MECHANICAL PROPERTIES OF CONCRETE WITH 5 AND 10 PERCENT PALM OIL BOILER STONE (POBS) AS FINE AGGREGATE REPLACEMENT

LEE CHOOI YING

A thesis submitted in partial fulfillment of the requirements for the award of degree of Bachelor of Civil Engineering.

Faculty of Civil Engineering and Earth Resources
Universiti Malaysia Pahang

NOVEMBER 2010

ABSTRACT

Large quantities of wastes are produced from agro-based industries every year. With the enormous increase in the quantity of waste needing disposal and acute shortage of dumping sites, the use of these waste materials in construction industry would contribute towards a cleaner environment. On this matter, a study has been conducted to look into the performance of Palm Oil Boiler Stone (POBS) as fine aggregate material replacement in concrete. This study presents the results of an experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was partially replaced with POBS. Fine aggregate was replaced with 5% and 10% of POBS by weight. Tests were performed for properties of fresh concrete. Splitting tensile strength and flexural strength were determined at 7, 14 and 28 days. The splitting tensile strength and flexural strength of specimens with 10% POBS content were 15% and 33% respectively, higher than those of the control specimen at 28 days. Test results indicate significant improvement in the strength properties of plain concrete by inclusion of POBS as partially replacement of fine aggregates.

ABSTRAK

Begitu besar jumlahnya sisa-sisa yang dihasilkan dari industri agro tiap-tiap tahun. Dengan peningkatan kuantiti sisa yang diperlukan untuk dibuang dan kekurangan tempat pembuangan, penggunaan bahan-bahan sisa dalam industry pembinaan akan memberikan sumbangan terhadap persekitaran yang bersih. Dalam hal ini, sebuah kajian telah dilakukan untuk melihat prestasi Palm Oil Boiler Stone (POBS) sebagai bahan pengganti agregat halus dalam konkrit. Kajian ini menyajikan hasil penyelidikan eksperimen dilakukan untuk melihat sifat mekanik daripada campuran konkrit dimana sebahagian agregat halus (pasir) diganti dengan POBS. Agregat halus diganti dengan 5% dan 10% POBS daripada jumlah berat agregat halus yang diperlukan. Ujian ini dijalankan untuk sifat konkrit segar. Kekuatan tarikan dan kekuatan lenturan ditentukan pada hari ke 7, 14 dan 28. Dengan gantian 10% POBS, kekuatan tarikan dan kekuatan lenturan bagi ujian spesimen adalah 15% dan 33%. Keputusan ujian ini menunjukkan bahawa penggantian POBS dalam agregat halus adalah lebih tinggi berbanding dengan spesimen kawalan pada hari ke 28. Penggantian POBS dalam agregat halus memainkan peranan penting dalam meningkatkan kekuatan untuk konkrit.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE PAGE	**i**
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGEMENT	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	TABLE OF CONTENTS	**vii**
	LIST OF TABLES	**x**
	LIST OF FIGURES	**xi**
	LIST OF SYMBOLS	**xiii**
	LIST OF APPENDICES	**xiv**
1	**INTRODUCTION**	
	1.1 Background of Study	1
	1.2 Problem Statement	2
	1.3 Objective of Study	3
	1.4 Scope of Study	4

2	**LITERATURE REVIEW**	
	2.1 Introduction	6
	2.2 Concrete	6
	2.2.1 Cement	8
	2.2.2 Water	8
	2.2.3 Conventional Concrete Aggregate	9
	2.2.4 Types of Sand Replacement Material	9
	2.2.4.1 Recycled Aggregate	9
	2.2.4.2 Fly Ash	10
	2.2.4.3 Quarry Dust	11
	2.2.5 Palm Oil Boiler Stone (POBS)	11
	2.3 Curing	15
	2.4 Flexural Strength of Concrete	15
	2.5 Splitting Tensile Strength of Concrete	16
	2.6 Factor Influencing Strength	17
	2.6.1 Water/cement (w/c) Ratio	17
	2.6.2 Cement	18
	2.6.3 Aggregate	19
	2.6.4 Compacting	20
	2.6.5 Curing	21
	2.7 Review of Relevant Research	22
3	**METHODOLOGY**	
	3.1 Introduction	26
	3.2 Materials	28
	3.2.1 Cement	28
	3.2.2 Water	28
	3.2.3 Fine Aggregate (sand)	29
	3.2.4 Coarse Aggregate	29
	3.2.5 Palm Oil Boiler Stone	30

	3.3	Preparation of Specimen	31
		3.3.1 Mixture Process	31
		3.3.2 Casting	32
		3.3.3 Curing	33
		3.3.4 Specimen Testing	34
		3.3.4.1 Splitting Tensile Strength Test	34
		3.3.4.2 Flexural Strength Test	37
4	**RESULT AND DISCUSSION**		
	4.1	Introduction	39
	4.2	Effect of POBS to Splitting Tensile Strength	40
		4.2.1 Replacement of 5% POBS	41
		4.2.2 Replacement of 10% POBS	43
		4.2.3 Splitting Tensile Strength Development for All Mixes	44
	4.3	Effect of POBS to Flexural Strength	46
		4.3.1 Replacement of 5% POBS	47
		4.3.2 Replacement of 10% POBS	49
		4.3.3 Flexural Strength Development for All Mixes	50
	4.4	Mathematic Relationship between Compressive, Splitting Tensile and Flexural Strength	51
5	**CONCLUSION AND RECOMMEDATION**		
	5.1	Conclusion	58
	5.2	Recommendation	60
	REFERENCES		61
	APPENDICES A – B		65-66

LIST OF TABLE

TABLE NO.	TITLE	PAGE
2.1	Typical properties of normal strength Portland cement concrete	7
3.1	Details of test specimens	32
4.1	Splitting test result for different mix ratios	40
4.2	Flexural test result for different mix ratios	46

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Recycled aggregates	10
2.2	Fly ash	10
2.3	Quarry dust	11
2.4	Water Tube Boiler	12
2.5	POBS produce from the boiler	12
2.6	Shell and fibres from palm oil before burning	13
2.7	Palm oil boiler stone	13
2.8	Palm oil boiler stone (POBS) production process at the ash conveyor	14
2.9	Curing process for concrete after remove from the mould	15
2.10	Schematic represent of two fresh cement pastes having water cement mass ratio of 0.65 and 0.25	18
3.1	Procedure chart of the study	27
3.2	River sand as fine aggregate in concrete mix	29
3.3	Coarse aggregate	30
3.4	Palm oil boiler stone before crushed	31
3.5	Water curing for the concrete specimens	33
3.6	Specimen undergo splitting tensile strength test	35
3.7	Cylinder concrete control samples at age of 7 days	35
3.8	Cylinder concrete samples with 5% replacement of POBS at age of 7 days	36
3.9	Cylinder concrete sample with 10% replacement of POBS at age of 7 days	36
3.10	Flexural strength testing machine	37

3.11	Prism concrete specimen after testing	38
4.1	Splitting Tensile Strength versus Age	41
4.2	Splitting tensile strength development of concrete (5% of POB)	42
4.3	Splitting tensile strength development of concrete (10% of POBS)	44
4.4	Splitting tensile strength development of concrete for various mixes	45
4.5	Flexural strength versus age	47
4.6	Flexural strength development of concrete (5% of POBS)	48
4.7	Flexural strength development of concrete (10% of POBS)	49
4.8	Flexural strength development f concrete for various mix	51
4.9	Relationship between compressive strength and splitting tensile strength (control)	53
4.10	Relationship between compressive strength and splitting tensile strength (5% of POBS)	54
4.11	Relationship between compressive strength and splitting tensile strength (10% of POBS)	54
4.12	Relationship between compressive strength and splitting tensile strength (combined all)	55
4.13	Relationship between compressive strength and flexural strength (control)	55
4.14	Relationship between compressive strength and flexural strength (5% of POBS)	56
4.15	Relationship between compressive strength and flexural strength (10% of POBS)	56
4.16	Relationship between compressive strength and flexural strength (combined all)	57

LIST OF SYMBOLS

ACI	-	American Concrete Institution
ASR	-	Alkali-Silica Reaction
BS	-	British Standard
DOE	-	Department of Environment
°F	-	Fahrenheit
HPC	-	High Performance Concrete
kg/m^3	-	Kilogram per unit volume
m	-	meter
mm	-	millimeter
MPa	-	Mega Pascal
MR	-	Modulus of rupture
N/mm^2	-	Newton per millimeter square
POBS	-	Palm Oil Boiler Stone
w/c	-	water/cement
%	-	percent

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Results of splitting tensile test	65
B	Results of flexural test	66

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is one of the oldest manufactured construction materials that had been used in construction of various types of structures globally until today. Most of the construction project used the conventional concrete mix design which the materials included cement, water, fine aggregates, coarse aggregates and admixture if needed.

Fine aggregate is one of the essential components of concrete. Natural river sand is the most commonly used for fine aggregate (Felixkala et.al, 2010). The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand of the natural river sand is quite high in developed countries owing to infrastructural growth.

With the rapid expansion of the construction activities for housing, buildings and other structures, the demand of the construction materials especially the concrete which is kept rising. Due to high demanding of the concrete, shortage in concrete will be occurred in the future.

In order to solve the problem of the extensive use of the river sand for concrete and the waste disposal problems, an alternative method need to be done and study to replace the material used for conventional concrete mix in building material. In the present work, it is aimed at developing a new building material from the agricultural waste as a replacement material of fine aggregate in concrete. By using the agricultural waste namely palm oil boiler stone (POBS) produce from the oil palm fruit, totally replacing the fine aggregate in concrete, a concrete has been developed which possesses the potential of being used in building construction.

1.2 Problem Statement

Malaysia is one of the countries that possess a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. This growth is jeopardized by the lack of natural resources especially the sand that are available for concrete mix. Natural resources are depleting at the same time the generated wastes from the industry are increasing substantially.

Since there is acute shortage of sand, the concrete price will be raise up. Hence, it will increase the construction cost, thereby translating increase in house prices. If the sand shortage persisted, construction costs would go up. This will inevitably put inflationary pressure on the economy as construction materials become more expensive.

Solid waste is one of the three major environment problems in Malaysia. It plays a significant role in the ability of nature to sustain life within its capacity. Currently, over 23000 tonnes of waste is produced each day in Malaysia. However, this amount is expected to rise to 30000 tonnes by the year 2020. The amount of waste generated continues to increase due to the increasing population and development, and only less than 5% of the waste is being recycled or being use (Anon, 2010).

Meanwhile, Malaysia is the world's leading producer and exporter of palm oil and palm oil product with a reputation for quality and consistency. To date, there are more than two hundred palm oil mill plants operating in the country that are self sufficient industry as far as energy utilization is concerned. Due to that, the wastes from the palm oil industries increase enormously. The waste from the palm mill include empty fruit bunches, shells, fibres, fuel ashes and boiler stones.

The volumes of the wastes from this industry generally rise up. Large amount of untreated waste from palm oil industrial sectors contaminate land, water and air by means of leaching, dusting and volatilization. Improper management for those solid wastes such as lack of the disposal place, poor waste management system, and inefficient storage and collection systems will cause the environment pollution problems occur.

Thus, it is necessary to develop an alternative material in concrete mix which is fully utilizing the wastes as well as possible which can use in construction materials to forbid the production of the wastes keep increase. In order to solve this problem, POBS is highly recommended as partially sand replacement in concrete mix due to its high quantities production. POBS is a residue which from the burning of the shells and fibres of the palm oil in water boiler.

1.3 Objective of Study

This study is carried out to accomplish some predefined objectives. These objectives are:

1. To evaluate the mechanical properties of concrete added with 5% and 10% palm oil boiler stone (POBS).

2. To compare the strength performance of POBS with conventional concrete mix.

3. To investigate the effect of POBS in concrete.

1.4 Scope of Study

This study is based on specific scope in conducting mechanical test on concrete. The limits of this study are as follow:

i. Mechanical Test

This study is to investigate mechanical properties of hardened concrete partially added with POBS by followed flexural strength test and splitting tensile test according to British Standard.

ii. Materials properties

Design strength estimated to be obtained is 30 N/mm^2 using Ordinary Portland Cement, coarse aggregate, fine aggregate and POBS as replacement of 5% and 10% of fine aggregate.

iii. Specimens

For the flexural strength test, the 100 mm x 100 mm x 500 mm of prisms is needed to be prepared for the testing. Also, 150 mm x 300 mm of cylinder concrete specimen is needed to undergo the splitting tensile strength test. The ages for the both testing are on the 7, 14 and 28 days after the water curing process. The total number of the prisms and cylinders concrete that needed in this study is 54 of samples which are 27 for each type.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The mechanical properties of the concrete which is included the flexural test and splitting test will be deal in this chapter. Large number of researcher conducted since last century has provided a wealth of information on the composition and characteristic on properties of concrete by using other sand replacement materials. However, published literatures on the performance of concrete containing palm oil boiler (POBS) stone have not yet been found.

2.2 Concrete

Concrete has been the construction material used in the largest quantity for several decades. It is absolutely indispensable in modern society's fascination with new roads, buildings and other constructions. Besides that, it can be manufactured to an inexhaustible range of specifications to suit all applications. This is possible by using different proportions of the natural ingredients or by the use of different materials.

Concrete is made by mixing cement, water, coarse and fine aggregates or admixtures (if required).. Cement is the fixture that binds the ingredients together, water gives the concrete viscosity in order to be molded and react with the ingredients, and the aggregates are what adds bulk to the concrete, but are not involved in the chemical processes.

Concrete has relatively high compressive strength, but significantly lower tensile strength (about 10% of the compressive strength) (Anon., 2006). Table 2.1 shows the typical properties of normal strength Portland cement concrete.

Table 2.1: Typical properties of normal strength Portland cement concrete.

Characteristic:	
Density	2240-2400kg/m^3
Compressive strength	20-40 MPa
Flexural strength	3-5 MPa
Tensile strength	2-5 MPa
Modulus of elasticity	14000-41000 MPa
Permeability	1 x10^{-10} cm/sec
Coefficient of thermal expansion	10^{-5}°C^{-1}
Drying shrinkage	4-8 x 10^{-4}
Drying shrinkage or reinforced concrete	2-3 x 10^{-4}
Poisson's ratio	0.20-0.21
Shear stress	6000-17000MPa
Specific heat capacity	0.75 KJ/Kg K

2.2.1 Cement

Portland cement, the basic ingredient of concrete, is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients to which gypsum is added in the final grinding process to regulate the setting time of the concrete. When the cement is mixed with water, it will form a paste. This pastes act like glue and holds or bond the aggregates together.

2.2.2 Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fill voids within it, and allows it to flow more freely. Less water in the cement paste will yield a stronger, more durable concrete; more water will give a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, which is often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles, and other component of the concrete, to form a solid mass.

A high strength concrete requires being as free from voids as possible. If water in excess of the amount required for the chemical reaction with the cement is present in the mix, this water remains in a free state and the concrete sets around the drops of water. Such particles of water form pores and voids in the concrete, resulting in weakness and permeability.

2.2.3 Conventional Concrete Aggregate

Conventional concrete aggregate consists of fine aggregate and various sizes and shape of gravel or stones. Fine aggregate is made up of particles which can pass through a 3/8 in sieve; coarse aggregates are larger than 3/8 inch in size.

Aggregates should be clean, hard, and well graded, without natural cleavage planes such as those occurs in slate or shale. The quality of aggregates is very important since they made up about 60 to 75% of the volume of the concrete; it is impossible to make good concrete with poor aggregates.

The grading of both fine and coarse aggregate is very significant because having a full range of sizes reduces the amount of cement paste needed. Well-graded aggregates tend to make the mix more workable as well.

2.2.4 Types of Sand Replacement Material

The main sand replacement materials in use world-wide included recycle aggregate, fly ash, quarry dust and etc.

2.2.4.1 Recycled Aggregate

Recycled aggregate is the aggregate arising from construction and demolition (concrete, bricks, and tiles), highway maintenance (asphalt planning), excavation and utility operations.

Recycled concrete aggregates (RCA) contain not only the original aggregates, but also hydrated cement paste. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity of RCA leads to a higher absorption. As replacement amounts increase drying shrinkage and creep will increase and tensile strength and modulus of elasticity will decrease.

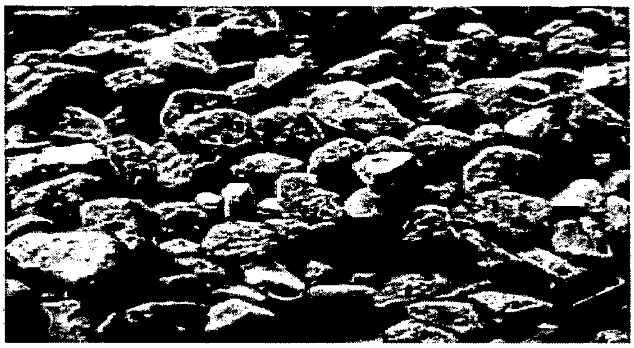

Figure 2.1: Recycled Aggregates

2.2.4.2 Fly Ash

Fly ash is the finely divided mineral residue resulting from the combustion of powdered coal in electric generating plants. Fly ash consists of inorganic, incombustible matter present in the coal that has been fused during combustion into glassy, amorphous structure. Coal can range in ash content from 2% - 30% and of this around 85% becomes fly ash. It can add to the final strength of the concrete and increase chemical resistance and durability.

Figure 2.2: Fly ash

2.2.4.3 Quarry dust

Quarry dust is obtained from a by-product from the crushing process during quarrying activities is one of those materials being studied, especially as substitute material to sand as fine aggregates. Quarry dust have been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave block (Safiuddin et al., 2001).

It was deduced that partial replacement of sand with quarry dust without the inclusion of other admixtures resulted in enhanced workability in the concrete mix, but in a reduced compressive strength and durability (Raman et al., 2003).

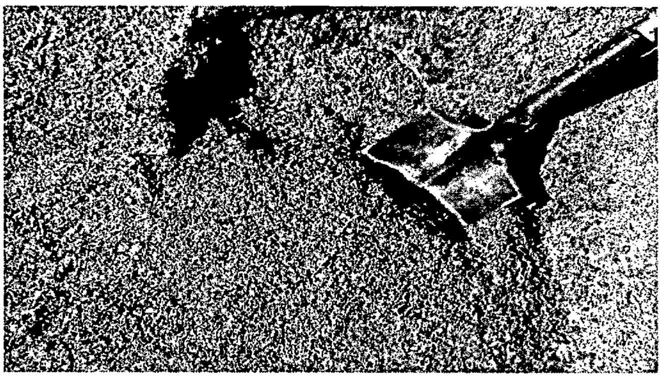

Figure 2.3: Quarry dust

2.2.5 Palm Oil Boiler Stone (POBS)

POBS is the residue produced by burning palm fiber and shell is considered to be a waste product, the disposal of which causes lot of environment problems. As a normal practice this stone is dumped into wastelands behind the mill. The palm fibre and shell obtained as waste product by the industry are generally used as a boiler fuel to produce stem for electricity generation a palm extraction process. This

POBS will be produced at least every two hours during the process of palm extraction.

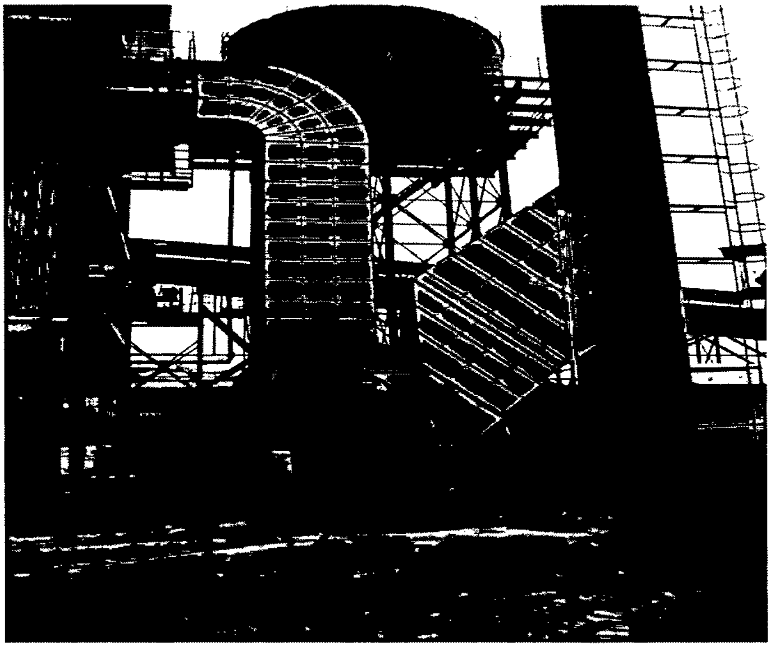

Figure 2.4: Water Tube Boiler

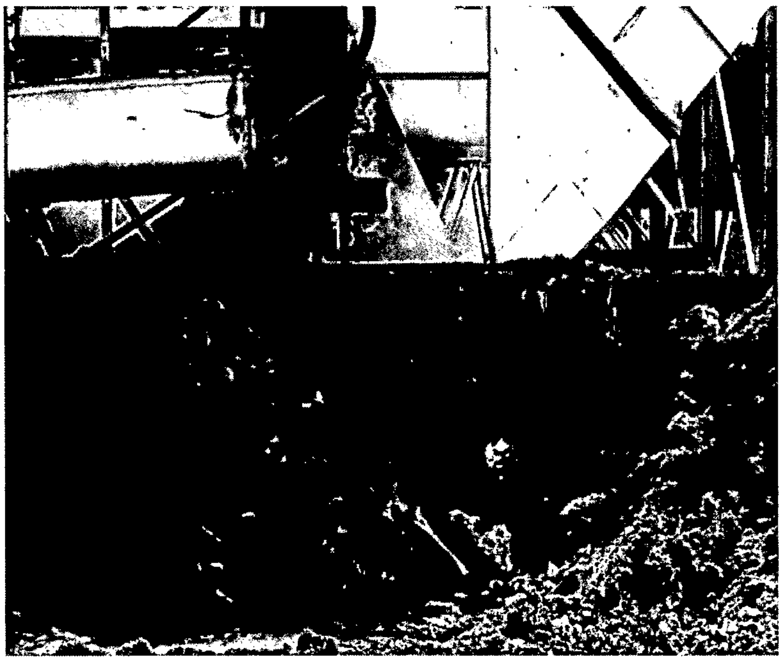

Figure 2.5: POBS produced from the boiler.

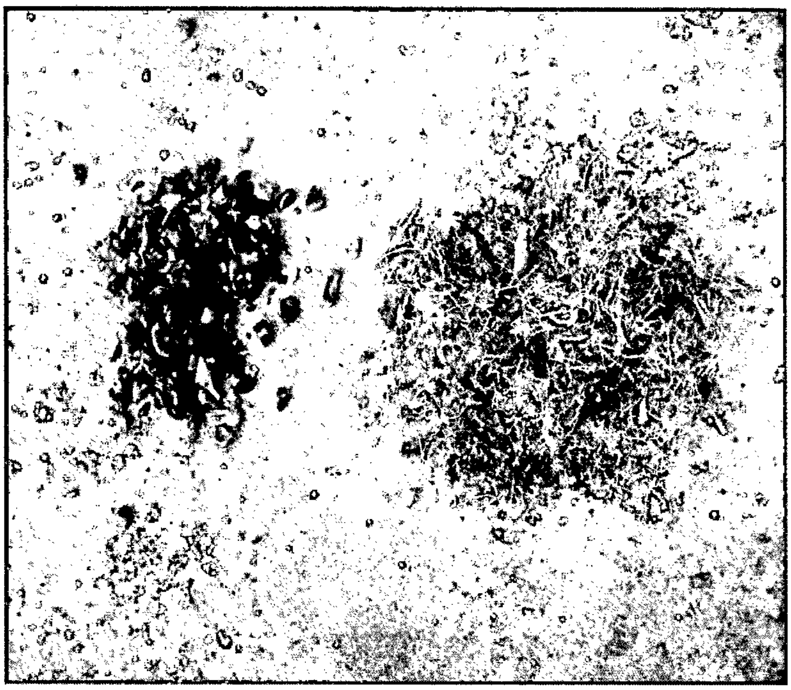

Figure 2.6: Shell and fibres from palm oil before burning.

Figure 2.7: Palm Oil Boiler Stone