

**DEVELOPMENT OF A BIO-COMPOSITE INTERLOCKING BLOCK
SYSTEM FOR RIVER REVETMENT**

By

NOR AZLINA BINTI ALIAS

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

September 2006

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

DEVELOPMENT OF A BIO-COMPOSITE INTERLOCKING BLOCK SYSTEM FOR RIVER REVETMENT

By

NOR AZLINA BINTI ALIAS

September 2006

Chairman: Associate Professor Thamer Ahmed Mohamed, PhD

Faculty: Engineering

In Malaysia, many types of revetment systems are used in channel lining. These systems are mostly manufactured and patented overseas or designed using technologies transferred from foreign countries. Development of an interlocking block with environmental consideration is a new approach that may help in river protection and restoration. It is important to design and develop locally a new revetment block which is economical, durable and environmentally friendly.

In this study, a block has been developed to be used as river revetment. As it also incorporates a bio-material, it is called a bio-composite revetment block. The block has a dimension of 400 mm x 400 mm x 100 mm (length x width x thickness) and it is designed to resist forces developed after installation at site and it complies with the requirements of the design and theory of existing blocks. The bio-composite block is made of concrete and it consists of tongue and groove to provide self interlocking between the blocks. In the opening at the centre of the block, a 10 mm layer of coconut husk is held in its place by two layers of plastic meshes that are embedded in concrete.

Laboratory tests carried out were the flexural and tensile strength test on a single and multiple blocks. To conduct these tests, a special testing set-up was used. Direct tensile tests for single blocks indicate the failure was at 9.16 kN while for a group of blocks, the system failed at 5.81 kN. A finite element software called ANSYS was used to validate the failure pattern obtained from the laboratory tests and it was found to be in agreement with the predicted failure pattern by ANSYS. Laboratory experiment on biological materials showed that the coconut husk was the best medium for grass to grow compared to other media (oil palm husk and sugar cane husk).

Field tests were conducted in which a 15 m stretch of a stream inside Universiti Putra Malaysia with a top width of 7 m was selected to install the bio-composite block. The purpose of field test is to measure the flow velocity and Manning roughness coefficient for the bio-composite block after installation. The average value of Manning roughness coefficient was found to be 0.040. The stability of the block and the rate of grass growth were also monitored. There was no block failure observed and a rapid grass growth was noticed with a rate of growth of 1.4% to 15% per week.

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

**PEMBANGUNAN SISTEM BLOK BIO-KOMPOSIT SALINGKUNCI
UNTUK LAPIS LINDUNG SUNGAI**

Oleh

NOR AZLINA BINTI ALIAS

September 2006

Pengerusi: Profesor Madya Thamer Ahmed Mohamed, PhD

Fakulti: Kejuruteraan

Di Malaysia, banyak jenis blok lapis lindung yang digunakan dalam projek-projek perlindungan saluran. Blok-blok ini dikilangkan serta diimport dari luar negara ataupun direkabentuk menggunakan teknologi-teknologi yang dibawa masuk dari negara luar. Merekabentuk blok lapis lindung yang baru dengan mengambilkira keadaan alam sekitar adalah satu pendekatan baru dalam mengekalkan keadaan sungai yang sedia ada dan ia penting untuk membangunkan blok lapis lindung yang ekonomi, tahan lasak dan mesra alam.

Dalam kajian ini, blok mesra alam dicadangkan sebagai lapis lindung sungai dan dinamakan blok lapis lindung bio-komposit. Blok ini berdimensi 400 mm x 400 mm x 100 mm (panjang x lebar x tebal) dan direkabentuk untuk menahan daya terarak selepas pemasangan dengan mematuhi keperluan rekabentuk dan teori digunakan blok sedia ada. Blok lapis lindung bio-komposit ini mempunyai lidah dan alur yang menyediakan salingkunci diantara blok dan bukaan tengah blok. Di bukaan tengah blok, sabut kelapa setebal 10 mm dipegang oleh dua lapisan jejaring plastik dan dibanamkan dalam konkrit.

Ujian-ujian makmal dilakukan termasuk lenturan dan terikan keatas satu dan gabungan beberapa blok. Untuk menjalankan ujikaji, satu rangkaian khas untuk ujian dibuat. Ujian terikan keatas blok individu mencatatkan kegagalan adalah pada nilai terikan 9.16 kN manakala ujian keatas blok gabungan gagal pada nilai terikan 5.81 kN. Perisian Unsur Terhingga yang dikenali sebagai ANSYS digunakan untuk mengesahkan paten kegagalan dari ujian makmal dan paten kegagalan dari ujian makmal didapati sama dengan paten kegagalan yang diramal oleh ANSYS. Eksperimen di makmal ke atas bahan biologiikal menunjukkan bahawa sabut kelapa merupakan penggalak terbaik sebagai media pertumbuhan berbanding media lain (sabut kelapa sawit dan sabut tebu)

Ujian di tapak dilakukan di mana sungai sepanjang 15 m dengan lebar permukaan 7 m di Universiti Putra Malaysia digunakan untuk memasang sistem ini. Tujuannya adalah untuk mengukur halaju air dan pekali kekasaran Manning bagi blok bio-komposit selepas pemasangan. Nilai purata pekali kekasaran Manning adalah 0.040. Kestabilan blok dan kadar pertumbuhan rumput juga dicerap. Tiada kegagalan blok dicerap dan kepantasan pertumbuhan rumput dapat dikesan dengan kadar pertumbuhan sebanyak 1.4% hingga 15% dalam tempoh seminggu.

ACKNOWLEDGEMENTS

Thanks and gratitude to God for His Blessing and Grace, this thesis could be written successfully.

Special thanks and appreciation are due to my supportive supervisors; Assoc. Prof. Dr. Thamer Ahmed Mohammed, Assoc. Prof. Dr. Abdul Halim Ghazali and Assoc. Prof. Dr. Mohd Saleh Jaafar for their advice, guidance, ideas, their generous help and comments and encouragement during completing this project.

Special appreciation is extended to the technicians of Civil Engineering Department (UPM), especially to Mr. Mohd. Halim Othman for his help and cooperation during the development of this project. Deepest appreciation is also extended to the Department of Civil Engineering, Faculty of Engineering for providing all the facilities to complete the project successfully.

Greatest thanks are also extended to my beloved parents and friends for their encouragement through out my studies and their support in the making of the thesis.

Lastly, I would like to acknowledge all who have contributed towards the completion of this thesis.

I certify that an Examination Committee has met on 8 September 2006 to conduct the final examination of Nor Azlina Binti Alias on her Master of Science thesis entitled “Development of a Bio-composite Interlocking Block System for River Revetment” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Mohd. Razali Abdul Kadir, PhD

Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Lee Teang Shui , PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Katayon Saed, PhD

Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Othman Abdul Karim, PhD

Associate Professor
Faculty of Engineering
Universiti Kebangsaan Malaysia
(External Examiner)

HASANAH MOHD. GHAZALI, PhD

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Thamer Ahmed Mohammed, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Abdul Halim Ghazali, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohd. Saleh Jaafar, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD

Professor/ 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 UPM or other institutions.

NOR AZLINA BINTI ALIAS

Date:

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ABSTRAK	iv
ACKNOWLEDGEMENTS	vi
APPROVAL	vii
DECLARATION	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS/NOTATIONS/GLOSSARY OF TERMS	xviii
CHAPTER	
I INTRODUCTION	
Definition of Problem	2
Objectives of Study	4
Scope of Study	4
II LITERATURE REVIEW	
Revetment System	6
Functions of Revetment System	7
Bio-engineering Revetment System	8
Structural Revetment System	10
Gabion Revetment	11
Rock Revetment	13
Asphaltic Revetment	16
Pre-Cast Concrete Block Revetment	18
Bio-technical Engineering Revetment System	19
Cable tied Concrete Block	19
Cellular Concrete Block	20
Failure Modes of Revetment System	25
Theoretical Background of Block Design	28
Roughness Coefficient	37
Manning Roughness Coefficient	38
Effect of Vegetation to the Roughness Coefficient	41
Materials	43
Application of Finite Element Analysis	46
Selected Case Studies of Failed Revetment Systems in Malaysia	47
Summary	52
III MATERIALS AND METHODOLOGY	
Development of Block	54
Dimensioning of revetment block	55
Materials	58
Mould	65
Laboratory Experiments of the Interlocking Block	66
Tensile test on interlocking block	66

	Flexural test on interlocking block	68
	Finite Element Method	68
	Installation of Interlocking Block	70
	Site selection, survey and preparation	70
	Measurement of flow depth and velocity for various storms	74
	Manning n	75
	Monitoring period	75
	Summary	76
IV	RESULTS AND DISCUSSION	
	Development of Block	77
	Design concept and analysis	77
	Design of block	80
	Analysis of Results Obtained from Laboratory Experiments	83
	Analysis on Failure Modes of Interlocking Revetment Block	90
	Tensile strength	90
	Flexural strength	98
	Validation of Failure Pattern Using Finite Element Method	99
	Theoretical analysis of block failure	101
	Field Performance of Interlocking Blocks	106
	Effectiveness of biological materials after construction	107
	Determination of Hydraulic Properties of Field Measurement	112
	Summary	121
V	CONCLUSION	
	Conclusion	123
	Advantages of the interlocking block revetment system	124
	Suggestion	124
	REFERENCES	126
	APPENDICES	130
	BIODATA OF THE AUTHOR	148