UNIVERSITI PUTRA MALAYSIA

PROPERTIES OF KENAF BAST FIBRE CEMENT COMPOSITE BOARD

AMEL BASHER AHMED BASHER

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By

AMEL BASHER AHMED BASHER

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfillment of the Requirements for the Degree of Doctor of philosophy

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DEDICATIONS

This work is dedicated to my family,

my brothers and sisters

Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

PROPERTIES OF KENAF BAST FIBRE CEMENT COMPOSITE BOARD

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AMEL BASHER AHMED BASHER

February 2013

Chairman : Professor Paridah Md. Tahir, PhD.

Institute : Institute of Tropical Forestry and Forest Products

Kenaf bast fibre (KBF) is rich in cellulose and, has high tensile strength, which is suitable for reinforcement of cement-bonded board. This study used kenaf bast fibre as partial replacement for cement as well as reinforcement for cement board. The work comprised the evaluation of mechanical and physical properties of kenaf bast fibre which were separated using different extraction methods (water, decortication and chemical), hydration behaviour, and the effects of different board formulations on the properties of cement-bonded kenaf board (CBKB). The objectives of the study were: 1) to evaluate the effects of fibre separation method on the physical, chemical and mechanical properties of kenaf bast fibre, 2) to determine the effect of incorporation of kenaf bast fibre, accelerators (calcium chloride ($CaCl_2$), aluminium chloride ($AlCl_3$), sodium sulfate (Na_2SO_4) and calcium oxide (CaO_2)) and additives (silica fume and superplasticiser) on the hydration properties of Portland cement, 3) to evaluate the mechanical properties and dimensional stability of cement-bonded kenaf board, 4) to examine the curing behaviour of cement-bonded kenaf board, and 5) to characterize the permeability , surface and thermal behaviour of cement-bonded

kenaf board. The performance of different CBKB densities was evaluated based on the strength – modulus of rupture (MOR), the stiffness – modulus of elasticity (MOE) and internal bonding (IB). The dimensional stability was assessed by determining the percentage of water absorption (WA) and thickness swelling (TS).

The morphological properties of kenaf bast fibre were found to be significantly affected by the extraction methods used. Using sodium hydroxide (NaOH) for retting reduced the fibre lumen diameter and increased the cell wall thickness significantly. Both benzoate- and water-retted fibres experienced the same but at a much lesser effect. Mechanical decortication however was found to excessively reduce the cell wall thickness much thinner than the crude (unprocessed) fibre. There was a small increment in fibre density for NaOH-retted and benzoate-retted bast fibres over those of water, decorticated and crude (control). The densified fibre may be contributed by the amount of chemicals being absorbed into the fibre. Among the different extraction methods used, decorticated, water and NaOH-retted fibres have significantly higher tensile strengths.

The hydration test suggests that NaOH and benzoate were not suitable for the kenaf retting. Both NaOH- and benzoate-retted fibres had relatively higher pH hydration time and low maximum hydration temperature which is not conducive for curing of cement-bonded kenaf board. Both water-retted and decorticated KBF had good hydration properties, and suitable for cement board production. The suitable fibre size is > 3.5 mm. Fibres with smaller size apparently require the addition of accelerators to enhance their compatibility. Among the different accelerators used, $CaCl_2$, $AlCl_3$, Na_2SO_4 and CaO, both $CaCl_2$ and CaO proved to be the best with their

optimal concentration at 2%. Between the two additives used, silica fumes (SF) and superplasticiser (SP), the former was found to be a better choice based on it is hydration properties. Among the methods of fibre separation, water retting and decortication produced fibres of good quality, high tensile strength, good hydration properties, good fibre morphology and high cellulose content.

Incorporation of KBF in cement-bonded board generated reasonably light and strong panel, however, the IB was reduced significantly. The main reason for this is the separation of kenaf fibres from cement creating a weak inter-particle bonding within the board. Almost all the failures were observed to occur at the interface. Adding SF at 7% improved the IB by 83%. The presence of board density also has a negative effect on the mechanical properties and the dimensional stability of the boards. Among the three cement: KBF proportions (2:1, 2.5:1 and 3:1) used in this study, using 2:1 resulted in boards with the best performance in terms of MOR, MOE, WA and TS. The best combination to produce acceptable performance CBKB is by using decorticated KBF, at 2:1 (cement: KBF), 7% SF and board density (1100 kg/m^3). The properties: MOR (10.9 MPa), MOE (5061 MPa), IB (0.15 MPa), WA after 2h and 24h (23.7 and 27%, respectively), TS after 2 and 24h (0.87 and 3.01%, respectively).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah bagi Doktor Falsafah

CIRI-CIRI PAPAN SIMEN KOMPOSIT DARI SERAT KULIT KENAF

Oleh

AMEL BASHER AHMED BASHER

Jun 2013

Pengerusi : Profesor Paridah Md. Tahir, PhD.

Institut : Institut Perhutanan Tropika dan Produk Hutan

Gentian kulit kenaf (KBF) kaya dengan selulosa dan mempunyai daya regangan yang tinggi di mana ia sesuai untuk penghasilan papan simen terikat. Kajian ini menggunakan gentian kulit kenaf sebagai pengganti separa dan bahan pengukuhan bagi penghasilan papan simen. Kajian ini terdiri daripada evaluasi sifat mekanikal dan fizikal gentian kulit kenaf yang mana yang telah diasingkan dengan menggunakan kaedah pengekstrakan yang berbeza (air, dekortikator dan kimia), sifat penghidratan dan kesan perbezaan formula kepada sifat papan kenaf bersimen terikat (PKBT). Objektif kajian ini adalah : 1) untuk menilai kesan kaedah pengasingan gentian kepada sifat fizikal dan mekanikal gentian kulit kenaf, 2) untuk menentukan kesan mencampurkan gentian kulit kenaf, pemangkin/aselarator ($CaCl_2$, $AlCl_3$, Na_2SO_4, CaO) dan bahan aditif (silika and superplasticiser) ke atas sifat penghidratan simen “Portland”, 3) menilai sifat mekanikal dan kestabilan dimensi PKBT, 4) untuk menilai prilaku pematangan bagi PKBT dan 5) untuk mencirikan ketelapan,

permukaan dan sifat haba bagi PKBT. Prestasi ketumpatan yang berbeza telah PKBT dinilai berdasarkan kekuatan - modulus kepecahan (MOR), kekukuhan - modulus kekenyalan (MOE) dan ikatan dalaman (IB). Kestabilan dimensi telah dinilai dengan menentukan peratusan penyerapan air (WA) dan pembengkakan ketebalan (TS).

Sifat morfologi gentian kulit kenaf secara jelas dipengaruhi oleh kaedah pengekstrakan. Penggunaan sodium hidroksida (NaOH) semasa proses rendaman telah mengurangkan diameter lumen gentian dan meningkatakan ketebalan dinding sel secara signifikan. Benziot dan gentian yang direndam di dalam air menunjukkan hasil yang sama tetapi kesannya agak sedikit. Walaubagaimanapun, penyahkulitan mekanikal didapati secara berlebihan telah mengurangkan ketebalan dinding sel berbanding gentian yang tidak diproses. Terdapat sedikit peningkatan ketumpatan gentian bagi rendaman NaOH dan rendaman benziot bagi kulit kenaf berbanding rendaman air, penyahkulitan dan sampel kawalan. Gentian yang agak tumpat mungkin disebabkan oleh serapan bahan kimia ke dalam gentian. Antara beberapa kaedah pengekstrakan yang digunakan, gentian yang diproses melalui penyahkulitan, rendaman air dan rendaman NaOH menunjukkan kekuatan tegangan yang signifikan.

Ujian hidrasi mencadangkan NaOH dan benziot adalah tidak sesuai bagi rendaman kenaf. Kedua-duanya rendaman gentian memerlukan masa penghidratan pH yang lebih lama dan suhu penghidaratan maksimum yang rendah, di mana ia adalah tidak konduktif bagi rawatan PKBT. Rendaman air dan penyahkulitan papan gentian kenaf menunjukkan sifat hidrasi yang baik dan sesuai untuk penghasilan papan simen. Saiz gentian yang sesuai ialan >3.5mm. gentian yang lebih kecil memerlukan penambahan bahan pecutan untuk meningkatkan keserasian. Di antara beberapa

bahan pemangkin yang digunakan, $CaCl_2$, $AlCl_3$, Na_2SO_4 dan CaO, $CaCl_2$ dan CaO terbukti terbaik dimana kepekatan optimumnya adalah pada bacaan 2%. Di antara dua bahan tambah yang digunakan iaitu wasap silika dan superplasticiser, superplasticiser didapati pilihan yang lebih baik berdasarkan sifat hidrasi. Perbandingan di antara kaedah pengasingan gentian menunujukkan rendaman air dan penyahkulitan menghasilkan gentian yang berkualiti baik, kekuatan tegangan yang tinggi, kandungan selulosa yang tinggi, sifat hidrasi dan morfologi gentian yang baik.

Gabungan papan gentian kenaf dan simen terikat menghasilkan panel ringan yang bersesuaian dan kuat. Walaubagaimanpun , ikatan dalaman secara signifikan telah menurun. Punca utama kepada penurunan ini ialah pengasingan gentian kenaf dari simen yang mewujudkan ikatan partikel yang lemah. Hampir semua kegagalan terjadi pada bahagian antara muka. Penambahan 7 % wasap silika telah membaiki ikatan dalaman sebnyak 83%. Ketumpatan papan juga telah memberikan kesan negatif ke atas sifat mekanikal dan kestabilan dimensi papan. Di antara ketiga-tiga simen: perkadaran PGF (2:1, 2.5:1 dan 3:1) yang digunakan dalam kajian ini, kadar 2:1 menghasilkan keputusan papan pada prestasi terbaik bagi ujian modulus kepecahan, elastik, serapan air dan kekuatan tegangan. Kombinasi terbaik untuk menghasilkan PKBT ialah dengan menggunakan penyahkulitan papan gentian kenaf pada kadar 2:1 (simen : PGF), 7% wasap silica dan berketumpatan (1100 kg/m^3). Sifat: Modulus kepecahan (10.9 MPa), Modulus elastik (5061 MPa), ikatan dalaman (0.15 MPa), serapan air selepas 2j dan 24j (23.7 dan 7%), kekuatan regangan selepas 2j dan 24j (0.87 dan 3.01%).

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I certify that a Thesis Examination Committee has met on 3 June 2013 to conduct the final examination of Amel Basher Ahmed Basher on her thesis entitled "Properties of Kenaf Bast Fibre Cement Composite Board" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Edi Syams bin Zainudin, PhD
Associate Professor
Faculty of Enineering
Universiti Putra Malaysia
(Chairman)

Mohd Sapuan b Salit@Sinon, PhD
Professor
Faculty of Enineering
Universiti Putra Malaysia
(Internal Examiner)

Rasmina binti Halis, PhD
Lecturer
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

Alcides Lopes Leao, PhD
Professor
College of Agricultural Sciences
Sao Paulo State University, Brazil
(External Examiner)

_____

NORITAH OMAR, PhD
Assoc. Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 2 August 2013

This thesis is submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Paridah Md. Tahir, PhD
Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

H'ng Paik San, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)

Rahim Sudin, PhD
Senior Researcher
Forest Research Institute of Malaysia (FRIM)
(Member)

Zakiah Ahmed, PhD
Associate Professor
Universiti Technologi Mara, Malaysia.
(Member)

Zeinab A. Osman, PhD
Associate Professor
Institute for Technological Research,
Natural Centre for Research, Sudan
(Member)

_____
BUJANG KIM HUAT , PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

AMEL BASHER AHMED BASHER

Date: 3 June 2013

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