THERMAL INSULATION AND MECHANICAL PROPERTIES OF CONSTRUCTION MATERIALS WITH NITRILE RUBBER (NBR) WASTE FOR CONSTRUCTION INDUSTRY

RAFIDAH BINTI OTHMAN

UNIVERSITI TEKNOLOGI MALAYSIA

To my beloved mother, Hjh. Kalsom Hj Sabran, my supportive siblings and my faithful friends who had been my trusts, thanks for your priceless faith, understanding and never ending encouragement.

To all my friends and colleagues,

your support and kindness mean so much to me.

ACKNOWLEDGEMENT

I would like to take this opportunity to express my sincere appreciation to those who had given contributions and assisted me directly or indirectly in making my study a success.

First and foremost, I would like to thank Allah S.W.T for His grace, mercy and guidance throughout the completion of this study. My appreciation also goes to my supervisor, P.M Hanizam Sulaiman for his keen effort, interest, advice, continuous guidance and insightful comments throughout the whole thesis project.

My special gratitude dedicated to Mr Wong and Mr Othman from Top Glove Sdn. Bhd., Mr Yap, Pn. Sharifah, Mr. Bob and all the members of laboratory technicians in Golden Clay Sdn. Bhd., and all the members of laboratory technicians in Polymer Department for their guidance, supports and suggestions. Besides that, thanks to Nur Erma Shuhadah and all my friends who helped me throughout the period of my study.

The most special thank goes to my beloved family for the guidance, support, love and enthusiasm. Thank you for not giving up on me from the day I was born till now and forever.

ABSTRACT

Rubber waste is one of waste materials listed in the 'First Schedule' of scheduled waste list in Environmental Quality Regulation 2005 (Scheduled Waste). Scheduled wastes are normally associated with tight management and high cost of disposal. Conventionally, they are incinerated in combustion system with gases effluent treatment system. This research was aimed to investigate the effects of adding nitrile rubber (NBR) waste on the mechanical properties and thermal conductivity of clay bricks. For this investigation, mechanical tests; compression strength test and water absorption test were carried out on the samples of clay bricks impregnated with NBR waste. Samples used in this research were produced by compacting and extruding the mixture into the required size before being fired in an oven at 1060°C for ten hours.1.5 pphr of NBR waste was introduced into the standard mixture of clay bricks. Sodium silicate was used as stabilizer in both mixtures. It was observed that NBR waste-clay bricks performed higher percentage of water absorption while showed slight lower compressive strength than the standard bricks. NBR waste was found to improve the insulation property of clay bricks.

ABSTRAK

Sisa getah merupakan salah satu bahan sisa yang tersenarai dalam ‘Jadual Pertama’ pada Undang-undang Qualiti Alam Sekitar 2005 (Sisa Terjadual). Sisa terjadual kebiasaannya diselenggara dengan teliti dan perbelanjaan yang tinggi untuk tujuan perlupusan. Kaedah perlupusan sedia ada biasanya menggunakan insinerator dengan sistem pembakaran dan sistem perawatan gas yang terbebas. Kajian ini dilaksanakan dengan tujuan untuk mengkaji kesan penambahan sisa getah nitril (NBR) terhadap sifat mekanikaldan kekonduksian suhu bagi batu bata. Bagi kajian ini, ujian makanikal; ujian kekuatan mampatan dan ujian penyerapan air telah dijalankan terhadap sampel batu bata yang dihasilkan dengan penambahan sisa NBR. Sampel yang digunakan dalan kajian ini dihasilkan secara pemadatan dan penyemperitan adunan kepada saiz yang ditentukan sebelum dibakar di dalam oven pada suhu 1060°C selama sepuluh jam. 1.5 pphr sisa NBR ditambahkan dalam adunan piawai bagi batu bata. Sodium silikat digunakan sebagai penstabil dalam kedua-dua adunan. Pemerhatian yang dijalankan mendapati bahawa batu bata bersisa NBR menunjukkan penyerapan air yang lebih tinggi disamping sedikit pengurangan kekuatan mampatan berbanding batu bata piawai. Sisa NBR dikenal pasti dapat memperbaiki sifat penebatan batu bata.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SIMBOLS

A	-	Area, m^2
L	-	Length, m
T	-	Temperature
Qcond	-	Heat conduction
k	-	Thermal conductivity coefficient, W/(m.K)
ΔT	-	Temperature differential across layer
Δx	-	Thickness of layer
m	-	Mass, kg
Cp	-	Heat capacity, J/kg.K

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Today's construction industry had shown a lot of improvements to the materials. New technologies are applied to develop better construction material. Clay has been consumed in the area for bricks, pipes and roofs. Clay bricks comprise earth as the main part. Over thousands of years, clay bricks have been used in construction area as the resources are available, cheap and environmentally friendly. These are the reasons of using local resources to construct clay bricks to be used in this study.

Through thousands of years, clay has been used as one major resource for potential building materials around the world. The use of earth as a building material dates back to at least the Ubaid period in ancient Mesopotamia (5000-4000 B.C.). Earth basic construction materials have been gone through major improvement seen it's been invented. The earthen structure had changed from the traditional form of mud bricks to the machine produced fired clay bricks, from handmade construction method to extrusion method and from non-uniform dimensions to uniform standard shape and dimension. Engineers always play their roles to do more modification and improvement to the bricks properties in order to give better living condition.

Clay bricks manufactured from earth or clay as the major ingredients undergo some main specification and requirements for compressive strength, water absorption and soluble salt content for use in walling. These properties are identified to influence the quality of the clay bricks and classified under the BS3921:1985.

However, only compressive strength, water absorption and together with thermal insulation properties covered and discussed through this research. For all type of earth construction, the important properties to be considered for improvement are the water absorption and the compressive strength where most recent studies of bricks have been done. The compressive strength is an indication of durability while water absorption is a measure of porosity of the bricks. Both properties can put the bricks into certain grades which determine the value of the bricks. Basically, the aim of the research is to introduce synthetic rubber waste in the clay bricks in a way of minimizing synthetic rubber waste accumulation as suggested by Ministry of Environment through the 'Zero Emission' concept. Thermal conduction properties will be apart of the research as rubber is expected to decrease the thermal conductivity coefficient of the bricks. Therefore, this research was conducted to study the effect of synthetic rubber wastes influent the compressive strength, water absorption and thermal insulation properties of the clay bricks compared to the standard solid clay bricks.

1.1.1 Compressive Strength

Compressive strength describes how far bricks can withstand an amount of load. It determines the maximum value of load before the bricks meet failure or crush. According to Binici *et al.* (2005), bricks with higher compressive strength give result of reduction to the thickness of the outer load bearing walls. Basically, all studies on bricks will relate to compressive strength properties as it is a very important requirement. This research was concentrate to the effects of synthetic rubber waste to the clay bricks properties which compressive strength was taken into account.

1.1.2 Water Absorption

Water absorption of bricks can be defined as the ability of a certain numbers of bricks absorbs some amount of water. It explains how the bricks or bricks as in use as wall, can stand through weather especially rains and flood. Walls are normally built with bricks and coated with a layer of cement that can be used as a barrier as they give resistance to water from the outside of a building to absorb through during flood. This behaviour is strictly influent by the water absorption properties of the bricks used in the wall. Basically, the ingredients used to construct the bricks effluent the water absorption properties of the bricks.

1.1.3 Soluble Salt Content

Clay bricks can be classified into two major categories either low or normal based on the percentage by mass of soluble salt content. For low category clay bricks, the content of magnesium, sodium and potassium should not exceed than 0.030% while the content of sulphate is less than 0.50% by mass. The normal category of clay bricks should not content sum of magnesium, sodium and potassium exceed than 0.25% by mass and the sulphate content should be less than 1.6%.

1.1.4 Thermal

Thermal property is not currently listed in the requirement stated by BS3921. However, the energy crisis experienced in the past have shifted the focus of the economical gain to energy saving. Insulating buildings elements such as walls, roofs and doors, is an important matter for reducing the rate of heat loss in the houses. Binici *et al.*(2005) through their study, reported that fibre reinforce mud bricks house determine to be 56.3% cooler than the concrete bricks house in the summer and 41.5% warmer in the winter. Therefore, as synthetic rubber waste introduced to be

the issue of this research, it brings up the thermal insulation property along into accounts.

Kreith and S. Bohn (2001) had listed three types of heat insulation materials:

a) Fibrous

Fibrous material consist of small diameter particles of filaments of low density that can be poured into gap as 'loose fill' or formed into boards, batts, or blankets. Fibrous materials have high porosity (up to 90%). Mineral wool is common fibrous material for applications at temperatures below 700°C, and fiberglass is often used for temperature 200°C.

b) Cellular

Cellular insulations are closed or open cell materials that are usually in the form of extended flexible or rigid boards. They can, however, also be foamed or sprayed in place to achieve desired geometrical shapes. Cellular insulation has the advantage of low density, low heat capacity, and relatively good compressive strength.

c) Granular

Granular insulation consists of small flakes or particles of inorganic materials bonded into preformed shapes or used as powders.

1.2 Waste As Concrete Aggregate

The globalization, rapid population and industrial development throughout the world, have led to the generation of a huge quantity of industrial waste during the last few decades. Millions and millions tonnes of waste have accumulated at different sites, and the fact that it is increasing at an alarming rate has prompted governments and researchers holding hands to investigate solutions with technological options. It is estimated by the Local Government Department, Ministry of Housing and Local

Government in 2003 that about 17,000 of waste generated in Peninsular Malaysia with average per capita generation of waste 0.85 kg/cap/day.

Rubber industry in Malaysia has shown that Malaysia's rubber production increased by 188,946 tones or 19.2% on 1,174,593 tones in 2004 as Malaysia is the fourth biggest producer of rubber in the world. A huge amount of rubber consumption recorded as in 2004 came up with 500,230 tones which comprised 407,710 tones (81.5%) natural rubber, 82,805 tones of synthetic rubber and 9,715 tones of reclaimed rubber. Malaysian rubber product industry consist of more than 344 companies producing latex products, tires, industrial and general rubber products, footwear and components. These materials contribute to the increasing number of disposal sites as they are undegradable or took years to be degradated. Table 1.1 shows the composition of waste according to Ministry of Housing and Local Government in 2003 where rubber waste is listed but the amount is small compared to the other sources. However, rubber waste would be produced and increased along with the increasing of rubber products manufactured by the companies.

Rubber wastes, in any kind of form generated from industries are categorised as 'scheduled waste' under the Environmental Quality (Scheduled Waste) Regulation 2005. Thus, they should be precisely managed and handled with the guidelines of the regulations. The generators have to take full responsibility from the waste being generated till the waste disposed. Most of the rubber wastes were sent to Kualiti Alam, an authorised company responsible to dispose scheduled waste. Rubber waste from generators accumulated at the disposal sites and required high amount of cost to go through the disposing process. Therefore, this research investigated the ability of synthetic rubber waste as concrete aggregate in clay bricks in terms of the water absorption, compressive strength and the thermal conduction properties as a new approach to a better environment.

REFERENCES

Acost,.A., Iglesias I., Aineto, M., and Rincon, J. M. (2002), Utilization of IGCC Slag and Clay Striles In Soft Mud Bricks (By Pressing) For Use In Building Bricks Manufacturing, *Waste Management*, 22(2002): 887-891

Klundert, A. and Rehan, A.(1994), Rubber Recycling (2002), *Affordable Water Supply And Sanitation*, Colombo, 20th WEDC Conference: 169-171

Ngowi, A. B. (1997), Improving The Traditional Earth Construction: A Case Study of Bostwana, *Construction and Building Materials*, 11(1): 1-7

Binici, H., Orhan, A., Mehmet Nuri, B., Erhan, A., and Selim, K. (2005), Thermal Isolation And Mechanical Properties of Fibre Reinforced Mud Bricks As Wall Materials, *Construction and Building Materials*, 21(2007): 901-906

British Standard Institute (1985), *Specification of clay bricks*, London, BS 3921:1985

Cengel, Y.A. and Boles, M.A.(1998), Thermodynamics An Engineering Approach, 3rd edition, USA, Mc Graw Hill

Department of Environment (2005), *Environmental Quality (Scheduled Wastes) Regulation 2005*, Malaysia

Guerrero, I.C, Ocana, S. Martin and Requena I.G. (2004), Thermal-physical Aspects of Materials Used For The Construction of Rural Buildings In Soria(Spain), *Construction and Building Material*, 19(2005):197-211

Holman, J.P. (1972), Heat Transfer, USA, Mc Graw Hill

Lynch, G.C.J. (1993), Bricks: Properties And Classifications, *Structural Survey,* 12(4): 15-20

Local Government Department (2003), Overview of Solid Waste Management In Malaysia, Ministry of Housing and Local Government, Malaysia

Kreith, F. and Bohn M.S.(2001), Principles of Heat Transfer, 6th edition, USA, Brooks/Cole

Mc Dowall, I. C.(1973), Manufacture of Clay Bricks, *Notes on the Sciene Of Building,* Brisbane, Academy Press Pty Ltd

Sebastian, P.J, Custodio-Gracia, E., Campos-Alvarez, J., Trevinno-Palacios, C.G., Zarate, E.A., Cordova, Q.A. and O-leon, H. (2004), Solar Condition Heat Transfer In Fired Clay Bricks, Mexico: Elsevier Ltd

Table 1.1: Waste composition in Kuala Lumpur

No.	Source Of Waste	Residential	Commercial	Institutional
1	Food waste & organic	63.1	76.8	40.6
2	Mix paper	6.7	7.6	16
3	Mix plastics	14.3	9	17.2
4	Textiles	1.7	0.5	0.7
5	Rubber & leather	0.6	0.3	0.1
6	Yard waste	6.3	0.9	18.4
7	Glass	2.1	0.9	1.5
8	Ferrous	2.3	1.4	2.8
9	Aluminum	0.1	0.1	1.3
10	Others	2.8	2.5	1.4
	Total (2,3,7,8,9)	25.5	19	38.8

Source from: Ministry of Housing and Local Government, 2003

1.2.1 Synthetic Rubber Waste

Synthetic rubber waste consist of rubber glove waste, both rejects from manufacturers as well as soiled ones from factories, scraps from rubber product manufacturers, rubber treads, rubber fleshing (scraps from tyre manufacturers), nylon-belted tyres, tubes and rubber foam (from cushions and mattresses). It is expected that the consumption of synthetic keep increasing because the higher usage of nitrile rubber (NBR) for manufacture of nitrile glove. As the result, the synthetic rubber waste would be increase. These wastes contribute to the increasing number of disposal sites as they are undegradable or took years to be degradated. Currently, the most environmental friendly way to overcome the indestructible rubber waste is by recycling. The reclaimed rubber is used to make a wide range of rubber products such as tyre treads and inner tubes, carpet under layer, hoses and beltings, rubber mats, agricultural wheel, shoe soles, flooring for playgrounds and indoor recreational rooms, sealants and adhesives. Reclaimed rubber powder is sold to India for use as

road surfacing. This research investigated another alternative way to minimizing the synthetic rubber waste.

1.3 Problem Statements

Due to the industrial development and modernization, the synthetic rubber would have higher demand from the rubber product manufacturer. However, the increasing cost to produce synthetic rubber raise up the increasing cost problem for the production of rubber products. Currently, the industries have to pay for the rubber waste disposal purpose as it can not be dumb directly to drains or illegal waste disposal sites. With another alternative way to handle the waste, they can afford some benefits which can decrease their production cost. The alternative way would be discussed is introducing the synthetic rubber waste as component in clay bricks construction. The effects on water absorption and compressive strength will be investigated through the water absorption and compressive strength tests as described in BS3921. Together with that, a thermal insulation test will be carried over as expected that the newly constructed clay bricks can improve the quality based on the thermal insulation properties. These three properties for the clay bricks with synthetic rubber waste should be compared to the standard solid clay bricks.

1.4 Objectives

Improvements or modification of clay bricks construction are more subjected to water absorption and compressive strength requirement that limits the amount of water which can be absorbed through the bricks and increase the ability to carry load. Moreover, improvement on the thermal insulation properties can give some more value to the bricks. The research on the newly designed clay bricks with synthetic rubber waste would be done with the following objectives:

a. To design a method to construct clay bricks with synthetic rubber waste.
b. To investigate the effects of the synthetic rubber waste on the water absorption and compressive strength of clay bricks through water absorption and compressive strength tests as describe in BS3921.
c. To study the effects on thermal insulation property of the newly designed clay bricks with synthetic rubber waste by the thermal conductivity test.

1.5 Scopes Of Study

i)Study of clay bricks preparation consist of:

a. Formulation of grinded synthetic rubber and other ingredients to be used in making clay bricks.
b. Methods of preparing standard clay bricks and clay bricks with synthetic rubber waste.
c. Preparation of clay bricks to used in the water absorption, compressive strength and thermal insulation tests.

ii)Study of water absorption, compressive strength and thermal insulation properties consist of:

a. Effect of synthetic rubber in clay bricks on water absorption through water absorption test with comparison to the non-rubber content clay bricks.
b. Effect of synthetic rubber in clay bricks on compressive strength through compressive strength test with comparison to the non-rubber content clay bricks.
c. Effect of synthetic rubber in clay bricks on thermal insulation through thermal insulation test with comparison to the non-rubber content clay bricks.

iii)Tests related to study consist of:

a. Water absorption test as describe in BS3921 comprises of 10 samples for clay bricks with synthetic rubber and standard clay bricks respectively.
b. Compressive strength test as describe in BS3921 comprises of 10 samples for clay bricks with synthetic rubber filler and traditionally constructed clay bricks respectively.
c. Thermal insulation test referring to the thermal insulation test done by Binici *et al.*(2005).