UNIVERSITI PUTRA MALAYSIA

ACTIVATION AND CHARACTERIZATION OF DUNE SAND AS PARTIAL CEMENT REPLACEMENT FOR CONCRETE

ASIAH ABDULLAH

FS 2012 2

ACTIVATION AND CHARACTERIZATION OF DUNE SAND AS PARTIAL CEMENT REPLACEMENT FOR CONCRETE

By

ASIAH ABDULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

January 2012

To my precious parents who always give me fabulous love, spectacular care and support, to my adorable brothers, and sisters.

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

ACTIVATION AND CHARACTERIZATION OF DUNE SAND AS PARTIAL CEMENT REPLACEMENT FOR CONCRETE

By

ASIAH ABDULLAH

January 2012

Chairman: Professor Taufiq Yap Yun Hin, PhD

Faculty: Science

Dune sand obtained in the vicinity of Riyadh, Saudi Arabia has been investigated to be used as partial cement replacement materials for concrete. Physical and chemical properties of dune sand were evaluated and it was found that it has potential to be processed and used as partial cement replacement due to the high silica content of about 93.4%. However, dune sand is inert and chemically inactive under normal condition. Results show that the strength decreases with the increase of cement replacement by dune sand under normal condition. Therefore, different methods have been developed to enhance the reactivity of dune sand. Three ways were used to improve the pozzolanic reactivity including chemical activation, mechanical activation and thermal activation. For chemical activation, four inexpensive materials which are NaCl, Na_2SO_4, $CaSO_4 \cdot 2H_2O$ and $CaCl_2 \cdot 2H_2O$ were chosen for this study. Results showed that the addition of chemical activators did not demonstrate an obvious effect on the strength development of the cement. In the mechanical activation, the dune sand with prolonged grinding was investigated to study the effect of using different particle size on the dune sand reactivity. However, it did not result in substantial improvements to strength. For thermal activation, two different

techniques were used which are calcination (heat treatment) and autoclave curing. The calcination process was done to activate the raw material of dune sand at temperature ranging from 400^{o}C to 1000°C. Experimental results indicated that the ultimate strength of cement pastes decreased with increasing calcination temperature. The autoclave curing increased the pozzolanic activity of dune sand with significant improvement in strength. The maximum compressive strength was found at 30% replacement of cement by dune sand. The final products obtained were further analyzed by X-ray diffraction (XRD), scanning electron microscope (SEM), differential thermal analysis (DTA) and thermogravimetric analysis (TGA) to investigate the mechanism that caused the increase in the compressive strength. Elimination of $Ca(OH)_2$ peaks in the XRD analysis clearly proved that crystalline SiO_2 in dune sand can quickly react with $Ca(OH)_2$ that are formed from cement hydration to form a new type C-S-H hydrate (tobermorite) which improve the strength and concrete structure under autoclave curing. The compressive strength of autoclaved concrete containing 30% dune sand as partial cement replacement increased by 28% compared to concrete that have been subjected to the standard curing after 154 days. Free $Ca(OH)_2$ content was reduced from 26% in control paste under standard curing to about 3% in autoclaved cement paste containing 30% dune sand as partial cement replacement which experienced a reduction of about 89%. DTA results are also in good agreement with findings by TGA showing lower content of free $Ca(OH)_2$ in autoclaved products compared to the standard curing. In general, SEM investigation revealed that the utilization of concrete containing 30% dune sand as partial cement replacement subjected to autoclave curing produced more compact microstructure compared to those cured under normal curing.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGAKTIFAN DAN PENCIRIAN *DUNE SAND* SEBAGAI BAHAN SEPARA GANTI SIMEN BAGI KONKRIT

Oleh

ASIAH ABDULLAH

Januari 2012

Pengerusi: Profesor Taufiq Yap Yun Hin, PhD

Fakulti: Sains

Dune sand yang didapati dari kawasan Riyadh, Arab Saudi telah dikaji untuk diguna pakai sebagai bahan separa gantian simen dalam bancuan konkrit. Ciri-ciri fizikal dan kimia bagi *dune sand* telah dikaji. Bahan ini telah dikenalpasti mempunyai potensi untuk diproses serta digunakan sebagai bahan separa gantian untuk simen kerana mempunyai peratus kandungan silika yang tinggi iaitu sebanyak 93.4%. Walau bagaimanapun, dalam keadaan biasa, *dune sand* lengai dan tidak aktif secara kimia. Keputusan menunjukkan yang kekuatan spesimen semakin berkurangan dengan peningkatan penggantian ke atas simen oleh *dune sand* dalam keadaan biasa. Oleh itu, pelbagai kaedah telah dijalankan bagi meningkatkan kereaktifan *dune sand*. Tiga kaedah telah digunakan untuk meningkatkan kereaktifannya termasuklah pengaktifan secara kimia, pengaktifan secara mekanikal dan pengaktifan secara terma. Bagi pengaktifan secara kimia, empat bahan kimia dengan kos yang rendah iaitu NaCl, Na_2SO_4, $CaSO_4 \cdot 2H_2O$ dan $CaCl_2 \cdot 2H_2O$ telah dipilih untuk kajian ini. Keputusan menunjukkan penambahan bahan-bahan kimia ini ke dalam sistem tidak menunjukkan kesan yang ketara terhadap perkembangan kekuatan simen. Bagi pengaktifan secara mekanikal, *dune sand* telah dikisar kepada saiz yang lebih kecil untuk mengkaji kesan perbezaan saiz zarah terhadap kereaktifan *dune sand*. Walau

bagaimanapun, hasilnya juga tidak menunjukkan perkembangan kekuatan simen yang memberangsangkan. Bagi pengaktifan secara terma, dua teknik telah digunakan iaitu rawatan suhu (*calcination)* dan rawatan *autoclave*. Proses rawatan suhu telah dijalankan ke atas *dune sand* bermula dari suhu 400^{o}C ke 1000^{o}C. Keputusan menunjukkan kekuatan simen semakin berkurang dengan peningkatan suhu. Namun begitu, rawatan *autoclave* telah berjaya meningkatan kereaktifan *dune sand* berdasarkan peningkatan kekuatan simen yang telah terhasil. 30% penggantian ke atas simen oleh *dune sand* dikenalpasti sebagai peratus yang dapat memberi kekuatan yang maksimum kepada sampel. Produk akhir yang terhasil untuk sampel terpilih telah dicirikan dengan menggunakan pembelauan sinar-X (XRD), mikroskop elektron imbasan (SEM), analisis pembezaan terma (DTA) dan analisis termogravimetrik (TGA) bagi mengkaji mekanisme yang menyebabkan peningkatan kekuatan sampel. Kehilangan puncak bagi $Ca(OH)_2$ dalam analisis XRD jelas menunjukkan bahawa hablur SiO_2 di dalam *dune sand* dapat bertindak balas dengan $Ca(OH)_2$ yang terhasil dari proses hidrasi simen untk menghasilkan C-S-H jenis baru (*tobermorite*) yang dikenalpasti telah meningkatkan kekuatan dan struktur konkrit melalui rawatan *autoclave*. Kekuatan bagi konkrit yang mengandungi 30% *dune sand* sebagai bahan separa gantian simen dan dikenakan rawatan *autoclave* telah meningkat sebanyak 28% berbanding konkrit yang dirawat dalam keadaan biasa. Kandungan $Ca(OH)_2$ di dalam sampel *paste* telah berkurang sebanyak 89% iaitu dari 26% bagi *paste* kawalan yang dirawat dalam keadaan biasa kepada 3% bagi *paste* yang mengandungi 30% *dune sand* sebagai bahan separa gantian simen dan dikenakan rawatan *autoclave*. Keputusan DTA juga adalah selari dengan keputusan TGA di mana menunjukkan kandungan $Ca(OH)_2$ yang rendah bagi produk yang terhasil dengan rawatan *autoclave* berbanding rawatan biasa. Secara amnya,

berdasarkan keputusan SEM, penggunaan 30% *dune sand* sebagai bahan gantian untuk simen bagi konkrit yang dikenakan rawatan *autoclave* telah menghasilkan struktur mikro yang lebih mampat berbanding konkrit yang dirawat dalam keadaan biasa.

ACKNOWLEDGEMENTS

I wish to express my outmost gratitude to Allah subhanahua ta'ala for the strength and patience He bestowed on me to undertake this research project.

I would like to acknowledge my sincere appreciation to my supervisor, Prof. Dr. Taufiq Yap Yun Hin for his trust, dedicated supervision, outstanding guidance, patience and unconditional support throughout the duration of my master's studies and thesis project. My special thanks also dedicated to my project leader (co-supervisor), Prof. Ir. Dr. Mohd. Saleh Jaafar. If not for the generous help and advice offered by him, this project would have been a much more difficult task to accomplish.

I would also like to thank Mr. Halim Othman, Mr. Fairuz Ismail and Madam Khatijah Hassan from the Department of Civil Engineering, Faculty of Engineering for their support with technical advice, materials and laboratory facilities; also to Madam Norazlina Shari, Madam Zaidina Md. Daud and other Science Officers in the Department of Chemistry, Faculty of Science for their assistance in the characterization works. Not to forget officers in Characterization Lab and Electron Microscopy Unit, Department of Chemical and Environmental Engineering, Faculty of Engineering especially Mr. Ismail Abdul Ghani and Mr. Adli Nazri Mohd Kassim for their help and advice in running SEM and particle size analysis.

Special thanks are extended to Prof. Dr. Jamaloddin Noorzaei, Mr. Omer Abdalla Alawad, Ms. Farhana Abang Abdul Rahim, Mr. Lai Fok How, colleagues and friends for their help, valuable comments and suggestions during the course of this work.

Most especially, I wish to thank my parent and family for their love, never ending support and encouragement throughout these years.

Last but not least, sincere and great appreciation goes to the Management of the King Saud University (KSU), Saudi Arabia especially Prof. Dr. Abdurrahman M. Alhozaimy and Dr. Abdulaziz Al-Negheimish for providing research grant and to the Management of Universiti Putra Malaysia (UPM) for unfailing support for us to undertake this first ever joint research between the KSU and UPM. Financial support from Universiti Teknologi Mara and Ministry of High Education through Young Lecturer Scheme is gratefully acknowledged.

I certify that an Examination Committee has met on 10 January 2012 to conduct the final examination of Asiah Abdullah on her Master of Science thesis entitled "Activation and Characterization on Dune Sand as Partial Cement Replacement for Concrete" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

Kamaliah Sirat, PhD
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Anuar Kassim, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Mansor Hj Ahmad @ Ayob, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Yang Farina Abdul Aziz, PhD
Professor
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 2 March 2012

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of Supervisory Committee were as follows:

Taufiq Yap Yun Hin, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Mohd. Saleh Jaafar, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for the 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 at any other institution.

ASIAH ABDULLAH

Date: 10 January 2012

TABLE OF CONTENTS