Prof. Ir. Dr. Mohd Warid Hussin is a Senior Professor in the Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM) in Skudai. He received his PhD degree from the University of Sheffield, UK in 1985. Among the positions held in UTM for more than 40 years working with the university are: Head of Structures & Materials Department, Deputy Dean (Postgraduate & Research), Deputy Dean (Academic), Head of Construction Materials Research Group (CMRG) and Director of Construction Technology and Management Centre (CTMC). He is also member of IEM, BEM, Charter of International Ferrocement Society (IFS), Concrete Society of Malaysia (CSM) and ACI Malaysian Chapter. He has been involved with research on Fibre Reinforced Composites, Blended Cement Concrete, Aerated Concrete, Concrete Repair Materials, Ferrocement Technology and Geopolymer Concrete, and had published more than 300 papers in these fields in conference proceedings and journals. He is currently attached to UTM Construction Research Centre (UTM CRC) as a Senior Research Fellow.

Khairunisa Muthusamy is a senior lecturer who has been involved in teaching and research activities for almost 10 years in the Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang. She received her PhD in Civil Engineering from Universiti Teknologi Malaysia in 2009. Since then, she has been actively involved in environmental friendly concrete research. She has published almost of 60 journal papers and conference proceedings related to concrete research. Her keen interest in exploring the potential of local waste materials especially from palm oil industry for concrete use has resulted in development of green lightweight concretes. Her research product has won gold award in CITREX 2016 and silver award for green technology category in BIOMALAYSIA 2016 Exhibition. She is also the member of Board of Engineers Malaysia and Concrete Society of Malaysia.

Mohd Azreen Mohd Ariffin is a senior lecturer in Universiti Teknologi Malaysia. He obtained his first degree in Civil Engineering from Universiti Putra Malaysia in 2001 before joining the construction industry for few years before opting to be a lecturer in Civil Engineering field in Malaysian polytechnic. After completion of his master study in 2007 from Universiti Teknologi Malaysia, he pursued for doctorate study in the same university and graduated in 2014. At present he is actively involved in research of geopolymer concrete containing locally available waste materials.

Nur Farhayu Ariffin is a lecturer in Universiti Malaysia Pahang. She completed Bachelor, Masters and PhD from Universiti Teknologi Malaysia and she has more than 15 publications published. She has been involved in multidisciplinary research projects in different fields since 2010. She has numbers of award winning research product and has various patented trademarked in Malaysian construction industry. Her associated professional membership includes: Concrete Society Malaysia (CSM) and Board of Engineering Malaysia (BEM).

Nor Hasanah Abdul Shukor Lim is a PhD graduated student from Department of Structure and Materials, Universiti Teknologi Malaysia. She completed Bachelor and Masters from UTM, which is among the ASEAN top 10 universities based on QS university ranking released in 2014. She has more than 15 publications published while completing her PhD studies. She has been involved in multidisciplinary research projects in different fields since 2010. She has developed number of award winning research product and services that have been patented trademarked in Malaysian construction industry. Her associated professional membership includes: Concrete Society Malaysia (CSM) and Board of Engineering Malaysia (BEM).

ISBN 978-967-2054-03-0

PUBLISHER
UNIVERSITI MALAYSIA PAHANG

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

POFA CONCRETE
THEORY AND APPLICATION

MOHD WARID HUSSIN
KHAIRUNISA MUTHUSAMY
MOHD AZREEN MOHD ARIFFIN
NUR FARHAYU ARIFFIN
NOR HASANAH ABDUL SHUKOR LIM

POFA CONCRETE

THEORY AND APPLICATION

POFA CONCRETE

THEORY AND APPLICATION

MOHD WARID HUSSIN
KHAIRUNISA MUTHUSAMY
MOHD AZREEN MOHD ARIFFIN
NUR FARHAYU ARIFFIN
NOR HASANAH ABDUL SHUKOR LIM

Publisher
Universiti Malaysia Pahang
Kuantan
2016

First Published, 2016

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Mohd. Warid Hussin
POFA CONCRETE THEORY AND APPLICATION / Mohd Warid Hussin, Khairunisa Muthusamy, Mohd Azreen Mohd Ariffin, Nur Farhayu Ariffin, Nor Hasanah Abdul Shukor Lim.
Includes bibliographical references
ISBN 978-967-2054-03-0
1. Concrete--Additives--Testing. 2. Fibre-reinforced concrete. 3. Concrete. I. Khairunisa Muthusamy. II. Mohd. Azreen Mohd. Ariffin. III. Nur Farhayu. Ariffin. IV. Nor Hasanah Abdul Shukor Lim. V. Title.
666.893

Published By:
Publisher
Universiti Malaysia Pahang,
Lebuhraya Tun Razak,
Pahang Darul Makmur.
Tel: 09-549 3320 Fax: 09-549 3381

Layout & Printing:
Syarikat Percetakan Inderapura Sdn. Bhd. (8763 H)
Jalan Tanjong Api Off Jalan Telok Sisek
25050 Kuantan, Pahang Darul Makmur.
Tel: 09-5177225, 5177031 & 5177025
Fax: 09-5139434

TABLE OF CONTENTS

PREFACE

It is without doubt that the inclusion of siliceous admixtures as an essential component of concrete mixture imparts significant enhancement to the basic characteristics of the resulting concrete, both in its fresh and hardened states. The use of pozzolanic materials in concrete is expected to increase as the incorporation of these materials such as fly ash (FA), silica fume and natural pozzolans in concrete, contributes to the enhancement of quality of concrete in terms of its strength and durability. In addition, the incorporation of pozzolanic materials also contributes to the reduction in bleeding, improves workability, reduces heat of hydration, increases the resistance to aggressive chemical attack and minimizes the environmental pollution.

A series of research programmes has been initiated in the Faculty of Civil Engineering of the Universiti Teknologi Malaysia (UTM) to examine various aspects of strength and durability of blended cement concrete since the early nineties. Established in the year 2001, the Faculty of Civil Engineering and Earth Resources of Universiti Malaysia Pahang (UMP) also joined the research league to discover the potential of waste materials for the development of modern sustainable concrete which is in tandem with the Malaysian government policy to implement green technology in the local construction industry. Amongst the features of concrete that were considered significant to the construction sector were the performance behaviour of Palm Oil Fuel Ash (POFA) concrete in marine exposure, the development of high strength concrete using Timber Industrial Ash (TIA) and the application of slag cement based grout for concrete repair in tropical climate. The development of green lightweight aggregates concrete containing waste materials also offers attractive solution to the industry in managing environmental polluting wastes and in-house made lightweight concrete for more economical structural design.

As with the diversified use of the waste materials having pozzolanic character, more products are likely to be materialised for use in concrete. Blended cements are cements where there is a partial replacement of ordinary Portland cement (OPC) with an alternative cementitious material. Recently, blended cements, based on industrial and agricultural wastes, are well known for their improved long-term strength and durability. Pozzolanic materials, either naturally occurring or artificially made, have long been in practice since the early civilisation. FA is the most commonly used artificial pozzolans globally. With the increasing demand of concrete with high-performance characteristics, the need for such pozzolanic materials is also getting higher.

This book, however, presents a comprehensive review of the engineering properties of blended cement concrete incorporating POFA in various concrete types for different applications. The results comprise of test data from the past 20 years investigation carried out at UTM Civil Engineering Laboratory. The contribution of experimental results and research findings from researchers of the Faculty of Civil Engineering and Earth Resources, UMP is also included in this book. It was demonstrated that the use of cement replacement materials not only improved workability but also reduce bleeding significantly. Results on compressive strength reveal that it is possible to replace cement by 30% of POFA without any loss of strength, as explained in Chapter 1.0. Chapter 2.0 highlights the engineering properties of aerated concrete containing POFA as cement replacement. The ensuing chapter, Chapter 3.0 focuses on the mechanical properties of oil palm shell lightweight aggregates concrete produced using palm oil fuel ash as a mineral admixture.

Along with the strength, a number of durability performance data of concrete in aggressive chemical environments were also presented and discussed in Chapter 4.0. The more recent topic on blended cement concrete is the inclusion of nano-size material to enhance the concrete performance. Chapter 5.0 of the book discusses the effect of nano POFA as cement replacement in mortar and concrete. One of the key findings of the study is that the incorporation of 20% nano POFA by weight of cement into concrete exhibits better durability properties than OPC concrete. Furthermore, as CO_2 emissions have become a matter of increasing importance in the construction industry, concrete that uses less cement in its production and utilises a greater amount of waste, such as POFA, offers an environmentally viable solution. Moreover, 100% cement free geopolymer concrete, as described in Chapter 6.0, can be produced by using blended ash such as POFA and FA.

Conclusively, all the scientific results presented highlight the role of POFA in the development of sustainable construction material. Therefore, it is hope that this book will inspire the researcher and industries to collaborate in developing a green material “from waste to wealth”.

Prof. Ir. Dr. Mohd Warid Hussin
(Universiti Teknologi Malaysia)
Dr. Khairunisa Bt. Muthusamy
(Universiti Malaysia Pahang)

ACKNOWLEDGEMENT

This book chapter would not be possible to be produced without the cooperation and team work between researchers of the Faculty of Civil Engineering and Earth Resources of Universiti Malaysia Pahang (UMP) and Faculty of Civil Engineering of the Universiti Teknologi Malaysia (UTM). The strong support of Deans from both faculties Dr. Mohamad Idris Ali and Prof. Dr. Khairul Anuar Kassim are gratefully acknowledged. The authors would like to extend their gratitude to the research management centres of both Universiti Malaysia Pahang and Universiti Teknologi Malaysia for funding the researches. A word of thanks also goes to the industries especially local palm oil mills for providing palm oil fuel ash to be used in the researches. Words cannot express our gratitude to editor Assoc. Prof. Dr. Mohamed Abdel Kader Ismail of University Curtin Sarawak for his professional advice and assistance during the preparation of this manuscript. Thank you to Mr. Anwar Abdul Majeed for spending his valuable time to proofread and further polish this manuscript. Our appreciation also goes to Assoc. Prof. Dr. Mohd Ghani Awang and Mr. Muhammad Azli Shukri of UMP Publisher for assisting us in publishing this book chapter. Last but not least, we would like to thank our colleagues, lecturers and family members who supported us during the preparation of this book.