UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF HIGH STRENGTH CEMENT-BASED CONCRETE UTILIZING SILICON DIOXIDE NANOPARTICLES AND RICE HUSK ASH

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ITMA 2011 14

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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 Doctor of Philosophy

November 2011

Abstract of Thesis Presented to the Senate of Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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Chairperson: Associate Professor Suraya Abdul Rashid, PhD

Institute: Institute of Advanced Technology

Nano-engineering of concrete is a relatively new but rapidly growing area in concrete research. This study deals with development of high strength concrete incorporating agro-waste rice husk ash (RHA) and SiO_2 nanoparticles as supplementary cementing materials replacing cement particles in order to improve sustainability of concrete constructions as fundamental need. Various binary and ternary blended concrete mixtures were produced using two sizes of RHA (5 and 95 µm) and SiO2 nanoparticles (15 and 80 nm). Fresh and hardened concretes incorporating 5, 10, 15 and 20% of RHA and 0.5, 1, 1.5, and 2% of SiO2 nanoparticles with constant water to binder ratio and aggregate content were prepared and tested. Fresh mixtures were tested for workability and hardened concretes were tested for compressive strength and water absorption at 7, 28 and 90 days of curing. Additionally,

the effects of two different curing media, water and lime solution on compressive strength and water absorption of concretes were tested. Finally, using Artificial Neural Network (ANN) a model was proposed for the design procedure of concrete mixture proportioning with different sizes and contents of the utilized materials. Fresh concrete test results showed that workability of binary blends was improved in the presence of up to 20% of RHA in both particle sizes; however, workability was reduced in the presence of both sizes of SiO_2 nanoparticles. In ternary blends, workability was improved in the presence of up to 20% of RHA and 2% of SiO_2 nanoparticles (in both sizes). Hardened concrete test results revealed that in water-cured binary mixes compressive strength was enhanced with incorporation of both sizes of RHA up to 10%. Compressive strength of lime-cured mixtures, on the other hand, showed an increase up to 15% with coarser RHA blends but in finer RHA blends the highest strength was obtained at 20%. Similarly, the overall compressive strengths of concretes incorporating SiO_2 nanoparticles were enhanced both in water-cured and lime-cured mixes, however, concretes comprising larger particles with contents up to 1.5% and 2% in water and lime solution, respectively, improved the compressive strength. Smaller SiO_2 nanoparticles, on the other hand, improved compressive strength up to 1% and 2% in water and lime solution, respectively. In ternary blends, compressive strengths were enhanced with incorporation of RHA up to 20% and SiO_2 nanoparticles (with both sizes) up to 2%. In binary blends, the lowest water absorption for water-cured RHA blends for both sizes was obtained at 10%. In lime-cured mixes, 15% of coarser RHA and 20% of finer RHA replacement yielded the lowest values at 90 days of curing. Similarly, for SiO_2 nanoparticles in binary blends the lowest water absorption in both curing media across all percentages was obtained with 2% of both particle sizes at later curing ages. In ternary

blends, the lowest water absorption was obtained at 90 days of curing at 2% of SiO_2 nanoparticles (both sizes) in combination with 20% of RHA replacement. The overall results confirmed that ternary blends have better contributions to the mechanical and physical properties of concert due to the effects of SiO_2 nanoparticles. The results also indicated that ANN is an efficient model to predict unlimited number of necessary proportions for the mixtures by conducting a limited number of experiments. The employment of the model to predict the behavior of output variables saves a lot of library trials and computational efforts carried out in conventional methods. The implications of the study for concrete engineering in general and nano-engineering of concrete in particular have been discussed.

Abstrak Tesis Untuk Dikemukakan Kepada Senat Universiti Putra Malaysia Sebagai Memenuhi Keperluan Untuk ijazah Doktor Falsafah

KESAN-KESAN NANOZARAH SILIKON DIOKSIDA DAN ABU SEKAM PADI KE ATAS SIFAT-SIFAT KONKRIT SEBAGAI CAMPURAN SIMEN BINARI DAN TERNERI

Oleh

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Kejuruteraan-nano konkrit merupakan bidang yang relatifnya baru namun berkembang pesat dalam kajian konkrit. Penyelidikan ini membahaskan perkembangan konkrit kualiti tinggi yang menggabungkan agro-sisa abu sekam padi (RHA) dan nanozarah SiO_2 sebagai bahan penyemenan pelengkap menggantikan zarah simen. Pelbagai binari dan terner campuran konkrit dihasilkan menggunakan dua saiz RHA (5 dan 95 pm) dan nanozarah SiO_2 (15 dan 80nm). Konkrit yang baru disediakan dan keras deya menggabungkan 5, 10, 15 dan 20% dari RHA, dan 0.5, 1, 1.5, dan 2% dari nanozarah SiO_2 dengan air malar sebagai bahan pengikat, nisbah dan agregat isi diuji. Pasta segar diuji untuk kecekapannya dan konkrit yang dikeras diuji kekuatan keseluruhan dan

penyerapan air pada 7, 28 dan 90 hari pemeraman. Selain itu, kesan daripada pemeraman dua air-media yang berbeza dan penyelesaian-kapur terhadap kekuatan keseluruhan dan penyerapan air konkrit diuji. Akhirnya, dengan menggunakan Rangkaian Saraf Tiruan (ANN) sebuah model dicadangkan untuk prosedur rekaan perkadaran campuran konkrit dengan saiz yang berbeza dan isi dari bahan-bahan yang digunakan. Keputusan ujian konkrit segar menunjukkan bahawa kecekapan campuran binari dipertingkatkan hingga 20% dari RHA di kedua-dua saiz zarah, namun, kecekapan berkurang untuk kedua-dua saiz nanozarah SiO_2. Dalam campuran terneri, kecekapan dipertingkatkan hingga 20% dari RHA dan 2% dari nanozarah SiO_2 (untuk kedua-dua saiz). Keputusan ujian konkrit keras menunjukkan bahawa dalam air-binari yang disembuhkan, kekuatan keseluruhan campuran dipertingkatkan dengan penggabungan kedua-dua saiz RHA hingga 10%. Di samping itu, kekuatan keseluruhan campuran kapur yang ditambahbaik menunjukkan peningkatan hingga 15% dengan campuran RHA kasar. Walaubagaimanapun, dalam campuran RHA halus, kekuatan tertinggi diperolehi sehingga 20%. Demikian pula, kekuatan keseluruhan konkrit menggabungkan nanozarah SiO_2 dipertingkatkan baik dalam campuran air dan kapur yang ditambahbaik. Walaubagaimanapun, konkrit yang terdiri daripada zarah yang lebih besar dengan kandungan sehingga 1.5% dan 2% dalam air dan larutan kapur masing-masing, meningkatkan kekuatan keseluruhan. Nanozarah SiO_2 yang lebih kecil, di samping itu, meningkatkan kekuatan keseluruhan sehingga 1% dan 2% dalam larutan air dan kapur. Dalam campuran terneri, kekuatan keseluruhan dipertingkatkan dengan penggabungan RHA hingga 20% dan nanozarah SiO_2 (dengan kedua-dua saiz) sehingga 2%. Dalam campuran bineri, penyerapan air terendah untuk menggabungkan RHA air-sembuh untuk

kedua saiz diperoleh pada 10%. Dalam campuran kapur-sembuh , 15% dari RHA yang kasar dan 20% dari penggantian RHA halus menghasilkan nilai terendah pada 90 hari penyembuhan. Demikian pula, untuk nanozarah SiO_2 dalam campuran binari, penyerapan air terendah bagi kedua-dua media penyembuhan di seluruh peratusan diperolehi dengan 2% dari kedua-dua saiz zarah pada penyembuhkan kemudian. Dalam campuran terneri, penyerapan air terendah diperolehi pada 90 hari penyembuhan sebanyak 2% dari nanozarah SiO_2 (kedua-dua saiz) dalam kombinasi dengan 20% dari penggantian RHA. Keputusan keseluruhan membuktikan bahawa campuran terneri mempunyai sumbangan yang lebih baik terhadap sifat mekanik dan fizikal konsert kerana kesan daripada nanozarah SiO_2. Keputusan kajian juga menunjukkan bahawa ANN merupakan model yang cekap untuk meramal jumlah tidak terbatas perkadaran yang diperlukan untuk campuran dengan melakukan sejumlah eksperimen yang terhad. Penggunaan model untuk meramal perilaku hasil pembolehubah menjimatkan banyak kajian perpustakaan dan usaha pengkomputeran yang dilakukan dalam kaedah konvensional. Implikasi kajian ini untuk kejuruteraan konkrit pada umumnya dan kejuruteraan-nano konkrit khususnya telah dibincangkan.

Dedicated to:

My parents

ACKNOWLEDEGEMENTS

*In The Name of **ALLAH**, The Most Merciful and Most Beneficent*

First and foremost, a word of thanks is given to **ALLAH,** the source of all Knowledge, by whose abundant grace this work came to fruition.

I would like to express my sincerest appreciation to my supervisor **Associate. Prof. Dr. Suraya Abdul Rashid**, for the opportunity to do this work. Fairly speaking, this work has been done from first to last according to her ideas, kind guidance and invaluable advises and criticism throughout the work and particularly during writing this thesis. Special thanks go to the members of my supervisory committee **Dr. Farah Nora Aznieta Abdul Aziz** and **Dr. Mohamad Amran Mohd Salleh**. Their confidence, guidance, support, and catching optimism during my PhD studies were very important and continuously encouraging.

I am very grateful to all of my friends at the Institute of Advanced Technology and Engineering Faculty, UPM, especially to **Dr. Shamekhi, Dr. Ali, Dr. Afshin, and Dr. Sina** for their kindly help and supports.

Last but not least, I am immensely and forever grateful to my beloved parents and sisters for their love, supports, unending encouragement, highly appreciated patience day and night all over the time of my study and prays throughout my life. Allah bless them all forever.

I certify that an Examination Committee has met on 12 March 2012 to conduct the final examination of Alireza Naji Givi on his PhD thesis entitled "Development of High Strength Cement-Based Concrete Utilizing Silicon Dioxide Nanoparticles and Rice Husk Ash" 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 declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

ALIREZA NAJIGIVI

Date: 29 November 2011

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ABSTRAK	v
ACKNOWLEDGEMENTS	ix
APPROVAL	x
DECLARATION	xii
LIST OF TABLES	xvii
LIST OF FIGURES	xx
LIST OF ABBREVIATIONS	xxii
1 INTRODUCTION	**1**
1.1 Background	1
1.2 Research Objectives	6
1.3 Scope of the Study	7
2 LITRATUREREVIEW	**10**
2.1 Overview	10
2.2 Concrete Composition	11
2.2.1 Cement	11
2.2.2 Concrete Aggregates	14
2.2.3 Mixing Water	15
2.2.4 Admixtures	16
2.3 Concrete Properties	21
2.3.1 Workability	21
2.3.2 Compressive, Splitting Tensile and Flexural Strength	21
2.3.3 Water Absorption	25
2.4 Curing Process and Curing Medium	29

2.5 Nanotechnology and Its Applications in Concrete 32

2.5.1 Nanoparticles in Concrete 34

2.5.2 Nanoparticles as Nucleation Sites 36

2.5.3 Nanoparticles as Fillers 41

2.6 Modeling Concrete Properties through Artificial Neural Network 42

2.6.1 Back Propagation Neural Network 48

2.7 Summary 53

3 MATERIALS AND METHODS 56

3.1 Overview 56

3.2 Materials 56

3.2.1 Cement 57

3.2.2 Rice Husk Ash 57

3.2.3 Silicon Dioxide Nanoparticles 59

3.2.4 Aggregates 61

3.2.5 Mixing Water 62

3.3 Methods 62

3.3.1 Mix Design 62

3.3.2 Mixing and Curing Procedures 69

3.3.3 Testing Specimens 71

3.4 Modeling and Mixture Design 80

3.4.1 Steps in the Design of the Artificial Neural Network Model 81

3.4.2 Model Processing 83

3.5 Summary 86

4 RESULTS AND DISCUSSION **87**

4.1 Overview 87

4.2 Rice Husk Ash in Binary Blends 87

4.2.1 Rice Husk Ash and Workability of Binary Blends 89

4.2.2 Effects of Rice Husk Ash on Compressive Strength of Water-Cured and Lime-Cured Binary Blends 92

4.2.3 Effects of Rice Husk Ash on Water Absorption of Water-Cured and Lime-Cured Binary Blends 101

4.3 Silicon Dioxide Nanoparticles in Binary Blends 107

4.3.1 Silicon Dioxide Nanoparticles and Workability of Binary Blends 107

4.3.2 Effects of Silicon Dioxide Nanoparticles on Compressive Strength of Water-Cured and Lime-Cured Binary Blends 110

4.3.3 Split Tensile and Flexural Strength 115

4.3.3 Split Tensile and Flexural Strength 122

4.3.4 Effects of Silicon Dioxide Nanoparticles on Water Absorption of Water-Cured and Lime-Cured Binary Blends 123

4.4 Silicon Dioxide Nanoparticles-Rice Husk Ash in Ternary Blends 133

4.4.1. Silicon Dioxide Nanoparticles-Rice Husk Ash and Workability of Ternary Blends 133

4.4.2 Effects of Larger Silicon Dioxide Nanoparticles-Rice Husk Ash and Smaller Silicon Dioxide Nanoparticles-Rice Husk Ash Series on Compressive Strength of Ternary Blends 136

4.4.3 Effects of Larger Silicon Dioxide Nanoparticles-Rice Husk Ash and Smaller Silicon Dioxide Nanoparticles-Rice Husk Ash Series on Water Absorption of Ternary Blends 150

4.5. Prediction of Compressive Strength and Water Absorption Properties of Ternary Blends Using Artificial Neural Network 155

4.5.1 Modeling Results 155

5 Conclusions, Contributions and Recommendations **166**

5.1 Introduction 166

5.1.1 Binary Blends 167

5.1.2 Ternary Blends 172

5.1.3 Modeling of High Strength Concrete Mix Design 176

5.2 Contributions 177

5.3 Recommendations 179

REFERENCES 181
BIODATA OF STUDENT 201