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# Strike a Balance - Repair or Replace?

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**Abstract** The preservation and conservation of deteriorated historical structures is always a difficult but challenging task. Theoretically, all significant historic structures should be conserved and saved from being removed or discarded. Practically, this ideal may not always be achievable for all decayed components of the historic structures. Sometimes their conditions are too bad to be reasonably repaired to a safe state. On the other hand, replacement is not the only resort for all the damaged relics. There are situations that these relics should better be preserved, though more resources will have to be invested and greater challenge might be encountered in the course of work. This paper attempts to illustrate the deliberation with a case study - the preservation of wooden structures of Chik Kwai Study Hall in Hong Kong, and addresses the considerations in making decision between repair and replacement. Scientific or structural analysis has played a key role in directing our way to the final decision. Methodology used for guiding the whole conservation process will also be discussed.

**Keywords:** Conservation, consolidation, consolidant, restoration, gap-filling, gap-filler, historic structure

## Introduction

Chik Kwai Study Hall, a typical traditional Chinese study hall in Hong Kong, was built not later than 1899 by Lai clan in Sheung Tsuen, Pat Heung, Yuen Long. It was originally built for the education of young clansmen and had been used for ancestors worship since 1930s. It also served as a venue for holding clan meetings and traditional rituals, such as wedding ceremonies and ancestors worship at spring and autumn equinoxes.

Chik Kwai Study Hall is a typical example of traditional two-hall-one-courtyard structure of the Qing dynasty. The impressive facade of the green-brick study hall is distinguished by the solemn granite-block wall base and the overhanging roof supported by ornamental brackets, camel humps and granite columns. The roof ridge of the entrance hall is decorated with delicately made polychrome plaster moulding expressing the aspiration of "carp jumps over the dragon gate". In the interior, all the exquisitely craved camel humps and eaves boards depict various Chinese folk stories and traditional auspicious motifs. They demonstrate an outstanding and remarkable skill of craftsmanship amongst others, and are considered as one of the best and representative wooden carvings in the Chinese structures that still survive in Hong Kong (Ho and Lo et al. 2008).

Chik Kwai Study Hall was gazetted as a monument in 2007, and was in a state of bad disrepair. To preserve this valuable historic building, a full restoration programme has been carried out since 2009. After restoration, the building would be open for the public to appreciate its exquisite features and hence the local history and cultural heritage of the area.

*Figure 1: Front view of Chik Kwai Study Hall before restoration*

**The Problem** Being constantly affected by the adverse sub-tropical climate, the century old Study Hall was in an alarming state of deterioration when our conservators were enlisted to provide technical assistance. Among other problems, its timber members of the structural frames supporting the roof were suffering from a range of problems -- the biological growth and surface contamination of the wood materials, loss of pigments due to weathering, and the worst of all, signs of extensive termites attack resulting in damage of figurines and collapse of the wooden structures. The problem was so extensive and serious that it was doubtful if all of these wooden structures could be preserved without compromising the structural stability of the Study Hall. A careful and detailed assessment must be carried out as these wooden components, such as camel humps were the key components of the whole structural system. They served to support the upper wooden beams and in turn the entire tiled roof.

**Replace or Repair?**

Obviously from the views of the architects or structural engineers, the simplest and safest way to restore the Hall is to replace all the deterioated wooden components with new and structurally sound reproductions. Nevertheless, this implies that there would be total loss of the authentic carvings, pigment and thus the historical evidences of the building. To resolve the dilemma, a conservation strategy agreed by the conservators, curators, architects and village representatives was worked out for the necessary repair of wooden structures in the Study Hall with a view to meeting the principle of conservation on one hand and addressing the public safety concerns on the other. A 3-Class (I, II & III) appraoch has therefore been adopted:

1. Class I - total preservation and retention, in which all the finest parts of relics should be consolidated and preserved as far as possible. They should be properly treated and reinstated to their original state and position after conservation.
2. Class II - partial replacement, in which replacement with replica would be carried out for non-critical parts, supplemented with consolidation of weaker original parts, to ensure the strength of them would be comparable to the original wooden structures.
3. Class III - total replacement, in which the badly damaged wooden structures would be replaced with new reproductions.

Amongst the other considerations, our conservators would examine the authenticity and aesthetic merits of the wooden components, their degree of deterioriation and residual strength to contemplate a suitable class of treatment approach for the materials.

For instance, the carved figurines in front of the camel humps are said to have attained a very high level of aesthetic merits and exquisite craftsmanship, reflecting on the cultural aspirations of the ancestors. Though the figurines had suffered extensively from termite attack, all the stakeholders agreed to accord Class I treatment to them so as to preserve these character-defined elements. On the other hand, the back of camel hump depicting the engravings of some cloud patterns is nevertheless

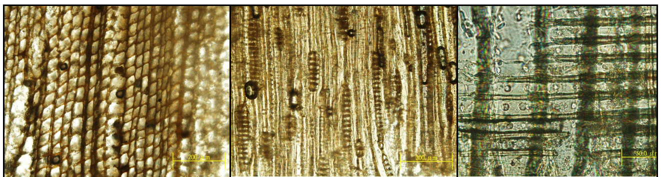
less distinctive or appealing when compared with the figurines in the front. In consideration of that very little fibres and strength have been left in this part of the wooden structure after the termites attack, they would be given a Class II treatment to re-generate the needed structural strength. And as an example of Class III treatment, the roof structure of the Study Hall had been subjected to serious termite infestation and its badly infested Chinese fir beams and purlins exhibited a high risk of collapse. In order to alleviate the immediate danger, this part of the structure which had no decorative elements on it was reproduced and refitted to position.

| Front of camel humps: Class I Treatment | Back of camel hump: Class II Treatment | Purlins and beams: Class III Treatment |
|---|---|---|

*Figure 2: Condition of wooden components before restoration*

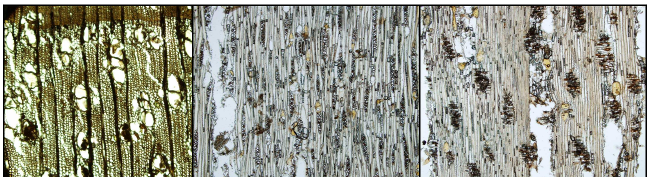
**Identification of Wood**

It was of paramount importance to learn of the species of the wood materials and to understand their physical and mechanical properties before our conservators proceeded with the Class I and Class II treatment for 8 wooden camel humps.  Hence, small samples of wood were cut out from the inconspicuous areas of the structures and trimmed by steel razor blade to reveal the cross, radial and tangential sections. The sections were then water mounted on microscopic glass slides and examined under polarized light microscope (Olympus BX 60). The images (Fig.3) were captured by digital camera (Olympus DP 70).



| *Cross section* | *Tangential section* | *Radial section* |
|---|---|---|

*Fig 3a The cross, tangential and radial sections of the sample obtained from one of  the camel humps show that it is Funeral Cypress in nature*



| *Cross section* | *Tangential section* | *Radial section* |
|---|---|---|

*Fig 3b The cross, tangential and radial sections of the sampleobtained from another camel hump show that it belongs to a Camphor tree*

*Figure 3: Images*

Two species of wood were identified in the samples from the 8 camel humps. Two of them were made of the Cuprecsus funebris Endl, commonly known as Funeral Cypress, and six of them were made of the Cinnamomum camphora (L.) Prest, commonly known as Camphor tree (Hoadley 1990). Both species are native of China and are typically used as timber materials for building construction, not only because of their desirable specific density which will largely determine the major strength properties of wood (Senft 2003) but also the fact that they contain a kind of volatile chemical compound emitting typical aromatic scent which will serve as an insect repellant or a preservative (Earthnotes Herb Library 2005). It was however ironic in Chik Kwai Study Hall that its wooden structures made of Camphor Tree had also been attacked by termites and left with millions of bored tunnels throughout the wood. It could be explained by our observations that the persistent seepage of rainwater had wetted the wooden components over time, which generated a favourable damp environment for microorganisms to grow on the wood materials and thus damaged their cell structure. As a consequence, the wood materials gradually lost their characteristics aromatic scent and

anti-insect function (Ridout 2000); hence the damp micro-environment invited the colonization of the destructive termites.

Moreover, Camphor Tree and Funeral Cypress have been the most favourable raw materials for carving as they are stable and moderately dense and hence rather resistant to deformation. This is why the finest carvings of the 8 wooden camel humps have been made on these wood materials.

**Choice of Conservation Methodology**

Though decision has been made to preserve the wooden carvings on the front surface of the camel humps as much as possible, the material substrates have been generally infested by termites and rotted to a state that the camel humps were virtually void of the substantive fabrics leaving behind only the surface profile. As they are considered as the structural components of the building, the course of conservation must comprise the consolidation and gap-filling work to resume the original strength of the substrates.

To meet this end, the choice of suitable consolidant and gap-filling materials was of paramount importance. An ideal consolidant and gap-filler should have the comparable texture, hardness and tensile strength with the wood of camel humps(Eaton 1993). In consideration of that the consolidant and gap-fillers would be in contact with each other as an integrated system of the restoration materials, it was desirable from the compatiblity point of view that they were the same class of materials so that they would bond well with each other. The identification of the wood species has made the literature search of the mechanical properties of the substrate possible, which provided important clues for the selection of appropriate consolidation and gap-filling materials for the camel humps. As a prerequisite, for instance, the hardness and tensile strength of the consolidants or gap-filler should be comparable with that of Camphor Tree and Funeral Cypress (Unger et al. 2001).

Liquid epoxide resin (ER) and epoxy wood enhancer (EWE) are consolidants commonly used for structural strengthening, whereas polyester resin (PR), epoxy wood substitute (EWS), wood adhesive powder (WAP) in aqueous medium are common gap fillers generally used for wood repair. Other than the aforesaid 3 gap fillers available in the market, sawdust was also added to ER and EWE respectively to test whether they could be used as gap-fillers. The addition of sawdust not only results in an increase in viscosity which makes the application easier in a paste form, but also has the merit of enhancing the texture and hardness of the wood substitute formed and consequently reducing the cost. Tests were carried out in order to evaluate the physical properties of the aforesaid materials and hence to find out the most suitable consolidant and gap filler for the camel humps. The hardness parameters were measured by a Durometer according to ASTM D2240, whereas the tensile strengths were measured by Tensile Test Machine according to ASTM D638. Table 1 shows the results of the measurements:

*Table 1: Hardness and tensile strength of various consolidants and gap-fillers*

| *Material* | *PR (1)* | *EWS(2)* | *WAP(3)* | *WAP+ Sawdust (4)* | *ER(5)* | *ER+ Sawdust (6)* | *EWE (7)* | *EWE+ Sawdust (8)* | *Camphor Tree* | *Funeral Cypress* |
|---|---|---|---|---|---|---|---|---|---|---|
| *Hardness* | 72 | 69 | 81 | 78 | 61 | 71 | 82 | 73 | 77 | 67 |
| *Tensile Strength [mPa]* | 81.0 | 108.6 | 34.4 | 48.0 | 44.2 | 49.8 | 454.9 | 193.9 | 464.7* | 243.5* |

**Tensile strength measured parallel to grains*

*1 = Unsaturated polyester resin: its hardener = 19.6 / 0.4 (w/w)*

*2 = Bisphenol-A-(epichlorhydrin) epoxy resin, glycidylester of neodecanoic acid: Mixture of isophorondiamine, polyoxypylendiamine, nonylphenol, and m-xylylendiamine (hardener) = 18.75/1.25 (w/w)*

*3 = wood adhesive powder: water = 3: 1 (w/w)*

*4 = wood adhesive powder: water: sawdust = 15: 5: 4 (w/w)*

*5 = Liquid epoxide resin: Proprietary liquid amines = 1 : 1 (w/w)*

*6 = Liquid epoxide resin: Proprietary liquid amines: sawdust = 5: 5: 2 (w/w)*
*7 =Bisphenol-A-epichlorhydrin resin : mixture of isophorondiamine,polyoxypylendiamine, nonylphenol, and m-xylylendiamine (hardener) = 3: 1 (w/w)*
*8 =Bisphenol-A-epichlorhydrin resin : mixture of isophorondiamine,polyoxypylendiamine, nonylphenol, and m-xylylendiamine (hardener): sawdust = 15 : 5 : 4 (w/w)*

From the results, the hardness of WAP with addition of sawdust (78) is closest to that of the Camphor Tree (77) amongst the gap-fillers tested while the hardness of ER with addition of sawdust (71) is closest to that of Funeral Cypress (67). However, their tensile strengths are far lower than that of the two timber species. Therefore, EWE was selected as the gap-filler for the camel humps made of Camphor Tree as their tensile strength and hardness were comparable with each other while EWE with sawdust was selected as the gap filler for the 2 camel humps made of Funeral Cypress for the same reason. To achieve good compatibility between the consolidant and the gap filler, EWE was also employed as the consolidant for camel humps.

It was moreover noted that the addition of sawdust to EWE could reduce the hardness from 82 to 73 and tensile strength from 454.9 to 193.5mPa. These reductions are beneficial to its use in the restoration of figurines as it is then easier to carve or cut the mixture to conform with the original shape, curvature and profile of the figurines. Therefore EWE was applied as the gap-filler for camel humps made of Camphor Tree to form a stronger and harder inner core to support the structures, whereas EWE mixed with an appropriate amount of sawdust was used to form the outer layer of the gap-filling to facilitate the carving. This strategy has been successfully employed for the whole restoration process.

*Front view* *Back view*

*Figure 4: Wooden camel humps after conservation*

## Replacement of Wood

The decayed back of the camel humps was replaced in accordance with the Class II approach. Conservative pieced-in repair was used to replace rotten substrates with the same wood species. There have been two options to avoid the potential problems of deformation or shrinkage which might occur in the new replicated wood materials. We might either seek to find the same type of wood materials with comparable age and in the neighbouring region of the Chik Kwai Study Hall, or use the new timber of the same species after artificial seasoning. The first option is preferable as the properties of the wood should remain relatively unchanged over time if the identified wood materials have been kept dry and free from mechanical and insect damage (Senft 2003). The quantity of the available wood materials might not meet the full demand of the job, we were therefore bound to adopt a certain amount of new wood as replacement materials, yet caution must be exercised to avoid further changes in condition such as formation or widening of cracks or splits due to the drying process, when the

equilium mosture content was brought down to the required level of 15% for the sack of pieced-in repair (The Grand Solution Manual Website 2008). Otherwise, the increase in strength as the moisture content decreases will be offset or nullified.

## Conclusion

The conservation of 8 camel humps has truely achieved the aim to conserve the fabulous features of a historic building, reinstating their loadbearing function and revealing their artistic and cultural value through improvement of their state. The principle from ICOMOC's Principles for the Preservation of Historic Timber Structure (1999) have been thoroughly observed, yet the conservation philosophy would not be achievable if without the necessary scientific support.

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