

PERFORMANCE OF LIGHTWEIGHT CONCRETE USING PALM OIL
CLINKER AS COARSE AGGREGATE

AZIZAH BINTI HARON @ HASSAN

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2017

To my beloved husband,

Muhammad Nur Daud

To my lovely children,

Amir, Aqila and Aqil

To my beloved mother

Wan Roihanas Wan Ab Rahman

To my supervisor

Dr Roslli Noor Mohamed

*And last but not least, to all my friends. Thank you for all of
your opinions and supports, may Allah bless you.*

ACKNOWLEDGEMENT

With my deepest gratitude, I would like to take this opportunity to thank my supervisor, Dr. Roslli Noor Mohamed who had always been helpful in guiding me throughout the whole process of this project report writing and conducting the laboratory test. The project would be nothing without the encouragement, guidance, critics and imagination from him. Besides that, this master project makes me realized that value of management and self-independent are very important to complete a task within a specific duration.

I am also sincerely express thanks to my beloved family member who always encourage and motivate me throughout the whole journey of this project. Without encouragement and advice from them, this project would not be a success.

I would like to thanks the staffs of Structures Laboratory for their assistance in the experimental work. Their cooperation is highly appreciated.

Finally, thanks to all my colleagues who have happen to help me in carrying out this study. Although their help seems to be little, but every single help means a lot for making this study successful.

ABSTRACT

Malaysia is one of the primary producers of palm oil in Asia and it is the second largest palm oil-producing country in the world. Due to a lot of waste from palm oil mill and the construction costs are rising, the alternative to recycle them should be taken. In this study, palm oil clinker (POC) aggregates were used as coarse aggregate replacement in lightweight concrete production. This study focused mainly on the physical properties of POC aggregate and the performance of fresh and hardened concrete mixture to identify the optimum content of replacement of POC as coarse aggregate in lightweight concrete to attain reasonable strength. The approach used in the mix design involved POC replacement of 0%, 33%, 67% and 100% of the content of coarse aggregates. Based on sieve analysis, the coarse aggregate was well graded. It was found that, as the percentage of replacement of POC increased, the workability of the fresh concrete and density of hardened concrete was decreased. This was due to the physical properties of POC aggregate which is porous, low specific gravity, low bulk density and high water absorption. The maximum compressive strength of the sample was 25.24 MPa at 7 days and 27.89 MPa at 28 days while splitting tensile strength and flexural strength achieved 5.12 MPa and 3.98 MPa. As obtained from experiment, the optimum content of replacement of POC as coarse aggregate to achieve lightweight concrete was about 67% since the results from mechanical properties test complied with the requirement of structural lightweight concrete as stipulated in British Standard, BS 8110 : Part 2 : 1985, RILEM's functional classification of lightweight concrete, ASTM C330 and other previous studies. Considering POC into the lightweight concrete structure, it is possible to reduce the dead load thus saving the construction cost by reducing the size of columns, footings and other load bearing elements of a concrete structure.

ABSTRAK

Malaysia merupakan salah satu daripada pengeluar utama minyak sawit di Asia dan ia adalah negara pengeluar minyak sawit kedua terbesar di dunia. Oleh kerana banyak sisa dari kilang minyak sawit dan kos pembinaan yang semakin meningkat, alternatif untuk kitar semula perlu diambil. Dalam kajian ini, agregat daripada klinker minyak sawit (POC) telah digunakan untuk menggantikan agregat kasar dalam penghasilan konkrit ringan. Kajian ini menfokuskan kepada sifat-sifat fizikal agregat POC dan prestasi konkrit segar dan keras untuk mengenal pasti kandungan optimum penggantian POC sebagai agregat kasar dalam konkrit ringan untuk mencapai kekuatan yang munasabah. Pendekatan yang digunakan dalam reka bentuk campuran dalam penggantian POC adalah sebanyak 0%, 33%, 67% dan 100% daripada kandungan agregat kasar. Berdasarkan analisis ayak, agregat dikategorikan dalam penggredan yang baik. Didapati bahawa, semakin meningkat peratusan penggantian POC, keboleherjaan konkrit segar dan ketumpatan konkrit keras telah menurun. Ini disebabkan oleh sifat-sifat fizikal agregat POC yang berliang, graviti tentu yang rendah, ketumpatan pukal yang rendah dan penyerapan air yang tinggi. Kekuatan mampatan maksimum sampel adalah 25.24 MPa pada hari ke 7 dan 27.89 MPa pada hari ke 28 manakala kekuatan tegangan dan kekuatan lenturan mencapai 5.12 MPa dan 3.98 MPa. Kandungan optimum penggantian POC sebagai agregat kasar untuk mencapai konkrit ringan adalah kira-kira 67% di mana keputusan daripada ujian sifat mekanikal mematuhi keperluan struktur konkrit ringan seperti yang ditetapkan dalam Standard British, BS 8110: Part 2: 1985, klasifikasi konkrit ringan daripada RILEM, ASTM C330 dan kajian lain sebelumnya. Memandangkan penggantian POC diklasifikasikan sebagai struktur konkrit ringan, ianya boleh mengurangkan beban mati sekali gus menjimatkan kos pembinaan dengan mengurangkan saiz tiang, papak dan unsur-unsur galas beban lain bagi struktur konkrit.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xii
	LIST OF SYMBOLS	xiv
	LIST OF APPENDICES	xv
1	INTRODUCTION	1
	1.1 Background Of Study	1
	1.2 Problem Statement	3
	1.3 Aims and Objective	4
	1.4 Scope Of Study	4
	1.5 Significance of Study	5
2	LITERATURE REVIEW	6
	2.1 Lightweight Concrete	6
	2.1.1 Classification of Lightweight Concrete	7
	2.1.2 Advantages And Disadvantages Of Lightweight Concrete	8

	2.1.3 Application Of Lightweight Concrete	8
2.2	Sustainable Design	10
2.3	Oil Palm Mill in Malaysia	11
2.4	Palm Oil Clinker	12
2.5	Previous Studies on Palm Oil Clinker Concrete	14
2.6	Critical Summary	17
3	RESEARCH METHODOLOGY	18
3.1	Flowchart of the Project	18
3.2	Preparation of Materials	22
	3.2.1 Cement	22
	3.2.2 Fine Aggregate	22
	3.2.3 Coarse Aggregate	23
	3.2.3.1 Crushed Granite Aggregate	23
	3.2.3.2 Palm Oil Clinker (POC)	23
	3.2.4 Water	25
	3.2.5 Superplasticizer	25
3.3	Physical Properties of POC	25
	3.3.1 Sieves Analysis	25
	3.3.2 Bulk Density	27
	3.3.3 Specific Gravity and Water Absorption Test	27
3.4	Preparation of Concrete Mix Design	28
	3.4.1 Determining the Free Water/ Cement Ratio	29
	3.4.2 Determining the Free Water Content	30
	3.4.3 Determining the Cement Content	31
	3.4.4 Determining the Total Aggregate Content	32
	3.4.5 Determining the Fine and Coarse Aggregate Content	32
3.5	Concrete Curing Method	33
3.6	Testing of Concrete	34
	3.6.1 Test on fresh concrete	35
	3.6.1.1 Slump Test	35
	3.6.2 Test on Hardened Concrete	37

	3.6.2.1 Density Analysis	37
	3.6.2.2 Compression Test	38
	3.6.2.3 Splitting Tensile Strength Test	41
	3.6.2.4 Flexural Strength Test	42
4	RESULTS AND DISCUSSION	44
	4.1 Introduction	44
	4.2 Physical Properties of POC	45
	4.2.1 Sieve Analysis	45
	4.2.2 Bulk Density	47
	4.2.3 Specific Gravity	48
	4.2.4 Water absorption	49
	4.3 Mix design	50
	4.4 Mechanical Properties of Fresh Concrete Mixture	51
	4.4.1 Slump Test	51
	4.5 Mechanical Properties of Hardened Concrete Mixture	53
	4.5.1 Density Analysis	53
	4.5.2 Compression Test	55
	4.5.3 Splitting Tensile Strength Test	58
	4.5.4 Flexural Strength Test	61
	4.6 Optimum Content to Lightweight Concrete	63
	4.7 Optimum Content of Strength – Weight Ratio	65
5	CONCLUSION AND RECOMMENDATION	69
	5.1 Conclusion	69
	5.2 Recommendation	72
	REFERENCES	73
	Appendices A	78 - 84

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Advantages and Disadvantages of Lightweight Concrete	8
2.2	Production Process of Palm Oil Clinker	12
2.3	Physical Properties of POC coarse aggregate	14
2.4	Selected mix proportion of POC concrete and its fresh and hardened properties	16
3.1	Concrete Dimension and the Number of Cast Specimen	19
3.2	Code of Practice for Testing	20
3.3	Numbers of Concrete Mix Specimens and Proportion	29
3.4	Description of Workability and Magnitude of Slump	36
3.5	Recommended Slumps for Various Types of Construction	36
4.1	Sieve Analysis Data of Crush Granite Coarse Aggregate	45
4.2	Sieve Analysis Data of POC Coarse Aggregate	46
4.3	Comparison Bulk Density Between Crushed Granite Aggregate and Palm Oil Clinker	48
4.4	Comparison Specific Gravity Between Crushed Granite Aggregate and Palm Oil Clinker	49
4.5	Comparison Water Absorption Between Crushed Granite Aggregate and Palm Oil Clinker	50
4.6	Mix Proportion of Concrete (kg/m ³)	51
4.7	Result of Slump Test	51
4.8	Result of Hardened Concrete Density of Samples at 28 days	53

4.9	Reduction of Wet and Dry Density Relative to Control Sample	55
4.10	Result of Compression Test	55
4.11	Reduction of Compressive Strength Relative to Control Sample	58
4.12	Result of Splitting Tensile Strength Test	59
4.13	Reduction of Splitting Tensile Strength Relative to Control Sample	60
4.14	Result of Flexural Strength Test	61
4.15	Reduction of Flexural Tensile Strength Relative to Control Sample	62

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	POC taken from palm oil mill	12
3.1	Methodology Flowchart	21
3.2	A large piece of POC collected from palm oil mill	24
3.3	POC aggregate size	24
3.4	Sieve Analysis Apparatus	26
3.5	Buoyancy Weighing System	28
3.6	Concrete Curing Tank	34
3.7	Slump Test	35
3.8	Measure Scale for Density Analysis	37
3.9	Concrete Cube Heat in Oven	38
3.10	Compression Test	39
3.11	Form of Satisfactory Failure of Test Specimens	40
3.12	Form of Unsatisfactory Failure of Test Specimens	40
3.13	Splitting Tensile Strength Test	41
3.14	Arrangement Loading of Beam	43
3.15	Flexural Strength Test	43
4.1	Grading of Crush Granite and Palm Oil Clinker Coarse Aggregate	47
4.2	Graph Slump (mm) vs Percentage of POC (%)	52
4.3	Concrete Density (kg/m^3) for Different Percentage of POC (%)	54
4.4	Compressive Strength (MPa) for Different Percentage of POC (%)	56

4.5	Failure Mode of Compression Test	57
4.6	Splitting Tensile Strength (MPa) for Different Percentage of POC (%)	59
4.7	Failure Mode of Splitting Tensile Strength Test	61
4.8	Flexural Strength (MPa) for Different Percentage of POC (%)	62
4.9	Failure Mode of Flexural Strength Test	63
4.10	Chart Hardened Concrete Density (kg/m^3) vs Percentage of POC (%)	64
4.11	Chart Compressive Strength (MPa) vs Percentage of POC (%)	65
4.12	Chart Splitting Tensile Strength (MPa) vs Percentage of POC (%)	66
4.13	Chart Flexural Strength (MPa) vs Percentage of POC (%)	67

LIST OF SYMBOLS

M	-	Margin
k	-	Value appropriate to the defect percentage permitted below the characteristic strength
s	-	Standard deviation
f_m	-	Target mean strength
f_c	-	Characteristic strength
W	-	Free water content
W_f	-	Free water content for uncrushed aggregate
W_c	-	Free water content for crushed aggregate
D	-	Density of fully-compacted concrete paste
C	-	Cement content
ρ	-	Density

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Concrete Mix Design	78

CHAPTER 1

INTRODUCTION

1.1 Background Of Study

The utilization of waste by-products in concrete has garnered positive outcomes over the past few decades in terms of the cost savings and conservation of natural resources (Kanadasan et al., 2015). The development of sustainability should be provided prudently due to the exponentially increasing population in the world and it implies that the degrading of natural resources rapidly might affect the future generation (Han, 2012). This has resulted in an increase in research to develop alternative feed to reduce and maintain a non-excessive usage of natural sources (Kanadasan et al., 2015). Therefore, researchers from the area of building and construction materials are trying to find an innovative solution to reduce the negative impact on the environment as well as to produce structural lightweight concrete. The idea is to use the solid waste from the agricultural and manufacture industries as coarse aggregate in lightweight aggregate concrete which will reduce the destruction of natural resources and demonstrate the proper management of solid waste (Nazmul et al., 2016).

1.5 Significance of Study

The significance of study and their performing analysis on replacement POC as coarse aggregate in concrete mix are :

- i) The waste materials from palm oil mill can be used as replacement of coarse aggregate in order to reduce the cost for the construction industry
- ii) By recycling and reuse of waste material, it can reduce the negative impact on the environmental
- iii) Guidelines for researcher to study on characteristic of POC and their mechanical properties of fresh and hardened concrete mixture

REFERENCES

- AV Product Inc.** (2008). *Anti-Vibration Rubber Mount Product*:
<http://www.avproductsinc.com>
- Cameron Motor Works.** (2005). *Engine Mount and Drive Installation*.
http://www.cameronsoftware.com/ev/EV_EngineMount.html
- Hairulizwan** (2007). *Design and development of CVT gearbox casing for automotive application*. Universiti Teknologi Malaysia. B. Eng. Unpublished
- James G. Skakoon** (2008). *The route that forces take*. Mechanical Engineering
- Kamarulzaman** (2008). *Engineering analysis on Reverse Forward Mechanism of DRG's EMDAP CVT*. Universiti Teknologi Malaysia. B. Eng. Unpublished
- Mohd. Ezlamy** (2008). *Engineering analysis on power screw mechanism in EMDAP CVT*. Universiti Teknologi Malaysia. B. Eng. Unpublished
- Shigley. J.E., Mischke. And Budynas, R.G** (2004). *Mechanical Engineering Design*. 8th ed. Singapore: McGraw-Hill

- BS EN 1097-3:1998. *Tests for mechanical and physical properties of aggregates. Determination of loose bulk density and voids*. London: British Standards Institution.
- BS EN 1097-6:2013. *Tests for mechanical and physical properties of aggregates. Determination of particle density and water absorption*. London: British Standards Institution.
- BS EN 1097-8:2009. *Tests for mechanical and physical properties of aggregates. Determination of the polished stone value*. London: British Standards Institution.
- BS EN 1992-3:2006. *Eurocode 2. Design of concrete structures. Liquid retaining and containing structures*. London: British Standards Institution.
- BS EN 12350-2:2009. *Testing fresh concrete. Slump-test*. London: British Standards Institution.
- BS EN 12390-2:2009. *Testing hardened concrete. Making and curing specimens for strength tests*. London: British Standards Institution.
- BS EN 12390-3:2009. *Testing hardened concrete. Compressive strength of test specimens*. London: British Standards Institution.
- BS EN 12390-5:2009. *Testing hardened concrete. Flexural strength of test specimens*. London: British Standards Institution.
- BS EN 12390-6:2009. *Testing hardened concrete. Tensile splitting strength of test specimens*. London: British Standards Institution.
- BS EN 12390-7:2009. *Testing hardened concrete. Density of hardened concrete*. London: British Standards Institution.
- BS EN 12620:2013. *Aggregates for concrete*. London: British Standards Institution.
- BS 8110-2:1985. *Structural use of concrete. Code of practice for special circumstances*. London: British Standards Institution.
- CIDB Malaysia. *Construction Industry Review and Prospect 2015/2016*. <http://www.cidb.gov.my/>. (retrieved on 29 May 2017).
- Dhanalakshmi, A. and Poonkuzhali, A. (2015). *Behavioural Study on Lightweight Concrete*. International Journal of Science and Research (IJSR). ISSN (online):2319-7064.
- DOE. (1988). *Theory of Mix Design*. British Department of Environment.
- FIP. (1983). *Manual of lightweight aggregate concrete*. 2nd ed. London: Surrey University Press.

Zakaria, M.L. (1986). Strength properties of oil palm clinker concrete. J. Teknol. UTM 8 (1), 28e37.