



Ain Shams University,
Women's Faculty for Arts,
Science and Education,
Cairo- Egypt.

Effect Of Nano Metakaolin On The Physico-Chemical And Mechanical Properties Of Various Blended Cement Pastes

A Thesis

Submitted to the Chemistry Department,
Women's Faculty, Ain Shams University.

In Partial Fulfillment of the Requirements for
the Degree of M. Sc. in Chemistry.

Presented by

Aya Allah Mahmoud Ebrahim
(B.Sc., 2011)

Supervised by

Prof. Dr. Wafaa S. Hegazi

Prof. of Physical Chemistry
Women's Faculty,
Ain Shams University, Cairo- Egypt.

Dr. Doaa A. Ahmed

Assistant Prof. of Inorganic Chemistry,
Women's Faculty,
Ain Shams University, Cairo- Egypt

Dr. Maha R. Mohamed

Assistant Prof. of Inorganic Chemistry,
Women's Faculty,
Ain Shams University, Cairo-Egypt

2015



سورة البقرة
(32)

Effect of nano metakaolin on the physico-chemical and mechanical properties of various blended cement pastes

THESIS ADVISORS

APPROVED

Prof. Dr. Wafaa S. Hegazi

Prof. of Physical Chemistry

Dr. Doaa A. Ahmed

Assistant Prof. of Inorganic Chemistry

Dr. Maha R. Mohamed

Assistant Prof. of Inorganic Chemistry

Head of Chemistry Department



Ain Shams University,
Women's Faculty for Arts,
Science and Education,
Cairo- Egypt.

Student Name : Aya Allah Mahmoud Ebrahim

Scientific Degree : B. Sc. (Chemistry)

Department : Chemistry

Name of Faculty : Faculty of Women

University : Ain Shams University

B. Sc. Graduation Date: 2011

ACKNOWLEDGMENT

Praise and Thanks be to **ALLAH**, the most merciful for assisting and directing me the right way.

I would like to submit my gratitude, sincere thanks and appreciation to ***Prof. Dr.Wafaa S. Hegazi***, Professor of Physical Chemistry, Women's Faculty, Ain Shams University, for her useful guidance, kind help, continuous interest and fruitful discussion, which have facilitated the interpretation of the data throughout this study and the preparation of the thesis in its final form.

I would like to express my deepest thanks to ***Dr. Doaa A. Ahmed***, Assistant Prof. of Inorganic Chemistry, Women's Faculty, Ain Shams University, for her kind, supervision, useful criticism, valuable explanation and fruitful discussion during the whole work.

My deepest gratitude and appreciation to ***Dr. Maha R. Mohamed***, Assistant Prof. of Inorganic Chemistry, Women's Faculty, Ain Shams University, for her real concern and her continuous effort in guiding me and for her sincere help throughout this work.

Thanks are also to all the members of the Chemistry Department, Women's Faculty, Ain Shams University, for their help and cooperation.

TO MY FAMILY

***I AM Very Grateful
To All Of You
For Your Support,
Kindness
and Love.***

Aya allah

NOTE

Beside the work done in this thesis, the candidate has attended post- graduate courses for one year in inorganic and analytical chemistry including the following topics:

- Instrumental Analysis.
- Thermodynamic Chemistry.
- Kinetics and Catalysis.
- Nuclear Chemistry.
- Structural Inorganic Chemistry.
- Electrochemical Analysis.
- Special Topics.
- Spectroscopy.
- Coordination Chemistry.
- Photo Chemistry.
- Advanced Chemical Reactions.
- English Language.

She has successfully passed written examinations in the above mentioned topics.

Head of Chemistry Department

CONTENTS

	Page
Acknowledgement	
List of Tables	
List of Figures	
Abstract	
 <u>CHAPTER (I)</u>	
<u>Introduction, Literature survey and Aim of the work</u>	
I. Introduction.....	1
I.1.1. Cement and admixtures	1
I.1.2 Portland cement.....	1
I.1.3 Manufacture of Portland cement.....	2
I.1.4 Mineralogical composition of OPC.....	2
I. 1. 5 Properties and hydration of the major constituents of PC	3
I.1.6 Types of Portland cement.....	7
I. 1. 7 Factors affecting the rate of hydration.....	7
I.1.8 Blended cement.....	10
I.1.9. Characteristics and advantages of some industrial pozzolanas	12
I.1.9. A. Clay "Meta-kaolinite and nano metakaolin".....	12
I.1.9. B. Cement kiln dust.....	13
I.1.9.C. Ground granulated blast-furnace slag.....	14
I.1.9. D. Silica fume.....	15
I.1.9. E. Ground clay brick.....	16
I.2. Literature survey: Effect of different additives on the characteristics of OPC pastes.....	18
I.2.A. Effect of NMK.....	18

	Page
I.2.B. Effect of CKD.....	20
I.2.C. Effect of GBFS.....	24
I.2.D. Effect of SF.....	27
I.2.E. Effect of GCB.....	31
I. 3. Aim of the work	36

CHAPTER (II)

Materials and Experimental Techniques

II. A. Materials	38
II. B. Experimental Techniques	40
II. B. 1. Sample preparation	40
II. B. 2. Determination of the compressive strength.....	43
II. B. 3. Determination of the total porosity (P %).....	43
II. B. 4. Stopping of hydration.....	43
II. B. 5. Determination of the chemically combined water content (Wn %).....	44
II. B. 6. X-Ray diffraction analysis (XRD)	45
II. B. 7. Spectral measurements (IR).....	45
II. B. 8. Thermogravimetric analysis (DTA)	45
II. B. 9. Scanning electro-microscopic measurments (SEM).....	45

CHAPTER (III)

Results and Discussion

III. 1. Hydration Characteristics	47
III. 1. a. Compressive strength.....	47
III. 1. b. Total porosity (P%).....	56
III. 1. c. Combined water content (Wn%)	59
III. 1. d. Phase composition.....	66
III. 1. e. Infrared spectroscopy (IR).....	93
III. 1. f. The morphology and microstructure.....	99
III. 1. g. Thermal analysis.....	102

	Page
<i>CHAPTER (IV)</i>	
<i>Summary and Conclusion</i>	
Summary and Conclusions	106
References	111
Arabic Summary	-

LIST OF TABLES

Table No.	Title	Page
CHAPTER II		
1	Chemical composition of the used materials	39
2	The mineralogical composition of the used Portland cement.....	39
3	The designation and composition of the prepared mixes	42
CHAPTER III		
4	Compressive strength values of the control mix and mixes containing NMK at different hydration ages	48
5	Compressive strength values of the control mix and mixes containing NMK, GCB and CKD at different hydration ages.....	50
6	Compressive strength values of the control mix and mixes containing NMK, GCB and SF at different hydration ages.	52
7	Compressive strength values of the blended mixes containing NMK, GBFS and CKD at different hydration ages.....	54
8	Compressive strength values of the control mix and mixes containing NMK, GBFS and SF at different hydration ages..	55
9	The porosity values of blended cement pastes at the hydration ages 7 and 180 days.....	58
10	Combined water content at different hydration ages of Mo and the mixes blended with NMK only	59
11	Combined water content at different hydration ages of cement mixes containing NMK, GCB and CKD.....	61
12	Combined water content at different hydration ages of cement mixes containing NMK, GCB and SF.....	62
13	Combined water content at different hydration ages of cement mixes containing NMK, GBFS and CKD.....	63
14	Combined water content at different hydration ages of cement mixes containing NMK, GBFS and SF.....	64

LIST OF FIGURES

Fig. No.	Title	Page
CHAPTER II		
1	X-ray diffraction pattern of NMK	40
CHAPTER III		
2	Effect of the hydration ages on the compressive strength values of the control mix and the mixes containing NMK.	49
3	Effect of the hydration ages on the compressive strength of the control mix and the mixes containing NMK, GCB and CKD.....	50
4	Effect of the hydration ages on the compressive strength of the control mix and the mixes containing NMK, GCB and SF.....	53
5	Effect of the hydration ages on the compressive strength of the control mix and the mixes containing NMK, GBFS and CKD	54
6	Effect of the hydration ages on the compressive strength of the control mix and the mixes containing NMK, GBFS and SF	55
7	Combined water content of Mo and the mixes blended with NMK only at different hydration ages.....	60
8	Combined water content of cement mixes containing NMK, GCB and CKD at different hydration age.....	61
9	Combined water content of cement mixes containing NMK, GCB and SF at different hydration age	62
10	Combined water content of cement mixes containing NMK, GBFS and CKD at different hydration age	64
11	Combined water content of cement mixes containing NMK, GBFS and SF at different hydration age	65
12	X-ray diffraction patterns of the control mix Mo.	68
13	X-ray diffraction patterns of the control mix MIA.....	70
14	X-ray diffraction patterns of the control mix MIB	71

Fig. No.	Title	Page
15	X-ray diffraction patterns of the control mix MIC	72
16	X-ray diffraction patterns of the control mix MID	73
17	X-ray diffraction patterns of the control mix MIIA	75
18	X-ray diffraction patterns of the control mix MIIB	76
19	X-ray diffraction patterns of the control mix MIIC	77
20	X-ray diffraction patterns of the control mix MIID	78
21	X-ray diffraction patterns of the control mix MIIIA	79
22	X-ray diffraction patterns of the control mix MIIIB	80
23	X-ray diffraction patterns of the control mix MIIIC	81
24	X-ray diffraction patterns of the control mix MIIID	82
25	X-ray diffraction patterns of the control mix MIVA	85
26	X-ray diffraction patterns of the control mix MIVB	86
27	X-ray diffraction patterns of the control mix MIVC	87
28	X-ray diffraction patterns of the control mix MIVD	88
29	X-ray diffraction patterns of the control mix MVA	89
30	X-ray diffraction patterns of the control mix MVB	90
31	X-ray diffraction patterns of the control mix MVC	91
32	X-ray diffraction patterns of the control mix MVD	92
33	a) IR spectra of blank cement paste hydrated for 90 days.....	94
33	b) IR spectra of the blended cement mix MIA hydrated for 90 days.....	94
33	c) IR spectra of the blended cement mix MID hydrated for 90 days.....	95

Fig. No.	Title	Page
33	d) IR spectra of the blended cement mix MIIA hydrated for 90 days	95
34	e) IR spectra of the blended cement mix MIID hydrated for 90 days	96
34	f) IR spectra of the blended cement mix MIIIA hydrated for 90 days	96
34	g) IR spectra of the blended cement mix MIIID hydrated for 90 days	97
35	h) IR spectra of the blended cement mix MIVA hydrated for 90 days	97
35	i) IR spectra of the blended cement mix MIVD hydrated for 90 days	98
35	k) IR spectra of the blended cement mix MVA hydrated for 90 days	98
35	l) IR spectra of the blended cement mix MVD hydrated for 90 days	99
36	SEM micrographs of blended cement pastes hydrated for 90 days, a) blank, b) MIA, c) MID, d) MIIA, e) MIID, f) MIIIA, g) MIIID.....	101
37	DTA curves for (a) Mo, (b) MIVA, (c) MIVD.....	104
38	DTA curves for (a) Mo, (b) MVA, (c) MVD	105

Influence of nano metakaolin on the physico-chemical and mechanical properties of various blended cement pastes

Abstract:

The physico-chemical and mechanical characteristics of various cement pastes are studied in presence of nanometakaolin (2, 4, 6 and 8%) and in absence and presence of different percentages of some industrial wastes such as ground clay bricks, ground granulated blast furnace slag, cement kiln dust and silica fume. The characteristics of these blended pastes are investigated at different hydration times (1-180 days) via determination of the compressive strength, total porosity and chemically combined water content. In addition, the phase composition of the formed hydrates is investigated through X-ray diffraction analysis. The microstructural changes are studied using scanning electron microscopy. The IR spectra and DTA of some cement pastes are also recorded. The results show that the highest compressive strength is obtained for the cement mix blended with 8% NMK in absence of any other additives. In presence of the above mentioned additives, the optimum compressive strength is attained for mixes B, which contain 70% OPC, 20% GCB or slag, 6% CKD or SF, beside 4% NMK. The data obtained for other parameter agree well with the above findings.