bodhisattvas or saints on the cloud, fine openwork of umbrellas on the ceiling, podium with lotus flower petals and the halo of Amitabha statue.

## 4. Repair and conservation of the door and wall paintings

A series of door and wall painting in the interior of Phoenix Hall, which portray 9 scenes of Raigo （来迎） where Amitabha Tathagata appears to spirit away a dying person, required intensive treatment of their surface for protection. Also, the original 4 pairs of door painting were replaced by reproductions and moved to storage of the museum.

## 5. Restoration of the main structure Hoo-do or Phoenix Hall

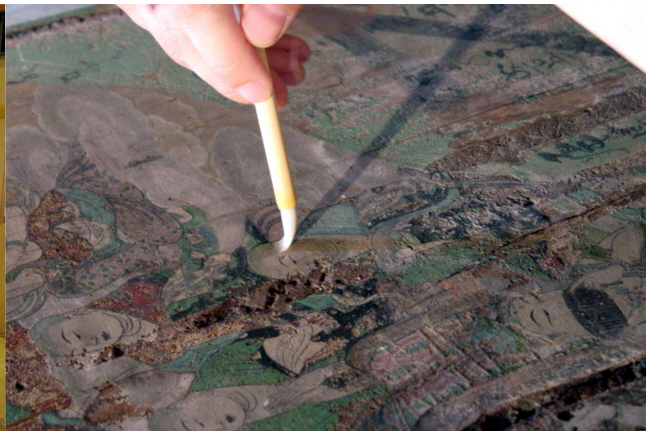
Major restoration works of Phoenix Hall included wooden works of overall structure and coating its surface with original painting materials, replacement of roofing tiles by those of the original design, and some repair works for the metal ornaments. The original color and its primary ingredient on the entire wooden structure were identified through the chemical analysis of the residues found on the original tiles and wooden parts.

Phoenix Hall after the restoration works

Archeological survey of the pure land garden

Exhibition hall in the museum

Repair works of Amitabha statue



Repair works of the door painting