UNIVERSITI PUTRA MALAYSIA

MECHANICAL PROPERTIES OF FULL SIZE KAPUR (DRYOBALANOPS SPP.) BEAMS AND CORRELATION FOR DIFFERENT NDT METHODS

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By

ALIK DUJU

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

Dedication to my wife Dumang Dullah, son Lawrence Insol and daughters Delphanie Lonnie and Valarie Ching for their time, concern and moral support during the period of my study.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

MECHANICAL PROPERTIES OF FULL SIZE KAPUR (*DRYOBALANOPS* SPP.) BEAMS AND CORRELATION FOR DIFFERENT NDT METHODS

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June 2002

Chairman: Mohd Ariff Jamaludin, Ph.D.

Faculty: Forestry

To cope with a large number of species and difficulties in species identification of tropical timbers, development of strength grading would be highly needed for an efficient and effective utilisation of structural components of our tropical timbers. To do that, an acceptable method of predicting timber strength has to be established in order to develop the confidence in using timbers as construction materials.

A total of 6 species of Kapur (*Dryobalanops* spp.) namely, Kapur bukit (*Dryobalanops beccarii* Dyer), Kapur empedu (*Dryobalanops fusca* V. Sl.), Kapur kelansau (*Dryobalanops oblongifolia* Dyer), Kapur paji (*Dryobalanops lanceolata* Burck), Kapur paya (*Dryobalanops rappa* Becc.) and Kapur peringgi (*Dryobalanops sumatrensis* (J. F. Gmelin) Kosterm) were used in this study. The trees selected for sampling possessed a healthy grown, straight bole and with

minimum diameter of 450 mm were collected from Mixed Dipterocarp Forest and Peat Swamp Forest. The sampling of test specimens was made throughout the whole lengths of tree bole. The nominal dimensions of 50 mm by 100 mm by 2000 mm and 50 mm by 100 mm by 3000 mm were used for bending and tensile tests both evaluated at green and air-dried conditions, respectively. The British Standard, BS 5820:1979 and BS 373:1957 were adopted to determine the strength of structural size and small clear specimens, respectively. The total number of samples tested were 240 pieces for bending and tensile tests at each test condition, respectively. In this study, six methods of measuring modulus of elasticity viz., longitudinal fundamental vibration frequency (E_{fr}), ultrasonic wave propagation (E_{usw}), deflection using dead weight loading at flatwise (E_{dwf}), deflection using dead weight loading at edgewise (E_{dwe}), apparent (E_{app}) and true (E_{tru}) were compared to predict the bending strength of full size structural components. Whilst for tensile strength, only three methods namely longitudinal fundamental vibration frequency (E_{fr}), ultrasonic wave propagation (E_{usw}) and modulus of elasticity in tension (E_{ts}) were applied.

It was indicated that the average moisture content was 54.05% for green and 15.56% for air-dried condition. It took an average of 9 months to dry structural size samples from green to dry until it reached the equilibrium moisture content. Moisture content plays an important role in strength especially below fibre saturation point. It was found that the rate of change in bending strength and modulus of elasticity were 1.50% and 0.36% respectively for every percent changes of moisture below fibre saturation point. At the 5th percentile, it was

indicated that there was a difference both in bending and tensile strength in which moisture has significant effect on strength. Based on its density, Kapur bukit exhibited the heaviest followed by Kapur peringgi, Kapur paji, Kapur kelansau, Kapur empedu and Kapur paya respectively with their mean basic density of 0.67 g/cm^3 and mean air-dried density of 0.77 g/cm^3. Hence, this species could be classified under Medium Hardwood.

Results of the study revealed that Kapur bukit was the strongest in term of bending strength followed by Kapur peringgi, Kapur paji, Kapur kelansau, Kapur empedu and lastly the weakest was Kapur paya, both at green and air-dried conditions. The overall average of bending strength was 68.14 MPa and 79.82 MPa at green and air-dried conditions, respectively. Whilst in term of tensile strength, Kapur bukit still indicated the highest strength followed by Kapur kelansau, Kapur paji, Kapur peringgi, Kapur empedu and Kapur paya both at green and air-dried conditions, respectively. The average tensile strength was 62.10 MPa and 71.50 MPa tested at both conditions, respectively. However, it was observed that there was a significant difference in bending strength and tensile strength between the timber species at 95% level of confidence. Further studies need to be carried out on regrouping the Kapur species according to their strength.

Results indicated weak correlation between visual parameters (i.e. knot size ratio at flatwise, knot size ratio at edgewise and sloping grain) with E_{fr}, E_{usw}, E_{dwf}, E_{dwe}, E_{app}, E_{tru}, E_{ts}, bending strength and tensile strength both at green and air-

dried conditions. Thus, it could be concluded that single visual parameter could not be used for predicting the strength properties of structural size timber. However, further study need to be carried out to incorporate all these visual parameters and others as specified under the Malaysian Grading Rules.

Strong correlation was observed between nondestructive moduli of elasticity both for dynamic and static. The same trend was also observed with bending and tensile strength tested at green and air-dried conditions. Hence, all the different nondestructive testing methods used in obtaining moduli of elasticity could be used to predict the strength properties of structural size timber. However, it is not recommended to use E_{usw} to predict the strength at green condition as the results indicated that high moisture content had a great influence on propagation time travel inside the timber. Thus, predicting the timber strength using E_{usw} was only advisable for air-dried timber samples. Linear regression equations were established to predict the strength of timber at both testing conditions. Among nondestructive methods, E_{fr} seemed to be the best compared to E_{usw}, E_{dwf}, and E_{dwe}. Fundamental vibration frequency method had the advantages, as it was more convenient and reliable, fast, easy to operate, easy to handle and most importantly of its non-contact measurement. Even though E_{app}, E_{tru} and E_{ts} indicated a good correlation with strength, however, these methods were found to be rather slow and more laborious in obtaining the test results. Furthermore, the testing machines used were very expensive.

The strength values obtained from small defect-free specimens indicated a weak correlation in predicting the strength values of structural size timber. Timber properties of structural size samples were very much difference compared to that of small defect-free specimens as earlier ones contained a lot of wood defects and other inherent factors that affected the strength. Bending strength ratio is the best to express their relationship and it was found that the ratio of almost defect-free structural size and small clear specimens were 0.75 and 0.77 for green and air-dried conditions, respectively.

There was a weak correlation between pilodyn-pin penetration depth with bending and tensile strength, however a slightly a better correlation was observed with basic and air-dried density. There was a strong possibility that this method could be used to predict the density. Further study need to be carried out in the future to substantiate this correlation. The equipment used is reasonably cheap, simple and easy to handle and therefore tapping the usage to predict the density is worthwhile to consider. Various types of rupture pattern were also discussed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains.

SIFAT-SIFAT MEKANIKAL KAYU BERSAIZ PENUH KAPUR (*DRYOBALANOPS* SPP.) DAN KORELASI UNTUK BERLAINAN KAEDAH PENILAIAN TANPA MUSNAH

Oleh

ALIK DUJU

Jun 2002

Pengerusi: Mohd Ariff Jamaludin, Ph.D.

Fakulti: Perhutanan

Untuk menanggani kepelbagaian spesis yang banyak dan masalah mengenalpasti spesis kayu tropika, pembangunan pemeringkatan kekuatan kayu sangatlah diperlukan supaya menggunakan komponen-komponen kayu bersaiz struktur dapat digunakan dengan lebih efektif dan efisien. Dengan itu, satu kaedah yang boleh diterima bagi meramalkan kekuatan kayu perlu diwujudkan bagi meyakinkan penggunaan kayu sebagai bahan binaan.

Sebanyak 6 spesis kayu Kapur (*Dryobalanops* spp.) terdiri daripada Kapur bukit (*Dryobalanop beccarii* Dyer), Kapur empedu (*Dryobalanops fusca* V. Sl.), Kapur kelansau (*Dryobalanops oblongifolia* Dyer), Kapur paji (*Dryobalanops lanceolata* Burck), Kapur paya (*Dryobalanops rappa* Becc.) dan Kapur peringgi (*Dryobalanops sumatrensis* (J. F. Gmelin) Kosterm) telah digunakan dalam kajian ini. Kayu yang dipilih mempunyai pertumbuhan yang baik, batang yang

lurus dan berdiameter minima 450 mm dipungut dari Hutan Dipterokarp Campuran dan Hutan Paya Gambut. Pensampelan spesimen ujian diambil dari seluruh batang kayu. Dimensi kayu yang berukuran 50 mm kali 100 mm kali 2000 mm dan 50 mm kali 100 mm kali 3000 mm digunakan untuk ujian kekuatan lenturan dan kekuatan tegangan yang dinilai dalam keadaan basah dan kering udara masing-masing. Piawaian British, BS 5820:1979 dan BS 373:1957 telah digunakan untuk menguji kekuatan sampel kayu bersaiz struktur dan bersaiz kecil masing-masing. Sejumlah 240 sampel kayu telah digunakan bagi ujian kekuatan lenturan dan kekuatan tegangan pada tiap-tiap keadaan ujian masing-masing. Dalam kajian ini, sebanyak enam kaedah bagi mengukur modulus kenyalan iaitu, frekuensi gegaran asas secara membujur (E_{fr}), perambatan gelombang ultrasonik (E_{usw}), pemesongan oleh beban mati merata (E_{dwf}), pemesongan oleh beban mati secara sisi (E_{dwe}), modulus kenyalan ketara (E_{app}) dan modulus kenyalan benar (E_{tru}) telah dibandingkan bagi meramalkan kekuatan lenturan komponen kayu yang bersaiz struktur. Manakala untuk kekuatan tegangan, hanya tiga kaedah iaitu, E_{fr}, E_{usw} dan modulus kenyalan dalam tegangan (E_{ts}) telah dijalankan.

Adalah didapati bahawa purata kandungan lembapan sampel kayu yang telah diuji ialah 54.04% bagi keadaan basah dan 15.56% bagi keadaan kering udara. Masa yang diperlukan untuk mengeringkan sampel kayu dari keadaan basah sehingga sampel tersebut mencapai tahap kandungan lembapan yang seimbang ialah 9 bulan. Kandungan lembapan memainkan peranaan yang penting dalam kekuatan kayu terutamanya dalam keadaan kandungan lembapan kurang daripada takat tepu gentian. Didapati bahawa kadar perubahan kekuatan lenturan dan modulus kenyalan adalah 1.50% dan 0.36% masing-masing setiap peratus perubahan lembapan kurang daripada takat tepu gentian. Pada tahap peraturan kelima, didapati perbezaan yang ketara berlaku pada kedua-dua kekuatan lenturan dan kekuatan tegangan dalam keadaan basah dan kering udara. Berdasarkan ketumpatan kayu, Kapur bukit didapati paling berat diikuti Kapur peringgi, Kapur paji, Kapur kelansau, Kapur empedu dan Kapur paya masing-masing. Purata ketumpatan asas adalah 0.67g/cm^3 dan ketumpatan kering udara adalah 0.77 g/cm^3. Oleh yang demikian, spesis ini boleh dikelaskan dalam kumpulan Kayu Keras Sederhana.

Kajian dapati bahawa Kapur bukit adalah paling kuat berdasarkan kekuatan lenturan diikuti oleh Kapur peringgi, Kapur paji, Kapur kelansau, Kapur empedu dan Kapur paya pada kedua-dua keadaan basah dan kering udara. Purata kekuatan lenturan adalah 68.14 MPa dan 79.82 MPa pada keadaan basah dan kering udara masing-masing. Manakala, berdasarkan kekuatan tegangan, Kapur bukit masih memberi kekuatan yang paling tinggi diikuti Kapur kelansau, Kapur paji, Kapur peringgi, Kapur empedu dan Kapur paya. Purata kekuatan tegangan adalah 62.10 MPa dan 71.50 MPa. Walau bagaimana, didapati perbezaan yang bererti pada kekuatan lenturan dan kekuatan tegangan dengan spesis kayu pada tahap 95%. Oleh yang demikian, kajian lanjutan harus dijalankan untuk membahagikan spesis Kapur kepada kumpulan-kumpulan tertentu berdasarkan kekuatan.

Keputusan menunjukkan hubung kait yang lemah diantara parameter yang menggunakan penglihatan (iaitu, nisbah saiz buku cara rata, nisbah saiz buku cara sisi dan ira serong) dengan E_{fr}, E_{usw}, E_{dwf}, E_{dwe}, E_{app}, E_{tru}, E_{ts}, kekuatan lenturan dan kekuatan tegangan yang telah dinilai pada keadaan basah dan kering udara masing-masing. Oleh yang demikian, boleh disimpulkan bahawa sesuatu parameter yang telah dinyatakan diatas tidak sesuai digunakan untuk meramalkan ciri-ciri kekuatan kayu yang bersaiz struktur. Walau bagaimanapun, kajian terperinci harus dijalankan dengan mengabungkan kesemua parameter dan lain-lain parameter seperti yang dinyatakan dalam Peraturan Pemeringkatan Malaysia.

Hubung kait yang kuat didapati diantara tanpa musnah modulus kenyalan sama ada secara dynamik ataupun statik. Keputusan menunjukkan trend yang sama diperolehi dengan kekuatan lenturan dan kekuatan tegangan dalam keadaan basah dan kering udara. Oleh yang demikian, kesemua keadah yang telah digunakan memperolehi modulus kenyalan boleh digunakan untuk meramalkan ciri-ciri kekuatan kayu yang bersaiz struktur. Tetapi, kaedah E_{usw} hanya baik untuk kayu yang berkeadaan kering udara. Pada kayu yang keadaan basah, lembapan yang tinggi mempengaruhi masa perambatan melalui kayu. Persamaan regresi linear telah diwujudkan bagi menanggarkan kekuatan lenturan dan kekuatan tegangan kayu dengan keadah tertentu dalam keadaan basah dan kering udara. Daripada kesemua keadah tanpa musnah, E_{fr} merupakan keadah yang baik sekali dibandingkan E_{usw}, E_{dwf} dan E_{dwe}. Kaedah frekuensi asas gegaran mempunyai kebaikan dari segi boleh dipercayai, senang digunakan, senang dikendalikan dan pengukuran tidak melalui sentuhan. Meskipun, E_{app}, E_{tru} dan E_{ts} menunjukkan korelasi yang baik tetapi keadah tersebut didapati memerlukan masa yang lama dan tenaga kerja yang banyak bagi memperolehi keputusan ujian. Tambahan, harga mesin penguji yang digunakan adalah terlampau mahal.

Keputusan menunjukkan korelasi diantara nilai kekuatan kayu yang didapati daripada sampel kayu yang bersaiz kecil dan kayu yang bersaiz struktur adalah kurang memuaskan. Didapati sifat-sifat kekuatan kayu agak berbeza diantara kedua-dua sampel tersebut. Ini adalah disebabkan kayu bersaiz struktur banyak mengandungi kecacatan kayu dan faktor-faktor dalaman yang boleh mempengaruhi kekuatan. Nisbah kekuatan lenturan merupakan nilai yang terbaik bagi menyatakan hubungan tersebut. Didapati bahawa nisbahnya adalah 0.75 dan 0.77 pada keadaan basah dan kering udara masing-masing.

Terdapat korelasi yang lemah diantara kedalaman pin pilodyn dengan kekuatan lenturan dan kekuatan tegangan, tetapi keputusan menunjukkan korelasi yang lebih baik didapati dengan asas ketumpatan dan ketumpatan kering udara. Ini menunjukkan kemungkinan besar bahawa keadah ini mempunyai potensi yang baik dalam meramalkan ketumpatan kayu. Oleh yang demikian, kajian lanjutan harus dijalankan pada masa hadapan bagi mengesahkan korelasi tersebut. Disebabkan peralatan ini agak murah, mudah dan senang digunakan adalah wajar diambil perhatian selanjutnya. Jenis-jenis kecacatan selepas ujian pada sampel juga dibincangkan.

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Mohd Ariff Jamaludin, Ph.D.,
Faculty of Forestry,
Universiti Putra Malaysia.
(Chairman)

Mohd. Hamami Sahri, Ph.D.,
Associate Professor,
Faculty of Forestry,
Universiti Putra Malaysia.
(Member)

Paridah Md. Tahir, Ph.D.,
Faculty of Forestry,
Universiti Putra Malaysia.
(Member)

AINI IDERIS, Ph.D.,
Professor/Dean
School of Graduate Studies,
Universiti Putra Malaysia.

Date:

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