UNIVERSITI PUTRA MALAYSIA

DETERMINATION OF SEWAGE SLUDGE COMPOSITION AS PARTIAL SUBSTITUTE IN CLAY BRICKS

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DETERMINATION OF SEWAGE SLUDGE COMPOSITION AS PARTIAL SUBSTITUTE IN CLAY BRICKS

By

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

August 2002

UPM

Dedicated To:

My dearest and beloved late father, mother, sisters and brother in-law
for their loving care
and endless encouragement

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

DETERMINATION OF SEWAGE SLUDGE COMPOSITION AS PARTIAL-SUBSTITUTE IN CLAY BRICKS

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August 2002

Chairman: **Associate Professor Dr. Azni Bin Haji Idris**

Faculty: **Engineering**

Sludge is an unavoidable by-product of wastewater treatment and creates problem of disposal. Generally, dewatered sludge is disposed of by landfilling. However, this option might not be appropriate due to land limitation and stringent environmental regulations imposed. Therefore, a joint effort study between IWK and UPM was carried out to investigate the possibility of incorporating dried sludge in building bricks at laboratory level as an alternative means of sludge disposal while being an innovative way of making construction materials.

Bricks were produced with sludge additions ranging from 10 to 40% by dry weight. The texture and finish on the surface of sludge-amended clay bricks were rather poor. Nonetheless, they were every bit as attractive due to being light red in colour and odourless. As for physical and chemical properties, bricks with up to 40wt% sludge were capable of meeting the appropriate technical standards. However, bricks with more than 30wt% sludge amendment were not recommended for use since they were brittle and easily broken even when handled gently. Heavy metal leaching test carried out on crushed brick samples to simulate

extreme environmental conditions resulted in leachate losses way below the US-EPA extraction procedure regulatory limits. Therefore, all the bricks with different proportions of sludge were classified as non-hazardous materials and should be safe for use as a building material.

In this study, which used the classical handmoulding method to compact the brick specimens in custom-made wooden moulds, the quality of bricks produced were quite varied and the structural properties results obtained were less than satisfactory compared to that of other researchers (using extruders) mainly due to the more uniform and higher moulding pressure applied on their bricks. However, results obtained in this study would serve as a guide to subsequent full-scale studies. On top of that, some anticipated improvements for future full-scale brickmaking process based on the preliminary results, to produce better quality bricks, was given due attention. Knowing that the technical criteria of the bricks could be optimized, however, this process may require consumer education and regulatory assistance for long term success and acceptance.

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

KAJIAN KOMPOSISI ENAPCEMAR SEBAGAI GANTIAN-SEPARA DALAM BATU-BATA TANAH LIAT

Oleh

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Enapcemar merupakan suatu bi-produk yang tidak dapat dielakkan daripada rawatan sisa air dan ini menimbulkan masalah pembuangan. Secara umum, enapcemar yang telahpun dikeluarkan airnya dibuang ke kawasan pelupusan sampah. Walau bagaimanapun, opsyen ini tidak lagi sesuai disebabkan tanah yang ada terhad dan peraturan persekitaran yang ketat dikenakan. Oleh itu, satu kajian gabungan tenaga antara IWK dan UPM telah dijalankan untuk menyiasat kemungkinan menggabungkan enapcemar kering ke dalam batu-bata pada peringkat makmal sebagai langkah alternatif pembuangan enapcemar disamping menjadi satu cara inovatif membuat bahan binaan.

Batu-bata telahpun dihasilkan dengan penambahan enapcemar sebanyak daripada 10 hingga 40% berat kering. Tekstur dan kesempurnaan pada permukaan batu-bata tanah liat yang dimasukkan enapcemar adalah serba kurang. Sungguhpun begitu, batu-bata ini menarik disebabkan warnanya yang merah muda dan tidak berbau. Dari segi ciri-ciri fizikal dan kimia, batu-bata yang dimasukkan sehingga 40% enapcemar berupaya mencapai piawai teknikal yang sesuai. Walau

bagaimanapun, batu-bata yang berisi lebih daripada 30% enapcemar tidak disyorkan untuk penggunaan kerana bersifat rapuh dan mudah pecah walaupun dipegang dengan lemah-lembut. Ujian kelarutlesapan logam berat yang dijalankan ke atas pecahan sampel batu-bata untuk menjadikannya subjek kepada keadaan persekitaran yang terlampau, telah menunjukkan kehilangan larutlesap logam berat jauh dibawah had peraturan prosedur pengekstrakan US-EPA. Oleh itu, kesemua batu-bata dengan kandungan enapcemar yang berbeza diklasifikasi sebagai bahan tidak berbahaya dan sepatutnya selamat digunakan sebagai bahan binaan.

Penggunaan kaedah acuan tangan klasik untuk memadatkan specimen batu-bata ke dalam acuan kayu buatan-sendiri dalam kajian ini telah menghasilkan batu-bata dengan kualiti yang agak berbeza dan ciri struktur diperolehi pula adalah kurang memuaskan berbanding dengan hasil kerja penyelidik lain (yang menggunakan mesin acuan) yang berkemungkinan besar berlaku atas sebab penggunaan tekanan membentuk batu-bata yang lebih tinggi dan sekata dalam penyelidikan mereka. Walau bagaimanapun, keputusan yang diperolehi dalam kajian ini boleh dijadikan sebagai panduan untuk kajian skala-penuh yang berikutnya. Selain itu, cadangan yang dijangka dapat membaikkan proses membuat batu-bata skala-penuh pada masa depan berdasarkan keputusan pendahuluan rintis yang diperolehi dari kajian ini untuk menghasilkan batu-bata yang lebih berkualiti, telah juga diberikan perhatian yang sewajarnya. Akhir sekali, walaupun diketahui bahawa kriteria teknikal batu-bata boleh dioptimumkan, proses ini juga memerlukan didikan pengguna dan bantuan peraturan bagi menjamin kejayaan dan penerimaan proses ini secara umum dalam jangka masa panjang.

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I certify that an Examination Committee met on 7th August 2002 to conduct the final examination of Calvin Wong Hong Kiat on his Master of Science thesis entitled "Determination of Sewage Sludge Composition as Partial-Substitute in Clay Bricks" 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:

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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.

_____

CALVIN WONG HONG KIAT

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TABLE OF CONTENTS

		Page
DEDICATION		ii
ABSTRACT		iii
ABSTRAK		v
ACKNOWLEDGEMENTS		vii
APPROVAL		ix
DECLARATION		xi
LIST OF TABLES		xiv
LIST OF FIGURES		xvi
GLOSSARY OF TERMS		xviii
CHAPTER		
1	INTRODUCTION	1.1
	1.1 General	1.1
	1.2 Objectives of the Study	1.4
	1.3 Scope of the Study	1.5
	1.4 Significance of the Study	1.5
2	LITERATURE REVIEW	2.1
	2.1 What is Sewage Sludge?	2.1
	2.1.1 Types of Sewage Sludge	2.1
	2.1.2 Characteristics of Sewage Sludge	2.6
	2.1.3 Treatment Processes of Sewage Sludge	2.6
	2.2 Production Output of Sludge	2.15
	2.2.1 Problems and Constraints Related to Sludge	2.17
	2.2.2 Mitigation of These Adverse Effects	2.19
	2.3 Reuse Options and Ultimate Disposal of Sludge	2.21
	2.3.1 Land Application	2.21
	2.3.2 Landfill	2.25
	2.3.3 Land Reclamation	2.26
	2.3.4 Composting	2.26
	2.3.5 Thermal Treatment	2.27
	2.4 Concept Review of Sludge-Amended Brick Production	2.29
	2.4.1 Historical Background of Brick Manufacture	2.29
	2.4.2 Types of Bricks, Its Application and Defects	2.31
	2.4.3 Manufacture of Bricks	2.35
	2.4.4 Brickwork	2.43
	2.4.5 Manufacturing of Conventional Clay Bricks in Yap Khay Cheong Brickworks (M) Sdn. Bhd.	2.45
	2.4.6 Supplemental Brick Additions	2.51
	2.5 Sewage Sludge as Brickmaking Material	2.71
	2.5.1 How Did the Idea Appear?	2.71
	2.5.2 Chronology of Events for This Study Till Today	2.75
	2.5.3 Benefits of Reuse	2.78

	2.5.4 Environmental Concern and Public Acceptance	2.80
3	MATERIAL AND METHODS	3.1
	3.1 Acquisition of Raw Materials	3.2
	3.1.1 Site of Samples	3.2
	3.1.2 On-Site Sampling Methods	3.2
	3.1.3 Representative Sampling for Subsequent Use	3.4
	3.2 Characterization of Raw Materials	3.7
	3.3 Experimental Set-Up	3.8
	3.3.1 General	3.8
	3.3.2 Apparatus	3.11
	3.3.3 Experimental Site	3.12
	3.4 Laboratory-Scale Production of Sludge-Amended Clay Bricks	3.12
	3.4.1 Complementary Drying of Raw Materials	3.12
	3.4.2 Preparation of Mixtures	3.13
	3.4.3 Moulding of Specimen	3.16
	3.4.4 Thermal Treatment of Specimen	3.18
	3.5 Integrity Analysis and Quality Testing of Sludge-Amended Clay Bricks	3.19
4	RESULTS AND DISCUSSION	4.1
	4.1 Characteristics of Clay and Sludge	4.1
	4.1.1 Physical Properties	4.2
	4.1.2 Micro-Characterization Properties	4.10
	4.1.3 Thermal Properties	4.15
	4.2 Characteristics of Sludge-Amended Clay Bricks	4.19
	4.2.1 Physical and Mechanical Properties	4.22
	4.2.2 Chemical Properties	4.39
	4.2.3 Micro-Characterization Properties	4.47
	4.3 Limitations of This Study in Comparison to Other Studies	4.56
	4.4 Feasibility Study for Subsequent Full-Scale Brick Production	4.60
5	CONCLUSION AND RECOMMENDATIONS	5.1
	5.1 Conclusion	5.1
	5.2 Recommendations for Future Works	5.7
	REFERENCES	R.1
	BIBLIOGRAPHY	B.1
	APPENDICES	A.1
	VITA	V.1

LIST OF TABLES

Table		Page
2.1	Typical Chemical Composition of Raw and Digested Sludge	2.6
2.2	Typical Contaminants in Sewage and Problems Caused	2.17
2.3	Conditions Applied in Pre-Heat, Firing and Cooling Zones of YKC Kiln	2.49
2.4	Calorific Value of Fuel Wastes	2.54
2.5	Technological Properties of Bricks Containing Fuel Wastes	2.55
2.6	Technological Properties of Bricks Containing Fly-Ash	2.65
2.7	Technological Properties of Bricks Containing Fluxing Wastes	2.67
2.8	Technological Properties of Bricks Containing Plasticity Reducing Wastes	2.70
2.9	Properties of Bricks Made from Sludge	2.77
3.1	Analytical Methods for Characterization of Clay and Sludge	3.7
3.2	Mass of Raw Materials Required as Per Brick for Different Proportions of Clay-Sludge Mixtures	3.13
3.3	Identity of Samples with Different Proportions of Sludge Amended in Bricks	3.17
3.4	Number of Bricks Required for Testing	3.20
4.1	Physical and Chemical Properties for Clay and Sludge	4.1
4.2	Total Mass of Raw Material and Amount of Water Required as Per Brick for Different Proportions of Clay-Sludge Mixtures	4.7
4.3	Heavy Metals (Including Salts) in Clay and Sludge	4.9
4.4	Chemical Compositions for Clay and Sludge	4.10
4.5a	Classification of Sludge-Amended Clay Bricks by Water Absorption According to BS 3921: 1985	4.28
4.5b	Classification of Sludge-Amended Clay Bricks by Water Absorption According to MS 7.6: 1972	4.29
4.6a	Classification of Sludge-Amended Clay Bricks by Compressive Strength According to BS 3921: 1985	4.31
4.6b	Classification of Sludge-Amended Clay Bricks by Compressive Strength According to MS 7.6: 1972	4.32
4.7	Degree of Visible Salting on Sludge-Amended Clay Bricks in Efflorescence Test	4.34
4.8	Classification of Sludge-Amended Clay Bricks by Soluble Salts Content	4.40
4.9	Chemical Compositions for Sludge-Amended Clay Bricks	4.47
4.10a	Cash Flow Analysis for Implementing the Sludge-amended Clay Bricks Manufacturing Process for Year 1	4.64
4.10b	Cash Flow Analysis for Implementing the Sludge-amended Clay Bricks Manufacturing Process from Year 2 and Onwards	4.65
4.10c	Payback Time for Implementing the Sludge-amended Clay Bricks Manufacturing Process	4.66

4.11a	Sensitivity Analysis (by Varying the Transport Cost) for the Brick Manufacturing Process that Amends 20wt% Sludge after Year 1	4.69
4.11b	Sensitivity Analysis (by Varying the Transport Cost) for the Brick Manufacturing Process that Amends 20wt% Sludge after Year 2 and Onwards	4.70
4.11c	Effect on Payback Time with respect to Variation in Transport Cost for the Brick Manufacturing Process that Amends 20wt% Sludge	4.71
4.12a	Sensitivity Analysis (by Varying the Labour Cost) for the Brick Manufacturing Process that Amends 20wt% Sludge after Year 1	4.72
4.12b	Sensitivity Analysis (by Varying the Labour Cost) for the Brick Manufacturing Process that Amends 20wt% Sludge after Year 2 and Onwards	4.73
4.12c	Effect on Payback Time with respect to Variation in Labour Cost for the Brick Manufacturing Process that Amends 20wt% Sludge	4.74
5.1a	Status of Sludge-Amended Clay Bricks Classified based on Water Absorption According to BS 3921: 1985	5.2
5.1b	Status of Sludge-Amended Clay Bricks Classified based on Water Absorption According to MS 7.6: 1972	5.2
5.2a	Status of Sludge-Amended Clay Bricks Classified based on Compressive Strength According to BS 3921: 1985	5.3
5.2b	Status of Sludge-Amended Clay Bricks Classified based on Compressive Strength According to MS 7.6: 1972	5.4
5.3	Status of Sludge-Amended Clay Bricks Classified based on Efflorescence, Soluble Salts Content and Heavy Metal Leaching	5.5
5.4	Application of Sludge-Amended Clay Bricks Corresponding to Classifications Cited in BS 3921: 1985 and MS 7.6: 1972	5.6

LIST OF FIGURES

Figure		Page
2.1	Sludge Treatment and Disposal Methods	2.14
2.2	Total Volume of Sludge Production in Malaysia	2.17
2.3	Stages in the Manufacture of Clay Bricks	2.35
2.4	A Typical Firing Schedule for Red-Burning Kaolinitic Clay in a Brick Kiln	2.41
2.5	Simplified Schematic Flowchart Showing Manufacturing Process for Full-scale Clay Bricks by YKC	2.46
2.6	Kiln Temperature Profile in YKC	2.50
2.7	Compressive Strength of Bricks Made from Sludge	2.78
3.1	Flowchart Depicting the Development of Sludge-Amended Clay Bricks in This Study	3.1
3.2	Simplified Cross Section of a Typical Sand Drying Bed	3.4
3.3	Apparatus Used for Moulding Brick Specimens	3.11
3.4	Plastic Containers Containing Different Proportions of Clay-Sludge Mixtures	3.14
3.5	Manual Mixing of Clay-Sludge Mixture	3.15
3.6	Transfer of Paste into the Wooden Mould	3.15
3.7	Glossy Surface of the Mould due to Coating of Lubricating Oil	3.15
3.8	Moulding a Brick Specimen by Compaction	3.17
3.9	Wet Bricks after Removal from the Mould	3.17
3.10	Measurements of Weight and Length of Green Bricks after Drying in YKC	3.19
3.11	Measurements of Weight and Length of Fired Bricks in YKC	3.19
4.1a	Particle Size Distribution Chart for Clay	4.4
4.1b	Particle Size Distribution Chart for Sludge	4.4
4.2a	Maximum Dry Density for Different Proportions of Clay-Sludge Mixtures from 'Ordinary' Compaction	4.6
4.2b	Total Amount of Water Required for Making Different Proportions of Sludge-Amended Clay Bricks	4.6
4.3	XRD Patterns for (a) Clay; and (b) Sludge	4.13
4.4a	DTA Curve for Clay	4.15
4.4b	DTA Curve for Sludge	4.17
4.5a	Representative Wet Bricks with Sludge Proportions Up to 40wt%	4.19
4.5b	Representative Fired Bricks with Sludge Proportions Up to 40wt%	4.19
4.6	Black Coring for Clay Brick Amended with 10wt% Sludge	4.21
4.7a	Effect of Different Amount of Sludge Added on Weight-Loss after Drying	4.22
4.7b	Effect of Different Amount of Sludge Added on Weight-Loss after Firing	4.22
4.8a	Effect of Different Amount of Sludge Added on Linear Drying Shrinkage	4.24

4.8b	Effect of Different Amount of Sludge Added on Linear Firing Shrinkage	4.25
4.8c	Effect of Different Amount of Sludge Added on Total Linear Shrinkage	4.26
4.9	Effect of Different Amount of Sludge Added on Water Absorption	4.27
4.10	Effect of Different Amount of Sludge Added on Compressive Strength	4.30
4.11a	Brick Specimens before Drying	4.35
4.11b	No Deposit of Salts after 7 Days Drying	4.35
4.11c	Slight Deposit of Salts after 14 Days Drying	4.35
4.11d	Slight Deposit of Salts after 28 Days Drying	4.36
4.11e	Slight Deposit of Salts after 56 Days Drying	4.36
4.12	Effect of Different Amount of Sludge Added on Bulk Density	4.37
4.13	Effect of Different Amount of Sludge Added on Thermal Conductivity	4.38
4.14a	Effect of Different Amount of Sludge Added on Leachability of Arsenic	4.43
4.14b	Effect of Different Amount of Sludge Added on Leachability of Barium	4.43
4.14c	Effect of Different Amount of Sludge Added on Leachability of Cadmium	4.44
4.14d	Effect of Different Amount of Sludge Added on Leachability of Chromium	4.44
4.14e	Effect of Different Amount of Sludge Added on Leachability of Lead	4.45
4.14f	Effect of Different Amount of Sludge Added on Leachability of Silver	4.45
4.15a	XRD Patterns for Clay Brick (a) Made in Factory; (b) without Sludge Amendment; and (c) with 10wt% Sludge Amendment	4.50
4.15b	XRD Patterns for Clay Brick with Sludge Amendments of (d) 20wt%; (e) 30wt%; and (f) 40wt%	4.51
4.16a	Electron Micrograph for Clay Brick Made in Factory	4.52
4.16b	Electron Micrograph for Clay Brick without Sludge Amendment	4.52
4.16c	Electron Micrograph for Clay Brick Amended with 10wt% Sludge	4.53
4.16d	Electron Micrograph for Clay Brick Amended with 20wt% Sludge	4.53
4.16e	Electron Micrograph for Clay Brick Amended with 30wt% Sludge	4.54
4.16f	Electron Micrograph for Clay Brick Amended with 40wt% Sludge	4.54

GLOSSARY OF TERMS

atm	Atmospheric pressure
ASTM	American Society of Testing Materials
B.C.	Before Christ
BS	British Standards
CE	Compactive Effort
CEC	Cation Exchange Capacity
CV	Calorific Value
DGSS	Director General of Sewerage Services, Malaysia
DOE	Department of Environment, Malaysia
EP	Extraction Procedure
EPA	Environmental Protection Agency
ESEM	Environmental Scanning Electron Micrograph
I.D.	Identity
IWK	Indah Water Konsortium Sdn. Bhd.
L.O.I.	Loss-On-Ignition
Max.	Maximum
MDD	Maximum Dry Density
MINT	Malaysian Institute for Nuclear Technology Research
MWCC	Metropolitan Waste Control Commission
OMC	Optimum Moisture Content
rpm	Revolution per minute
SEM	Scanning Electron Micrograph
SIRIM	Standards International and Research Institute of Malaysia
STF	Sludge Treatment Facility
STP	Sewage Treatment Plant
STW	Sewage Treatment Works
UKM	Universiti Kebangsaan Malaysia
US	United States of America
UTM	Universiti Teknologi Malaysia
wt%	Weight percentage
WWTP	Wastewater Treatment Plant
YKC	Yap Khay Cheong Brickworks (M) Sdn. Bhd.
no./No.	Number

CHAPTER 1

INTRODUCTION

1.1 General

Wastewater sludge is long considered to be a nuisance of environmental control. Increasingly stringent environmental regulations and industrial growth have increased the disposal requirements. Therefore, disposal of sludge from wastewater treatment plants (WWTPs) is a problem to any municipality.

Landfilling, ocean dumping, and spreading on reclaimed land are the most current sludge disposal methods worldwide. Some cities on the coastline even convey the sludge out to sea in pipes. Other cities solve their problems by incinerating after dewatering processes. In general, land disposal is the cheapest way of disposing sludge if it enables crops to be grown on poor land for agricultural purposes. All these methods have varying degrees of environmental impact. The problem of sludge disposal will intensify as the amount of sludge produced increases. Eventually, finding the appropriate location for landfilling will be a major problem.

As a third world developing nation and in her aim to successfully move towards Vision 2020, Malaysia with a population of approximately 22.71 million people (as of the year 1999) and still growing rapidly, the amount of sewage produced is steadily increasing. This sewage comprises of various pollutants from domestic, commercial and industrial premises. Unless treated at a sewage treatment plant (STP), this raw sewage and pollutants can end up in drains, rivers and coastal

waters, thus, risking public health, contaminating water resources and polluting the environment (IWK, 1997a).

Generally, all sewerage systems from septic tanks to the most sophisticated mechanical plants produce sludge. Each year, Malaysia produces 5 million m^3 domestic sludge. However, facilities to treat and dispose of this sludge are limited. At the moment, STPs with excess capacity are being used to treat septic tank sludge. By the year 2022, Malaysia is expected to produce over 7 million m^3 domestic sludge annually. Therefore, many new sludge treatment and disposal facilities will be required to manage this large volume.

All the above can be seen to be creating a major problem for Indah Water Konsortium (IWK), the sole private sewerage services company in Malaysia, and the disposal of sludge. In light of this matter, there is an urgent need for alternative methods of sludge disposal. Currently, IWK is actively undertaking technological development studies in collaboration with local public universities such as UPM and UTM to reduce and reuse sludge to minimize dependence on disposal of the solids in landfill, and has already offered part of its result for practical use.

According to Prouty *et al.* (1983), these alternative methods are divided into four general categories, which comprise air, water, land, and containment disposal, respectively. To alleviate burdens of disposal in problematic sludge, containment is desirable. Containment, in this text, means integration with another material for the purpose of binding or entrapping the sludge constituents. A potential

containment alternative, which may prove both cost-effective and environmentally beneficial, is the amendment of building and construction materials with sludge. The reuse of sludge into construction materials not only alleviates disposal problems but has economic, ecological and energy-saving advantages as well.

Researchers from all over the world have since carried out studies into the possible use of sewage sludge in brickmaking. The recently recorded work has been done mostly in the Far East, USA, Netherlands, Italy, former Yugoslavia and South Africa. Most of this work was done in the laboratory, on small pilot plant scale, or short-term trials on a brick factory, although in South Africa the use of sludge has been continuous on a production scale at one factory in Port Elizabeth (Slim *et al.*, 1991). Subsequent results obtained from these works indicated that sludge could, indeed, be successfully added in the manufacture of bricks.

Environmentally sound sludge management is the cornerstone of Malaysia's new approach to sewerage services. Proper sludge disposal options will contribute significantly in providing a cleaner and safer Malaysia for future generations. In relation to these options, it therefore seems sensible to study the use of sewage sludge in clay bricks if only from a waste disposal viewpoint, and if the energy saving implications are also included, it makes even greater sense here. Perhaps most importantly, this study might provide a complimentary addition to the existing options for beneficial sludge management in Malaysia.

This dissertation will initially give a brief outlook on what sewage sludge is all about and the different types of treatment processes involved. Apart from its

production output in Malaysia, the general problems faced and how to mitigate these adverse effects through the disposal and reuse of sludge deserves mention here. Next, the art and science of brick manufacture will be reviewed to provide a conceptual introduction to the involved technology applied by this concept. A detailed review for incorporation of sewage sludge into bricks follows suit. Finally, results of laboratory-scale testing will subsequently be reported to validate the brickmaking utility of the classical hand-moulding method by compaction applied here. The limitations of this study compared to that of the others and its feasibility for subsequent full-scale production are included next. A brief conclusion with recommendations for future works wraps up the flow of this thesis.

1.2 Objectives of the Study

Generally, this study conducted on a laboratory-scale aims to investigate the use of sewage sludge and its influences in the typical properties of the ceramic building material, in this case bricks, to build an alternative to sludge disposal options. More specifically, objectives of this study can be summarized as follows:

1. To characterize sludge to determine it's potential as clay amendment in producing bricks.
2. To determine the best possible sludge-clay mix ratio by carrying out product testing to study the effects on structural properties, and investigate leachability of heavy metals from the bricks produced.

1.3 Scope of the Study

This study was initiated with characterization of the physical and chemical properties of sludge (and clay) to determine its suitability and potential as amendment in clay bricks. The raw material used were septic tank sludge and clay soil. Subsequently, the raw materials were oven-dried and sieved. Then, they were formulated and weighed, respectively, in proportions of 0%, 10%, 20%, 30% and 40wt% sludge (dry basis). This variation in compositions was carried out to determine the most suitable sludge-clay mix ratio to produce quality bricks. Each wet brick has a specified standard work size. Prior to using classical handmoulding method to compact the brick specimens in custom-made wooden moulds, the prepared mixtures were each homogenized manually with addition of appropriate amount of water accordingly to ensure sufficient workability and consistency. Upon removal from the moulds, the wet bricks were subjected to drying and firing in a brick factory to produce reusable stabilized solids of sludge-clay mixtures that were pathogen-free. To verify the effects and outcome on structural properties of bricks produced in this study and also of those manufactured by YKC for comparison purpose, the fired bricks were subjected to a series of qualitative and quantitative evaluations. In addition, leachability of heavy metals from the sludge-adulterated clay bricks was also investigated.

1.4 Significance of the Study

It is expected that introduction of secondary wastewater treatment and the improvement of combined sewer system in Malaysia will increase the generation of sludge. Due to the presence of organic matter in sludge, the pathogenic, hygienic and nuisance factors must be considered first. In other words, this

wastewater solid must always be properly treated prior to disposal. Considering the increasing difficulties in securing new disposal sites, innovative measures have to be prepared to utilize and recycle sludge safely for the future. From these thoughts, IWK is repositioning sludge from a mere waste material to a valuable resource, and in some cases, has started to utilize and promote it, i.e. as compost.

This study, a joint effort between IWK and UPM, details an innovative and constructive approach in which vitrified bricks were derived from a sludge-amended classical hand-moulding process. From an environmental engineering perspective, the use of sludge in brickmaking is an attractive concept since it is a neat way of recycling a waste material, thereby contributing to a reduction in the ever-growing sheer volume of this unwanted commodity in Malaysia. This process also extracts from the sludge its energy content with combustion of its constitutive organic matter, besides, conceivably destroying or nullifying pathogens and heavy metals, both of which are harmful constituents (Churchill, 1994), which ultimately transforms this unwholesome commodity into a useful product.

On the other hand, this study will also significantly contribute a few operational benefits to brick manufacturers in Malaysia as well. The previously mentioned combustion of sludge organic matter may yield an exothermic heat release, which will consequently reduce the energy required for firing the bricks. In addition, combustion of this material may introduce small voids within the brick body that will prospectively improve the brick's bonding adherence to mortar besides making it lighter.