STRUCTURAL STRESS GRADING OF SELECTED SARAWAK TIMBER USING NON-DESTRUCTIVE TESTS

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DOCTOR OF PHILOSOPHY
UNIVERSITI SAINS MALAYSIA

2009

STRUCTURAL STRESS GRADING OF SELECTED SARAWAK TIMBER USING NON-DESTRUCTIVE TESTS

by

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Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

May 2009

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude and appreciation to my supervisors Associate Professor Dr. Badorul Hisham Abu Bakar and Senior Lecturer Dr. Megat Azmi Megat Johari of School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia (USM), Pulau Pinang, Malaysia for their invaluable guidance, suggestions and constructive criticisms that lead to the completion of the research project for Doctor of Philosophy (PhD).

Sincere thanks are due to the Managing Director/Chief Executive Officer of Sarawak Forestry Corporation Sdn. Bhd. (SFCSB), Datu Haji Len Talif Salleh, General Manager of Applied Forest Science and Industry Development (AFSID), SFCSB, Mr. Nigel Lim Poon Teck and Senior Assistant Director (Research and Development) of Forest Department, Sarawak, Tuan Haji Abang Mohamad Moktar Abang Pawozan for giving me the opportunity to use the research equipment and testing facilities.

Acknowledgements are due to Dr. Takashi Nakai, ex-JICA Team Leader, Dr. Naohiro Kuroda, Dr. Toshinari Tanaka and Dr. Hirofumi Nagao of Forestry and Forest Products Research Institute (FFPRI), Tsukuba, Japan, Professor Dr. Mohd. Hamami Sahri and Associate Professor Dr. Paridah Md. Tahir of Faculty of Forestry, Universiti Putra Malaysia (UPM), Serdang, Associate Professor Dr. Mohd. Ariff Jamaludin of Faculty of Applied Science, Universiti Teknologi Mara (UiTM), Shah Alam, Associate Professor Dr. Taksiah Abdul Majid and Lecturer Dr. J. Jayaprakash of School of Civil Engineering, Engineering Campus, SM and Manager Mr. Kandau Jenang, of Testing and

Consultancies, AFSID, SFCSB, for their comments and suggestions on the write-up of this thesis.

Thank you very much goes to the staff of Basic Wood Study of Forest Products of SFCSB particularly Development Executive Mr. Andrew Nyorik Nibu, Laboratory Technicians namely, Mr. Nungah Liang, and Mrs. Yeo Hui Choo for assisting in the preparation and testing of timber samples. Thanks also to Development Executive Mr. Lai Jiew Kok on assisting in the analysis of data using SPSS and Laboratory Technician Mr. Tan Jui Liah for his assistance in providing the data on drying of timber species. To all the staff of Wood Anatomy Section especially to Development Executive Mr. Yang Min Chin, Laboratory Technicians viz., Mr. Voon Shin Lee and Mr. Charles Diyom for assisting in identification of timber species are very much appreciated. Once again, I would like to express my profound thanks to all of them.

Finally, I like to convey my very special gratitude to my beloved wife, Dumang Dullah, my son Lawrence Insol who is currently pursuing his Bachelor of Science Degree in Timber Technology at UPM, daughters Delphanie Lonnie and Valarie Ching for their patience, love and encouragement. To my beloved mother Noi Insol, brother Ujoh Duju, sisters viz., Urie Duju, Gansau Duju, Tanai Duju, Choawan Duju and Runtie Duju, brother in-laws, sister in-laws, friends and colleagues for their encouragement, concern and moral support throughout the course of this study.

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LIST OF ABBREVIATIONS

ALAN	Alan batu
BS	British standard
AD	Air-dried density
E_{app}	Apparent modulus of elasticity, obtained at mid-span deformation under two-point loading
E_{dwe}	Dead weights loading modulus of elasticity at edgewise
E_{dwf}	Dead weights loading modulus of elasticity at flat-wise
E_{frl}	Dynamic longitudinal fundamental vibration frequency modulus of elasticity
EMC	Equilibrium moisture content
E_{tru}	True modulus of elasticity
FSP	Fibre saturation point
GERO	Geronggang
JONG	Jongkong
KAPA	Kapur paya
KSR	Knot size ratio
MC	Moisture content
MGR	Malaysian grading rules
MGRS	Menggris
MOE	Modulus of elasticity
MOR	Modulus of rupture (Ultimate bending strength)

MS	Malaysian standard
n	Number of test specimens
PYAU	Penyau
SG	Strength group
SLGB	Selangan batu bukit

PENGGREDAN TEGASAN STRUKTUR BAGI KAYU TERPILIH SARAWAK MENGGUNAKAN UJIAN-UJIAN TANPA MUSNAH

ABSTRAK

Sebanyak tujuh spesies kayu terpilih iaitu, Selangan batu bukit, Menggris, Penyau, Kapur paya, Alan batu, Jongkong dan Geronggang digunakan untuk mengkaji hubung kait diantara ciri-ciri kekuatan bagi kayu yang bersaiz struktur. Lima ujian-ujian tanpa musnah iaitu, E_{frl}, E_{dwe}, E_{dwf}, E_{app} dan E_{tru} telah dibandingkan bagi meramalkan ciri-ciri fizikal dan kekuatan lenturan kayu pada tahap kering udara. Hasil daripada kajian, didapati bahawa Selangan batu bukit merupakan spesies kayu yang paling kuat berdasarkan E_{app} dan E_{tru} diikuti oleh Menggris, Kapur paya, Penyau, Alan batu, Jongkong dan Geronggang. Berdasarkan nilai MOR, Selangan batu bukit juga adalah paling kuat diikuti oleh Menggris, Penyau, Kapur paya, Alan batu, Jongkong dan Geronggang. Didapati bahawa korelasi sederhana kuat hingga kuat diantara modulus kenyalan tanpa musnah dan MOR bagi kumpulan kayu keras berat, sederhana dan ringan. Dengan mengabungkan kesemua tujuh spesies kayu akan memberi keputusan korelasi yang lebih baik. Daripada kesemua keadah tanpa musnah, E_{frl} merupakan keadah yang paling baik sekali dibandingkan kaedah tanpa musnah yang lain bagi meramalkan ciri-ciri kekuatan kayu. Hubung kait antara ketumpatan, kedalaman pilodyn dan nilai kekuatan diperolehi daripada kayu bersiz kecil dengan ciri-ciri kekuatan struktur bagi tujuh spesies juga menghasilkan hubung kait yang kuat. Didapati bahawa dengan menggunakan nilai MOE_{min} dihasilkan dari kayu bersaiz kecil merupakan nilai yang selamat untuk tujuan rekaan.

STRUCTURAL STRESS GRADING OF SELECTED SARAWAK TIMBER USING NON-DESTRUCTIVE TESTS

ABSTRACT

A total of seven selected timber species namely, Selangan batu bukit, Menggris, Penyau, Kapur paya, Alan batu, Jongkong and Geronggang were used to study the relationship between the strength properties of full size structural timber. Five non-destructive tests namely, E_{frl}, E_{dwe}, E_{dwf}, E_{app} and E_{tru} were used to predict the physical and strength properties of air-dried full size structural timber. Results indicated that structural timber of Selangan batu bukit exhibited the highest values of E_{app} and E_{tru} followed by Menggris, Kapur paya, Penyau, Alan batu, Jongkong and Geronggang. Selangan batu bukit also produced the strongest in term of MOR followed by Menggris, Penyau, Kapur paya, Alan batu, Jongkong and Geronggang. Moderately strong to strong coefficient of correlations was observed between non-destructive moduli of elasticity and MOR on heavy, medium and light hardwood groups. Pooled results of the seven timber species indicated better correlations. E_{frl} seemed to be the best method compared to the other non-destructive tests in predicting the strength properties. Relationships between density, pilodyn penetration and strength values from small clear specimens with strength properties of structural timber of the seven timber species also indicated strong correlations. It was found that MOE_{min} values and their grade stresses derived from small clear specimens seemed to be safe values for use for design purposes.

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is very fortunate to be blessed with abundant tropical rain forests that contained the multi-species of fauna and flora. The forests provide a wide range of goods and services for the benefit of mankind and also play significant roles in the socio-economic development of our country. The tropical rain forests is heterogeneous and complex in nature where it contains various species of trees that produce timber and timber products that contributed significantly to the Growth of National Products (GNP) and foreign exchange. The natural heritage is a relatively cheap and renewable source of readily available foods and daily goods for the rural populace. In addition, it is important for environmental protection, source of invaluable genetic materials and to ensure a continuous supply of clean water to the mankind.

The natural forests of Sarawak alone are estimated to contain about 2,500 to 3,000 timber species and floristically are among the richest in the world (Anderson, 1980). Out of the total number of these timber species, the properties and characteristics of only a few hundred species have been properly described and are known for their commercial values through the publication of the Malaysian grading rules for sawn hardwood timber. The properties and characteristics of a large number of the timber species are not known because they were yet to be evaluated, documented and published. The large number of timber species available reflects the high species diversity and variation between species, which will lead to difficulties associated with species identification, classification and utilization. This has an

impact on the effective utilization of these timber species. Hence, it is necessary that the stress grading system for tropical timbers be introduced for an economical and efficient utilization if they are to be used as construction materials.

In Sarawak, sawn timber is widely used as construction materials especially in the housing and construction industry sector. Since timbers in popular demand are getting scarce and expensive, substitute for these timber species are made based on the end-use classification rather than by species selection. Timbers species that are well-known and readily available are always preferred for certain end-user. According to Mamit (1987) a total of twelve indigenous timber species commonly used in this industry in Sarawak. From the survey conducted, it was found that the use of timber in construction revealed that there are considerable differences in the specifications and sizes of timber used for specific building components. According to Mamit (1987) specifications made were found to be inadequate with respect to timber species, timber grades, moisture content and also preservative treatment. Therefore, it is necessary to introduce the recommended timber specifications meant for construction materials for the timbers to be utilized effectively and economically.

Generally, timbers intended for use as structural members are designed through engineering calculations to be applied to timber construction. These types of calculations, especially those adapted within engineering software are meant for homogenous structural materials and may not be applicable to non-homogenous material such as wood. This is very obvious especially in the housing and construction sector. The contractors tend to have prejudices to timber materials thus imposed high premium and insurance on timber buildings. The by-laws in the local

council normally inhibit the use of timber as permanent structures. Lately, metals and concrete have been preferred over wood for the structural components due to homogeneity in terms of their properties.

Generally, designers see timber as a novelty, suitable for domestic dwellings but not for structural application. This attitude towards timber arises because of timbers natural variation which tends to reduce designer's confidence in the material and also cause minor construction difficulties. To eradicate the prejudices on timber such as, fire hazards, not durable and meant only for temporary structures, there must be of good timber design, workmanship and proper timber specifications. For example, it is well-known that although timber is combustible materials, it has low ignitability and large cross-section do not buckles or crumbles like steel or concrete which are non-combustible materials under intense heat. It is also known that most of the designers, engineers and architects involved in the construction industry have very little or no knowledge at all on timber design as a result of training background. To have a proper utilization of timber as the materials, certain grading rules and guidelines have to be properly understood and strictly adhered to and perceptions of timber as a secondary construction material need to be changed.

Modern technology has made possible with the development of improved grading practices and improved engineered timber products. A faster, more reliable and cheaper way to determine the timber strength is inevitable as the demand of timber with high strength values that has been graded in a controlled manner is on the increase. After all, to use timber safely and reliably in construction, each member has to be assessed for its load-bearing capacities. Non-destructive evaluation is one

of the methods that can be useful in grading of structural materials. Non-destructive evaluation methods have been developed based on instrumented quantifiable measurements and thus minimize human subjectivity (Bodig, 1994). This is the potential method that can be tapped to replace the current visual grading which can be considered obsolete and outdated. Limited work has been done to develop and implement stress grading system for our tropical timber. In addition, so far there is no unified international standard used to grade timber especially for the tropical hardwood. The grading system for the tropical hardwoods based on the temperate softwood would be not appropriate and not applicable as properties of hardwood and softwood are very much different with each others.

The availability of renewable low-cost timber materials, coupled with technical data on strength and durability properties and a strong commitment to technology transfer and marketing to overcome the culture barrier can provide a significant increase in the use of timber as construction materials. Culture perceptions namely, the use of timber being reflective of a poor man's material, timber is non-durable material and being not able to acquire financing or insurance would contribute to the restriction of timber as construction materials. At the moment, there is no sawmill interested in producing mechanical stress graded timber because they perceived that lack of market for such materials both domestically and abroad. Unless there is a harmonized stress grading rule at least on a regional basis meant for tropical hardwood timbers.

There are various techniques and equipment available in the market that can be used for non-destructive evaluation of timbers, timber structures, wood products

and many others. The equipment available varies in term of the price, size, design, function, efficiency and reliability. In the temperate countries, non-destructive testing techniques have been widely used to grade and test full size timber structure. There is a need to determine if this equipment is suitable or reliable to be used for non-destructive testing equipment for tropical timbers.

1.2 Problem Statement

For the past years in Malaysia, strength properties of wood were determined by testing of small clear specimens. The test results obtained are being used to classify timber groups as stated in the Malaysian Grading Rules and also used to derive the grade stresses such as select, standard and common grades, respectively (Engku, 1971). However, it was found that the assumptions of stress ratio to derive the permissible unit stress could not work effectively for every timber species. According to the study conducted by Alik and Nakai (1997a) found that strength results determined from full size structural timber was considered to be more reliable to assign the design stress thus eliminates the risk of stress ratio assumptions.

Currently, visual stress grading rule is being used to grade timber however, the grading rules are often unknown, the benefits are not understood and there is no value-added pricing to the graded timber in the market place. It is used to grade timber based on size and position of wood defects such as knot, slope of grain, brittle-heart and wane (Anon, 1984). This type of grading on timber is more appropriate for non-structural applications as it is not able to estimate the loading capacity of timber in use. The highest grade with visual grading likely will not achieved the highest possible grade technically. This could be due to wide variation

in the inherent characteristics and properties of timber. The control process on the properties of timber through structural stress grading is an absolute necessity in order to instill confidence and reliability in using such materials for structural applications.

1.3 Objectives of Study

The main objective of this study is to evaluate non-destructive and destructive tests on the strength properties of full size structural timber in Sarawak. The objectives are as follows:

(i) To determine and compare the physical and strength properties of full size structural timber of selected species.

(ii) To determine the correlation between non-destructive testing and destructive testing methods.

(iii) To study the relationship between visual parameters and strength properties of full size structural timber.

(iv) To compare the grade stresses of timber for small clear specimens and full size structural timber samples.

1.4 Scope of Works

Study on relationship of physical and strength properties of full size structural timbers are limited to the timber species namely, Selangan batu bukit, Menggris, Penyau, Kapur paya, Alan batu, Jongkong and Geronggang only. They are selected for the reasons that the species are representative of each strength group as stated in Malaysian Standard MS 544: Part 2 and Malaysian grading rules (MGR), being

commonly used as construction materials and also due to accessibility and availability of the species.

Non-destructive tests are also limited to five methods viz., longitudinal fundamental vibration frequency, dead weights loading deflection at flat-wise and edgewise, load and deformation at mid-span and at moment constant area were used for determination of modulus of elasticity values in full size structural timber. These are considered as potential non-destructive testing methods that can be used for stress grading of tropical timber. In addition, pilodyn penetration is also used as non-destructive technique for prediction of physical and strength properties. Two-point loading and centre-point loading methods are used as destructive tests to determine the ultimate bending strength values of full size structural and small clear timber samples, respectively.

1.5 Outline of the Thesis

Chapter 1 explained the background of the project that includes richness of the timber species available in the country and only few hundred of these species are known in the international market. Building contractors have prejudices on the use of timber as construction materials hence, other materials such as metals and concrete are given the priority for the structural components. The problem arises as those involved in the construction industry have very little or no knowledge on the timber properties and characteristics. Visual grading is used to grade timber is more towards grading on its aesthetic rather than quantify the actual strength values. Permissible unit stresses used for grading are derived from testing of small defect-free specimens. Testing of full size structural timbers are very costly hence, the structural properties

most of timber species are not known yet. Therefore, testing the physical and mechanical properties of full size structural timber and establish the reliable stress grading method is a necessity as to develop the confidence of using timber as construction materials.

Chapter 2 outlined the literature review on forestry and forest sector of Sarawak. This sector contributed significantly towards socio-economic development of the state that accounted 39% of total revenue and provide employment about 300,000 people. It also highlighted the use of timber in which building and construction industry sectors are largest user of sawn timber. Properties and uses of the seven selected species are also described in details. The current grading systems of timber are also mentioned in details namely visual grading and mechanical grading of timber. Various non-destructive evaluation techniques used to measure and predict the property of timber and timber products used in the temperate countries are also reviewed. Constraints related to timber grading in the state are broadly divided into two aspects namely the availability of the raw materials and the costing are also discussed. Factors such as timber species, density, moisture content and wood defects on strength properties are also reviewed and highlighted.

Chapter 3 outlined the details on materials and methods in which seven selected timber species were used in this study. Timber samples were collected from the forests. The flitches obtained were subsequently machined and converted to the sample size of 50 x 100 x 2000 mm in length. Tests were conducted on air-dried samples. Dynamic and static non-destructive testing methods were used to determine modulus of elasticity values of the timber samples. Static bending rupture tests of full

size structural and small clear samples were carried out after completed the non-destructive tests. Rupture bending tests on timber samples were conducted in accordance to the British standards. Measurement of penetration depth of pin of Pilodyn wood tester and physical properties such as moisture content, density, grain angle and knot size ratio were also carried out.

Chapter 4 highlighted the results and discussion on the physical and mechanical properties of full size structural timber of seven timber species. Among the mechanical properties of structural timber compared and discussed namely the values of moduli of elasticity obtained by using the non-destructive and destructive tests. In addition, ultimate bending strength of the timber species is also discussed. Strength properties of small defect- free specimens are also included in the discussion. Physical properties such as density and moisture content of the timber species are also highlighted and discussed. Grades stresses of select, standard and common building on moduli of elasticity and bending strength of the timber species are compared and discussed. Various rupture patterns of static bending tests are mentioned in this chapter.

Chapter 5 also highlighted the results and discussion on the relationships among the moduli of elasticity for heavy hardwood, medium hardwood and light hardwood and also for all the seven timber species. Prediction of modulus of rupture using dynamic and static moduli of elasticity are also compared and discussed both for three timber groups and also for all the selected seven timber species. Relationships of density and strength properties are also discussed. In addition,

relationships between visual parameters with the strength properties are also mentioned and discussed.

Chapter 6 highlighted the conclusions and recommendations derived from the study. Among the conclusions that derived from the study namely the strongest and the weakest timber species in term of modulus of elasticity and modulus of rupture and also the heaviest and lightest timber species in term of their density. The best non-destructive and destructive methods to predict bending strength of the timber species are also concluded in the study. The minimum timber length recommended for measurement by using vibration frequency method. To determine whether the minimum values of modulus of elasticity derived from small defect-free specimens is safe values for design purpose. Some recommendations such as timber species, small diameter logs, height effect, creep deformation and mechanical grading of timber are put forward for further studies in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Forestry of Sarawak

Sarawak is one of the thirteen states in the federation of Malaysia. It is the largest states in Malaysia and located at the longitude from 109º 40' to 115º 40' E and latitude from 0º 50' to 5º N of the equator. The state has an area of 12.4 million hectares and it made up 37.5% of the total land of Malaysia. Out of the total land area, 8.46 million hectares or 68.7% of its land are covered with natural forest and often regarded, as the world's most complex in term of their ecosystem (Anon, 1990a). It is blessed with an abundance of natural resources and its natural forest provides the world of tropical hardwood and produces about 9.0 to 10.0 million cubic meters annually.

It is estimated that about 6.0 million hectares of the land are under the Permanent Forest Estate, which meant for sustainable timber production, 1.0 million hectares are designated as Totally Protected Area and the remaining is classified under State Land Forest. The natural forests in Sarawak can be classified into five main types viz., Mangrove Forest, Peat Swamp Forest, Hill Mixed Dipterocarp Forest, Kerangas Forest and Montane Forest. In term of forest area, Hill Mixed Dipterocarp Forest covers an area of 7,314 million hectares, Peat Swamp Forest comprises 1,246 million hectares and Mangrove Forest takes up 168,000 hectares. The other two namely Kerangas Forest and Montane Forest are minimal in size and of less economic importance as far as production of timbers is concerned (Anon, 1996). The forest types of Sarawak are shown in Plate 2.1.

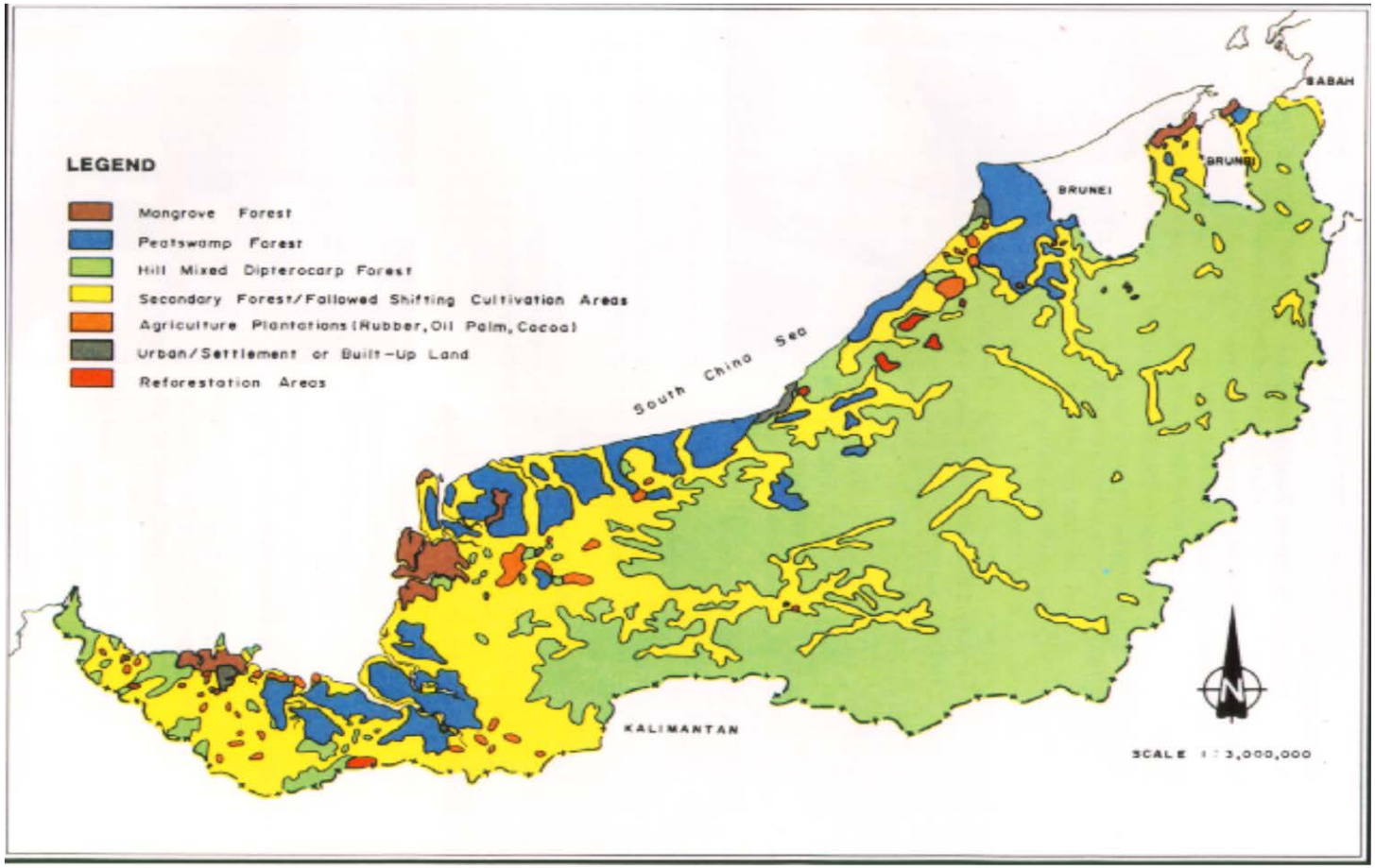

Plate 2.1 Forest types of Sarawak (Anon, 1996)

Hill Mixed Dipterocarp Forests are the most species-rich forest as far as different types of forests is concerned. It is known to have approximately 8,000 species of flowering plants of which most are of economically important species and over 20,000 species of animals of which the majority are insects. The dipterocarp comprised about 65 to 80% of the total stem wood volume of commercial trees and the rest belongs to non-dipterocarp (Anon, 1996). There are many valuable timber species found with different forest types in Sarawak as listed in Table 2.1.

Table 2.1 Timber species found in different forest types

No.	Forest Types	Timber Species
1.	Mixed Dipterocarp Forest	Selangan batu & Meranti group (*Shorea* spp.), Kapur *(Dryobalanops* spp.), Keruing (*Dipterocarpus* spp.), Resak (*Cotylelobium* spp. and *Vatica* spp), Keranji (*Dialium* spp.), Menggris (*Koompassia malaccensis*), Asam (*Mangifera* spp.), Durian (*Durio* spp.), Simpoh (*Dillenia* spp.), Kembang semangkok (*Scaphium* spp.) and Sepetir (*Copaifera palustris*)
2.	Samp Forest	Ramin (*Gonystylus bancanus*), Alan batu (*Shorea albida*), Jongkong (*Dactylocladus stenostachys*), Entuyut (*Tetramerista glabra*), Geronggang (*Cratoxylum* spp.) and Terentang (*Campnosperma* spp.)
3.	Mangrove Forest	Bakau (*Rhizophora* spp.), Perepat (*Sonneratia alba*.), Api-api (*Avicennia* spp.) Baru laut (*Hibiscus tiliaceus*), Pedada (*Sonneratia caseolaris*), Putat laut (*Barringtonia asiatica*) and Seladah laut (*Dacryodes incurvata*)

The forests are managed for both their economic utilization and protection of the environment, which takes into account the need to maintain a balanced eco-system, conservation of species and genetic resources, protection of wildlife and soil, safeguarding of water supplies as well as maintenance of sound climate conditions. The natural forests of Sarawak form extremely important and valuable resources. They provide essential life support systems for about 79% of the rural population living in villages and longhouses. The forests have been important sources of food, fuel, medicines and other produces for satisfying their basic needs since time immemorial.

The forest resources of Sarawak have been systematically managed since the beginning of the century by Forest Department, Sarawak. Over the years, ecologically and environmentally sound forest conservation and management practices have been developed to ensure that forest renewal and sustainable. Active conservation strategies in Sarawak dated back as early as in the 1950's. There are three legislative enactments in Sarawak pertaining to conservation viz., Forest Ordinance (Sarawak Chapter 126), National Parks Ordinance (Sarawak Chapter 127) and Wildlife Protection Ordinance (Sarawak Chapter 128). The forest management and conservation programs implementation by the state in the past, present and future are geared towards achieving the objectives of forest policy of the state (Anon, 1990a). As resources scarcity becomes more and more severe and the volume of common timber species is depleting thus emphasis will be on the lesser-known and under-utilized species as new raw materials. Land development and clearing of land for agricultural purposes also contributed to the increasing volume of those species.

Besides managing the natural forest systematically under sustained yield management and for the protection and conservation of soil and water, establishment of trial plot was initiated since 1980's. To date, the Forest Department of Sarawak has planted about 24,741.1 hectares of fast growing exotics and indigenous timber species (Anon, 2005). Amongst the species planted for establishments of forest plantation are *Acacia mangium*, *Albizzia falcataria*, *Eucalyptus* spp., *Gmelina arborea*, Binuang (*Octomeles sumatrana*), Engkabang jantong (*Shorea marcophylla*), Kapur bukit (*Dryobalanops beccarii*), Kelampayan (*Neolamarckia cadamba*) and Sentang (*Azadirachta excelsa*).

A total of 38 forest plantation licenses covering an area of 3.5 million hectares have been issued and out the total hectares, about 1.0 million hectares are targeted to be planted by the year 2020. In future, plantation species will become an important source of raw materials for the industries. The focus of the plantation forest is mainly due to the potentially high yield of plantation species, economics in growing and harvesting arising from the concentration of the crop in one place, uniformity of timber size and technical specifications. Hence, the development of forest plantation sector is essential in order to supplement the timber supply from the natural forests (Anon, 2005).

2.2 Forest Industry Sector of Sarawak

The forestry and forest industries sector has contributed significantly towards the overall socio-economic development of the state of Sarawak. This sector also contributes towards for increased in foreign exchange earnings, gross domestic production growth, government revenue, employment opportunities for resource

based industries and improvement in the livelihood of the rural population. The sector accounted for RM 0.824 billion in term of the state revenue that accounted 39% of the total revenue in 1999 and provides direct employment for more than 200,000 people and indirect employment for a further 100,000 people. There have been rapid and wide-ranging developments in Sarawak's timber processing industries particularly since the early 1980's. Sawmilling was the earliest processing industries established followed by plywood, moulding and chipboard industries which had expanded rapidly during 1980's as a result of increasing demand for timber and timber products in overseas markets. Now, the number of processing mills has increased significantly with the number downstream processing plants exceeding the primary processing mills.

Generally, processing industries can be categorized into primary, secondary and tertiary processing. To date, a total of 1,104 mills are operated in the state. The mills comprise 249 sawmill, 53 veneers and plywood mills, 21 dowels and moulding mills, 7 laminated board mills, 4 fiberboard/particleboard mills and more than hundred of furniture/carpentry shops and other timber mills engaged in the secondary and tertiary processing. The number and types of timber mills for the year 2007 are indicated in Table 2.2. The timber industry has maintained itself as an important contributor to the economic development of the state. The industry emerged as one the main foreign exchange earners in the commodity sector. Sarawak is the world's largest exporter of tropical logs mostly to Japan, Korea and Taiwan. The export level has been declining over the years especially after Papua New Guinea increasing its market shares to the importer countries.

Table 2.2 Number and types of timber mills in Sarawak*

No.	Types of Mills	No. of Mills
1.	Sawmill	249
2.	Veneer/Plywood	53
3.	Dowels/Mouldings	21
4.	Laminated Boards	7
5.	Wood Chips	3
6.	Wood Cement Board	1
7.	Parquet/Flooring Products	1
8.	Particleboard	1
9.	Medium Density Fibreboard	3
10.	Block Board	1
11.	Briquettes	2
12.	Furniture mills, Timber yards and Other Woodworking plants	763
	Total	1,104

*Source: TR&TTC, Sarawak Forestry Corporation

Logs production has decreased considerably in past years consistent with the efforts at forest conservation and also in line with the state policy to increase the amount of logs processed domestically. Now, emphasis is given to the export of processed timber products. The sawmilling industry is the largest timber processing industry in the state followed by veneer/plywood industry. The state earned about RM 5.0 billion from the export of timber and timber products in 2001. The biggest earnings from the timber industry, which remains a major revenue earner came from plywood which amounted to RM 2.2 billion. The government made every effort to promote downstream processing, especially in the manufacture of furniture in order to meet the demand from overseas as well as domestic market. Various policies and measures have been designed to accelerate the development of the furniture industry. In order to conserve timber resources as well as to encourage greater downstream

processing, the export of log from the state has tremendously decreased from year to year. To provide the necessary infrastructure and other supporting services are amongst the steps taken as to further facilitate the development of the industry.

There are numerous challenges faced by the industry either from the domestic market or the international market. Among the challenges are raw materials supplies for processing, skill manpower, low recovery rate and low productivity compared to the main competitor countries like Japan, Germany and Italy. The industry is also faced with competitions by low cost producing countries such as Indonesia, Vietnam and China. In order for the timber and timber products to be competitive, there must be proactive measures taken to enhance the quality, efficiency, expertise, skill as well as productivity through technology enhancement in processing and enhancing research and development activities in the state.

2.3 Utilization of Timber in Construction

Timber is one of the oldest building materials ever used and it has been utilized throughout the history of mankind. Timber has provided humans with a broad range of building products and construction materials. In line with the modernization of the building and construction industry, efforts to minimize the costs and new construction materials have to be produced. Non-wood products such as concrete, metal and steel have redefined the construction industry. Timber is an important building and construction materials in the state and the quality of its uses related directly to how designers, architects and engineers understand the characteristics and properties of the materials.

Timber has been known as a versatile material for building and construction and it is readily available locally. Timber being a non-toxic, biodegradable, environmental-friendly, renewable and relatively cheap source of raw material will continue to be popular items for human livelihood. Timber can be planed, cut and chiseled to the desired size and shape either by hand or by machine. Its high strength to weight ratio and its ease of handling make it an ideal material for housing frame for wall, floor and roof. For the same weight, timber possesses tremendously high strength, which is more superior compared to other raw materials such as plastic, steel and metal. On durability aspects, some species of timber are naturally highly resistant to rot and decay and can be treated with preservatives to be resistant. Timber is also more fire resistant compare to steel. Large solid timber member chars at a predictable rate with the charcoal forming the insulating layer that protects an inner core of materials.

The abundance timber species found in the state reflect that the forests are very heterogeneous and complex in nature, which yielded a large number of timber species for various purposes and applications. Traditionally, timber is classified into two major groups namely hardwood and softwood but for structural application, this form of classification is inadequate and requires grouping of timbers according to their load carrying capabilities. Currently, in Malaysia about 700 timber species have been identified and widely being used in building constructions. Out of the total number, 468 species have been introduced to the domestic and international markets under the Malaysian grading rules for sawn hardwood timber (Anon, 1984). The properties have been properly described and are known in the international trade for their commercial values. These species are aggregated into 100 timber groups that

mainly constitute of commercial timbers. Other species that are not included are due to the small in volume or of less economic importance. The availability of such a large number of timber species has often caused problems to the users for example in predicting the actual supply of the species when required.

In Malaysia, sawn timber and plywood have been used extensively in building construction. In general, the building and construction sectors are the largest consumer of locally produced sawn timber that accounts about 60% of the total sawn timber sold domestically (Anon, 1990b). Domestic demand for plywood used in the construction sector, which absorb about 70% of the plywood while furniture industry and packaging industry accounts for 17 and 4%, respectively. Timber has long been and continues to be the predominant structural materials used in residential construction in Sarawak especially in the rural areas. There are also many notable examples of timber used especially in low cost houses, longhouses and kampong houses.

The demand for construction materials has led to a better utilisation of wood, which mainly comes from mixed species from different types of forests and of small diameter trees. In addition, difficulties are also associated with the identification and classification of our timber species. Freezaillah (1984) mentioned that most of the timber species have been facing difficulties associated with identification and marketing, particularly of lesser-known species. As for the users there is no simple technique for species identification of sawn timber and also the standing trees. The fact is that about 70% of our commercial timbers are sold under mixed species (Anon, 1986). Hence, an efficient and effective utilisation of species is a challenge to

the construction and building industries in Malaysia. Technique and technology for coping with multi-species forest will also be the greatest challenge in the use of timbers for building and construction purposes.

There are changes in the specifications according to the classification of the timber species when specifying sawn timber. Currently, classifications of our timber are viz., heavy hardwood, medium hardwood and light hardwoods. Strength groupings were used in specifying timber for the various applications in construction both for non-structural and structural applications are shown in Appendices A, B and C.

2.4 Properties of Selected Timber Species

A comprehensive knowledge on the characteristics and properties of any timber is essential to determine utilization aspect of the species. The acquisition of basic information on physical and mechanical properties is complicated due to the fact that their properties are subjected to wide variations brought about by the external factors affecting the tree growth. In addition, timber is a product on of not one but of many species of trees therefore each kind of timber exhibits its own anatomical, physical, mechanical and chemical characteristics and properties. The properties of selected timber namely, Salangan batu bukit, Menggris, Penyau, Kapur paya, Alan batu, Jongkong and Geronggang as follows:

2.4.1 Selangan batu bukit (*Shorea foxworthyi*)

Selangan batu bukit (*Shorea foxworthyi*) belongs to the family of Dipterocapaceae. It is widely distributed throughout the State and commonly found in lowland forest. The species occurring over a wide variety of habitats except peat swamp forest. A total of 27 species of Selangan batu are recorded in the state (Ashton, 1968). The species is considered one of the best heavy construction timbers with the Strength group A (Anon, 1999b) Strength group SG 1 under MS 544 (Anon, 2001). The average density at air-dry condition is 906 kg/m^3. The colour of heartwood is yellow-brown to reddish brown whilst the sapwood is lighter in colour. The longitudinal surface of the timber is shown in Plate 2.2.

Plate 2.2 Longitudinal surface of Selangan batu bukit

The timber is well-known for heavy construction, marine and wharf construction, piling, boat building, parquet and heavy duty flooring, fence posts

telegraph and power transmission poles, columns, posts, joists, rafter, joinery, heavy duty furniture, door and window frame.

2.4.2 Menggris (K*oompassia malaccensis*)

Menggris (*Koompasia malaccensis*) belongs to the family of Leguminosae. The species is found very widespread throughout Sarawak and not concentrated in any one locality. The species found in peat swamp forests and throughout the lowland forests. The other names of the species are Kempas (Peninsula Malaysia) and Impas (Sabah). The trees are tall and having large buttresses. The crown is cylindrical and columnar and exhibits a wide variety of forms, ranging from closely fissured, scaly, cracked and lenticellate to minutely dippled (Wong and Kochumen, 1973). The tree is capable of achieving 55 meters in height and 6.5 meters in girth,.

The timber is classified as a medium hardwood (Anon, 1984) strength group (SG) 2 under MS 544 (Anon, 2001). The timber is relatively strong, hard and heavy with an average density of 890 kg/m^3 at 15% moisture content. The sapwood is pale yellow in colour and easily distinguished from the heartwood. The heartwood is brick red when freshly sawn and darkening to orange red or reddish brown. The timber is very strong and dries readily but must be carefully handled to avoid checks and honeycombing. It is considered difficult to work with and moderately durable when exposed to our environment. The longitudinal surface of the timber is shown in Plate 2.3.

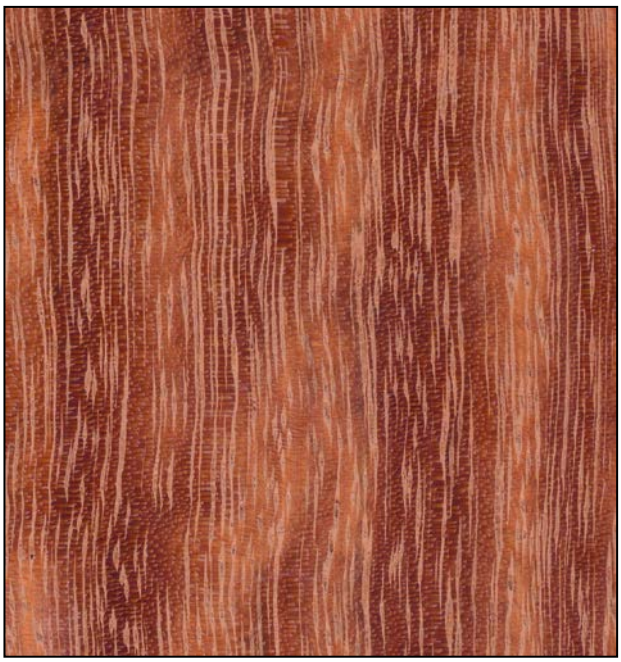

Plate 2.3 Longitudinal surface of Menggris

The timber has gained a reputation for use in flooring and railway sleepers. The timber is suitable for heavy construction works, posts, beam, joists, rafter, door and window frames, vehicle bodies, tool handles, paneling and partitioning, furniture making, parquet and strip flooring.

2.4.3 Penyau (*Upuna borneensis*)

Penyau (*Upuna borneensis*) belongs to the family of Dipterocarpaceae. The mono species is widespread throughout the State and mostly found at sub-coastal from Lundu to Lawas. The timber is classified under heavy hardwood and strength group A (Anon, 1999b) strength group (SG) 3 under MS 544 (Anon, 2001). It has mean density of 871 kg/m^3. The colour of sapwood is light yellowish brown to light brown while the heartwood is yellowish brown or brown and darkens to dark brown. The longitudinal surface of the timber is shown in Plate 2.4. The grain is shallowly