NATURAL DURABILITY, PRESERVATIVE TREATABILITY AND PROTECTION OF SEVERAL HARDWOODS OF SARAWAK

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ABSTRACT

Natural durability, preservative treatability and protection of several hardwoods of Sarawak

by

Ling Wang Choon

Before 1977, there were no studies on natural durability and treatability of Sarawak timbers. Most information on durability was anecdotal, the species then assumed to be very durable were Belian, Selangan batu, Penyau, Kapur, Resak and Bakau. Timber Research and Technical Training Centre therefore established a graveyard test site for such field studies so that useful data on utilization of Sarawak timbers could benefit the Sarawak forest products industry. The objectives of this thesis are to determine from 30 years of research on natural (in-ground) durability (of mainly the outer heartwood present in a majority of wood species studied) and preservative treatability the relative natural durability and degree of protection of some preservative treated Sarawak timbers. The durability of 26 refractory and 106 non-refractory timber species with and without preservative treatments was established by regular assessment of stakes in ground contact at the Sarawak Tree Improvement Centre located at Oya Road, Sibu, adopting the ASTM D1758 for assessing replicated stakes of the wood species [stake replication, 20; stake size: 19 x 19 x 457 (long.) mm]. To ensure uniform and good decay condition, plots were alternated between areas with original vegetation cover and a permanent vegetation belt was maintained around each row of stakes. Stake specimens planted over the years 1977-2000 were each visually rated at 6-month intervals for the first 10 years from installation and subsequently once a year until April 2008. The field results were analyzed using SPSS Windows Version 15.0. Comparative natural durability ratings between
the 133 wood species, matched against wood density groups, commercial timber groups (e.g. the keruings, mixed light hardwoods, the merantis, the kapurs) and refractory-versus-permeable groups, revealed statistically that the very durable species are *Eusideroxylon zwageri*, *Shorea pluricostata*, *Upuna borneensis* and *Gymnostoma nobile*. The 16 durable species included *Shorea exelliptica*, *Shorea flava*, *Shorea laevis*, *Pentace corneri*, *Shorea acuminatissima*, *Tectona grandis*, *Palaquium rivulare*, *Hopea latifolia*, *Hopea beccariana* and *Shorea uliginosa*. The 39 moderate durable species included *Tristania whiteana*, *Cantleya corniculata*, *Jackia ornata*, *Parashorea snythiesii*, *Dialium indum*, *Dacrydium elatum*, *Anisophyllea beccariana*, *Shorea carapae*, *Lithocarpus cantleyanus*, *Pometia pinnata* and *Anisoptera grossivenia*. The remaining 74 species, including potential plantation species such as *Acacia mangium*, *Neolamarckia cadamba*, *Shorea macrophylla*, *Dyera polyphylla* and *Octomeles sumatrana*, were found to be non-durable.

Statistically, it was shown that wood species with high Chromated Copper Arsenate (CCA) retentions with mean retention values <20 kg/m$^3$ were in good condition after 20 years in ground contact while a majority of Chromated Copper Borate (CCB) treated timbers at a mean retention <24 kg/m$^3$ lasted just 10 years. Creosote treated timbers (mean retention 108 kg/m$^3$) failed by the 13th year while Fluor-Chrome-Arsenate-Phenol (FCAP, mean retention 21 kg/m$^3$) failed by the 8th year. From statistical analysis of OHW, natural durability of 133 timber species as well as durability of 131 timbers treated with these wood preservatives was found to vary considerably. Overall, it was found that 26 species (19.5% of all species tested) were refractory treated using CCA full-cell treatment while 107 species (80.5%) were non-refractory. The 26 refractory species consisted of four very durable (3% of all species), seven durable (5.2%) and 15 moderately durable (11.3%) species. None of the refractory species
belonged to the non-durable group. The non-refractory group had 74 species (55.6% of all species) belonging to non-durable group, 24 species (18.1% of all species) belonging to moderately durable and nine species (6.8%) belonging to durable group. None of the non-refractory species belonged to the very durable grouping.

From these overall findings the timber utilization prospects and issues of untreated and treated Sarawak species are discussed in relation to matters such as: similar work around the world, test methodology issues, wood used in agriculture, construction and wood composites, their wood density classes, trends between botanical groups of species, future plantations, and future research needs beneficial to the Malaysian and Sarawak forest products industry are proposed.
ABSTRAK

Ketahanan semula jadi, kebolehrawatan pengawet dan Perlindungan Kayu-kayu keras dari Sarawak

Oleh

Ling Wang Choon


Analisis menunjukkan bahawa spesies kayu yang mengandungi Chromated Copper Arsenate (CCA) yang tinggi dengan nilai pengekalan min \(<20 \text{ kg/m}^3\) berada dalam keadaan yang baik walaupun lebih daripada 20 tahun di dalam tanah. Kebanyakan kayu yang dirawat dengan pengekalan min \(<24 \text{ kg/m}^3\) Chromated Copper Borate (CCB) pula tahan selama 10 tahun. Kayu-kayu yang dirawat dengan Creosote (pengekalan min 108 kg/m\(^3\)) gagal bertahan sehingga tahun yang ke-13 manakala kayu-kayu yang dirawat dengan Fluor-Chrome-Arsenate-Phenol (FCAP, pengekalan min 21 kg/m\(^3\)) tahan sehingga tahun ketujuh sahaja. Daripada analisis statistik OHW, ketahanan semula jadi 133 spesies kayu balak dan 131 kayu yang telah dirawat menunjukkan perbezaan yang amat ketara. Secara keseluruhannya,
didapati 26 spesies (19.5% dari jumlah spesies yang dikaji) ialah kayu refraktori yang tidak mudah dirawat dengan CCA sementara 107 spesies (80.5%) berjaya dirawat. 26 spesies refraktori termasuk empat spesies yang sangat tahan (3% dari jumlah spesies), tujuh yang tahan (5.2%) and 15 spesies yang sederhana tahan (11.3%). Semua spesies kayu refraktori tidak digolongkan dalam kumpulan kayu yang tidak tahan. Dalam kumpulan kayu bukan refraktori, 74 spesies (55.6% dari jumlah spesies) digolongkan dalam kumpulan tidak tahan, 24 spesies (18.1% dari jumlah spesies) digolongkan dalam kumpulan sederhana tahan dan 9 spesies (6.8%) digolongkan dalam kumpulan tahan. Tiada spesies dari kumpulan bukan refraktori dalam kumpulan kayu yang sangat tahan.

Dapatan daripada penyelidikan ini, prospek penggunaan kayu balak dan isu-isu kayu dari Sarawak yang dirawat dan tidak dirawat dibincangkanseperti hasil kajian dari Negara-negara lain, isu berkaitan dengan metodologi ujian, penggunaan kayu untuk pertanian, industri pembinaan, komposisi kayu, pengelasan ketumpatan, perbezaan botani antara spesies, perladangan dan keperluan penyelidikan pada masa hadapan yang memanfaatkan industri hasil hutan Sarawak dan Malaysia juga dicadangkan.
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<tbody>
<tr>
<td>ASTM</td>
<td>American society for testing of materials standard</td>
</tr>
<tr>
<td>BFCA</td>
<td>Borate-Fluor-Chrome-Arsenate</td>
</tr>
<tr>
<td>CCA</td>
<td>Chromated Copper Arsenate</td>
</tr>
<tr>
<td>CCB</td>
<td>Chromated Copper Borate</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organization, Australia</td>
</tr>
<tr>
<td>DMRT</td>
<td>Duncan’s multiple range test</td>
</tr>
<tr>
<td>FCAP</td>
<td>Fluor-Chrome-Arsenate-Phenol</td>
</tr>
<tr>
<td>FD</td>
<td>Forest Department, Sarawak</td>
</tr>
<tr>
<td>FRI/FRIM</td>
<td>Forest Research Institute Malaysia, Kepong</td>
</tr>
<tr>
<td>H1</td>
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<tr>
<td>H2</td>
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</tr>
<tr>
<td>HHW</td>
<td>Heavy hardwoods</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
</tr>
<tr>
<td>kg/m$^3$</td>
<td>kilogram per cubic meter</td>
</tr>
<tr>
<td>kPa</td>
<td>kilo Pascal</td>
</tr>
<tr>
<td>LOSP</td>
<td>light organic solvent preservative</td>
</tr>
<tr>
<td>LVL</td>
<td>laminated veneer lumber</td>
</tr>
<tr>
<td>MGR</td>
<td>Malaysian Grading Rules</td>
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<tr>
<td>MHW</td>
<td>medium hardwoods</td>
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<td>MLH</td>
<td>mixed light hardwoods</td>
</tr>
<tr>
<td>MC</td>
<td>moisture content</td>
</tr>
<tr>
<td>MKK</td>
<td>Meranti, Kapur, Keruing</td>
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<tr>
<td>MTIB</td>
<td>Malaysian Timber Industry Board</td>
</tr>
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<td>MWPA</td>
<td>Malaysian Wood Preserver’s Association</td>
</tr>
<tr>
<td>M$^3$</td>
<td>cubic meter</td>
</tr>
<tr>
<td>od</td>
<td>oven dry</td>
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<tr>
<td>OHW</td>
<td>outer heartwood</td>
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<td>Sp./spp.</td>
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<td>Total active element</td>
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<td>TRTTC</td>
<td>Timber Research and Technical Training Centre</td>
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CHAPTER 1. INTRODUCTION

This thesis provided an extensive record of findings from a long term research project to establish the in-ground durability and that of preservative treated outer heartwood (OHW) of Sarawak timbers (unless a species is not known to form heartwood). It was a project that I have proposed and executed during my 33 years employment in the Sarawak Forest Department over the period 1975-2008 and have published records of parts of the project outcomes over the period 2005 to 2011. During the last 37 years, a lot of changes worldwide in the use of treated wood have occurred due to stricter environmental controls in wood protection; such as in the 1970’s, in the use of Sodium Pentachlorophenate to control sapstains as a standard industrial practice is now no longer environmentally acceptable. Nevertheless a few of the traditional wood preservatives that would be reported in this thesis were once acceptable for wood treatment when the in-ground durability research project was initiated in 1975 and evaluated over several years. Their reduced usage or non-usage nowadays worldwide, in favour of non-arsenicals or chromium-free biocides, was not initially anticipated when the project started. Nevertheless a majority of these traditional preservatives are still being used in Southeast Asia and South Africa at least, hence the thesis findings would still be somewhat useful to wood preservation in these regions. Also, the findings should give some guidelines on the relative order of failure for the timber species examined, irrespective of the preservative used.

1.1 Research problems and hypothesis

There is a large diversity of timber species in tropical countries such as Malaysia, with little recorded comparative information regarding their durability and preservative properties.
Some of the anecdotal information available is wrongly interpreted, as pointed out for Bakau in Section 5.7.2. This thesis has sought to compare a wide range of timber species from Sarawak under similar conditions at the one test site, and provides reliable comparative data on durability and treatability. It would be amongst the largest natural durability trials conducted around the world especially of tropical timbers exposed in tropical environment. The effort and attention to detail needed to assemble and verify the wood samples from three trees of each species cannot be underestimated. At the start of the project individual stake details were recorded so that the initial hypothesis could be tested regarding the importance of radial position in the tree (inner heartwood, outer heartwood (OHW), sapwood), density, treatability (permeable or refractory), and have proved to be crucial in understanding of the results. To confirm whether the hypothesis that the direct relationship exists between thicknesses of test stakes and durability of species is also true for tropical climate, a special study on effect of cross-sectional areas was carried out and reported in Section 4.1.2.

1.2 Objective and scope of the research project

The objective of the project was to provide the timber industry of Sarawak with a foundational document that would compare the natural durability, treatability and durability of the most common timber species growing in that State. The longevity of the durability exposures (20-30 years) ensures that full value has been obtained. This work will provide context for future durability projects in Malaysia, and guidance to the timber industry. The specific objectives are provided on Section 1.3 of the thesis.

The scope of the project was confined to testing the natural durability of close to 133 common species out of the over 2500 tree species found in Sarawak in the Sibu Oya Road test
site and to study the treatability of these species as well as monitoring the performance of these stakes after treatment using common wood preservatives like Celcure A (P), Tanalith C, Bolidken K33, FCAP, Copas LC, CCB and Creosote.

As initial statistical analysis using unsorted data failed to show any significant differences in results due to large variation within and between species, an attempt was made to segregate stakes by broad botanical groupings of Dipterocarp and non-Dipterocarp, 3 density groups of light, medium and heavy and treatability grouping of refractory and permeable. With these derived groupings statistical analysis on performance of stakes were carried out and found to be statistically significant.

As there is considerable interest in forest plantation species and the increasing importance of plantation resource in the timber industry, the durability of some potential plantation species were also studied and reported in this thesis.

1.3 Aims of thesis

Against the background of the Introduction and Literature reviewed in the next Chapter, the key objectives of the thesis are:

(i) Establishment of a comprehensive in-ground natural durability and treated durability stake test applicable to timber products (posts, poles, piles, other timber in contact with soil).

(ii) Determination by stake test of the long term service life of a wide representation of several wood species from natural forests of Sarawak (i.e. the natural durability) based on
the heartwood in many cases or else sapwood of those species that do not form heartwood.

(iii) Determination by stake test the long term service test of wood of these species treated with a selection of wood preservatives at high retentions when pressure impregnated to refusal with high preservative concentrations.

(iv) Classify wood durability according to different categories of wood species such as wood density groups, traded timber groups or botanical groups and preservative treatability groups.

(v) To link the natural durability findings with practical implications to the Sarawak Forest Products Industry and for those interested in further research on durability and preservation of Sarawak indigenous and plantation-grown timbers as well the other tropical timbers of the world.

(vi) To provide Forest Department, Sarawak with a record of research findings from the only long term research project on the durability of Sarawak timbers under tropical conditions and to provide baseline data for future research on timber durability in Sarawak.
CHAPTER 2. LITERATURE REVIEW

2.1 Environment aspects affecting wood durability

A hazard class selection guide is devised by the wood protection professionals to assist in the prescription of untreated and treated wood exposed to a range of temperate or tropical environments in the choice of wood species, wood preservatives, treatments methods, penetration and retention of wood preservatives. Morris (1994) proposed a unified set of hazard classes based on abiotic factors and added further features to account for climate, biodeterioration agents, natural durability and expected service life. The hazard classes he proposed were $H_1$: above ground protected from liquid water, $H_2$: above ground coated intermittent exposure to liquid water or uncoated constant exposure to high humidity, $H_3$: above ground intermittent exposure to water, uncoated, $H_4$: in contact with soil, constantly wet building material or fresh water, $H_5$: in contact with highly fertile organic soil, and $H_6$: in contact with estuarine or marine waters. He also proposed 5 climate zones as follows:

**Zone 1**: Sub-polar or arid, **Zone 2**: Temperate, **Zone 3**: Mediterranean, **Zone 4**: Subtropical, and **Zone 5**: Tropical. The biological areas he proposed in his hazard class guide were (i) beetles and fungi, (ii) beetles, fungi and subterranean termites (excluding *Coptotermes* spp.), (iii) beetle, fungi and *Coptotermes*, (iv) *Teredo, Bankia* and *Limoria* excluding *L. tripunctata*, (v) *Teredo, Bankia* and Pholads and (vi) *Sphaeroma terebrans*, *L. tripunctata*, *Teredo* or Pholads. Additionally in his guide, Morris proposed service life classification category with service life 1: 0-10 years, service life 2: 11-20 years, service life 3: 21-40 years, service life 4: 41-60 years and service life 5: more than 60 years. His proposal for classification of exposed heartwood preservative penetration were: P0: none, P1: with analysis zone 3 mm lateral sap: coated, P2: coated with analysis zone 5 mm lateral sap, P3: coated, analysis zone 12.5 mm
lateral sap, P4: 80% with 5 mm, analysis zone full penetration of sapwood or 5 mm lateral heartwood penetration, P5: 80%, 10 mm analysis zone full sapwood or 10 mm lateral heart, P6: 80% 12.5 mm, analysis zone full sapwood or 12.5 mm heartwood, P7: 80% complete, analysis zone full sapwood or full heartwood, and P8: complete, analysis zone full sapwood or full heartwood. Retention classes for Chromated Copper Arsenate (CCA) were grouped between 4 and 40 kg/m³. Such complexity in hazard class guide would deter its adoption by treated timber users, and it is a basis for evolution of a simplified user-friendly guide.

Later several modifications from Morris (1994) to the biological hazard class guide were made by various wood preservation organization/associations to fit the particular regions, and a Malaysian version, adapted from the Australian version was also designed (Wong 2004, Anon. 2000b). Recognizing the influence of climate and the environment on wood biodegradation among regions therefore, a hazard class selection guide is essential to the wood protection professionals to assist in the preservation of untreated and treated wood exposed to a range of environments, in the choice of wood species, wood preservatives, treatment methods and retention of wood preservatives.

Recently developed economic region grouping such as the European Union, North America, Japan, South Korea, Australasia, are requiring the use of environmentally acceptable wood preservatives as part of “green building” programmes where traditional preservatives such as CCA can only be confined to non-residential users. Hence for example, Greaves and Norton (1998) were involved in recommending the use of timber in the built environment of the year 2000 Sydney Olympic village together with the support of Greenpeace Australia. Timber was adopted as an environmentally acceptable building material as the energy required for wood