



**CIVIL ENGINEERING, SCIENCE AND
TECHNOLOGY CHALLENGES:
STRUCTURAL ENGINEERING AND
CONSTRUCTION MATERIALS**

E D I T E D B Y

**Wan Hashim Wan Ibrahim
Siti Noor Linda Taib
Norsuzailina Mohamed Sutan**

**CIVIL ENGINEERING, SCIENCE AND
TECHNOLOGY CHALLENGES:
STRUCTURAL ENGINEERING AND
CONSTRUCTION MATERIALS**

© Wan Hashim Wan Ibrahim, Siti Noor Linda Taib, Norsuzailina Mohamed Sutan

2022

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publisher.

Published in Malaysia by
UNIMAS Publisher,
Universiti Malaysia Sarawak,
94300 Kota Samarahan,
Sarawak, Malaysia.

Perpustakaan Negara Malaysia

Cataloguing-in-Publication Data

CIVIL ENGINEERING, SCIENCE AND TECHNOLOGY CHALLENGES: STRUCTURAL
ENGINEERING AND CONSTRUCTION MATERIALS / EDITED BY Wan Hashim

Wan Ibrahim, Siti Noor Linda Taib, Norsuzailina Mohamed Sutan.

Mode of access: Internet

eISBN 978-967-2298-90-8

1. Structural engineering.
2. Building materials.
3. Government publications--Malaysia.
4. Electronic books.

I. Wan Hashim Wan Ibrahim. II. Siti Noor Linda Taib.

III. Norsuzailina Mohamed Sutan.

624.1

The book is based on scientific and technological advances in various Structural Engineering and Construction Materials areas of Civil Engineering. It nurtures therefore the exchange of discoveries among research workforces worldwide including those focusing on the vast variety of facets of the fundamentals and applications within the Structural Engineering and Construction Materials arena. To offer novel and rapid developments, this book contains original contributions covering theoretical, physical experimental, and/or field works that incite and promote new understandings while elevating advancement in the Structural Engineering and Construction Materials fields. Works in closing the gap between the theories and applications, which are beneficial to both academicians and practicing engineers, are mainly of interest to this book that paves the intellectual route to navigate new areas and frontiers of scholarly studies in Structural Engineering and Construction Materials.

CIVIL ENGINEERING, SCIENCE AND TECHNOLOGY CHALLENGES: STRUCTURAL ENGINEERING AND CONSTRUCTION MATERIALS

Editors in Chief

Wan Hashim Wan Ibrahim
Siti Noor Linda Taib
Norsuzailina Mohamed Sutan

Editors

Raudhah Ahmadi
Idawati Ismail
Abdul Razak Abdul Karim
Azida Rashidi
Delsye Teo Ching Lee
Mohd Raduan Kabit
Mohammad Ibrahim Safawi bin Mohammad Zain
Ahmad Kueh Beng Hong
Mohammad Abdul Mannan
Ng Chee Khoon
Leonard Lim Lik Pueh
Alsidqi Hasan
Charles Bong Hin Joo
Mah Yau Seng
Norazzlina bt M. Sa'don

Advisory Editors

Taksiah A.Majid
Megat Azmi Megat Johari
Zainah Ibrahim
Mohd Saleh Jaafar
Farah Nora Aznieta Abd. Aziz
Fadzli Mohamed Nazri
Ahmad Baharuddin Abd. Rahman
Md. Habibur Rahman Sobuz

Copy Editors/Proofreaders

Chuah Kee Man
Zayn Al-Abideen Gregory
Helmy Hazmi
Annisa Jamali

Layout Editor

Nur 'Ain Binti Shardi
Freddy Yeo Kuok San
Rose Sima Anak Ikau

TABLE OF CONTENTS

CHAPTER	TITLE OF CHAPTERS	PAGE NO
1	Modified Cement System: Durability And Aesthetics	1
2	Utilization Of Recycled Aggregate As Coarse Aggregate In Concrete	6
3	Effect Of Aggregates And Curing Conditions On The Compressive Strength Of Concrete With Age	13
4	Effect Of Seawater On The Properties Of Epoxy Modified Concrete	21
5	Study The Structural Behavior Of Ferrocement Beam	29
6	Effect Of PFA On Strength And Water Absorption Of Mortar	37
7	Laboratory Study Of Water Absorption Of Modified Mortar	42
8	Performance Of Profiled Steel Sheet Dry Board System Under Flexural Bending And Vibration	48
9	The Effect Of Reinforcement, Expanded Polystyrene (EPS) And Fly Ash On The Strength Of Foam Concrete	57
10	Status Of Industrialized Building System Manufacturing Plant In Malaysia	65
11	Evaluation Of Acacia Mangium In Structural Size At Green Condition	76
12	Basic And Grade Stress For Some Timber In Sarawak	84
13	The Behavior Of Strength Properties From Three Different Tree Boles Of Aras In Sarawak	88
14	Initial Surface Absorption Of Pozzolan And Polymer Modified Mortar	93
15	The Influence Of Finely Ground Mineral Admixture (FGMA) Of Efflorescence	99
16	Characterization Of Early Pozzolanic Reaction Of Calcium Hydroxide And Calcium Silicate Hydrate For Nanosilica Modified Cement Paste	106
17	Strength Characteristics Of Mortar Containing Different Sizes Glass Powder	113
18	Influence Of Silica Based Waste Materials On The Mechanical And Physical Properties Of Mortar	120
19	Effect Of Curing And Mixing Methods On The Compressive Strength Of Mortar Containing Oil	126
20	Improving The Strength Performance Of High Volume Periwinkle Shell Ash Blended Cement Concrete With Sodium Nitrate As Accelerator	133
21	Chloride Resistance Of Blended Ash Geopolymer Concrete	138
22	Evaluation Of Water Hyacinth Stem Ash As Pozzolanic Material For Use In Blended Cement	150
23	Pozzolanic Properties Of Glass Powder In Cement Paste	158
24	Effect Of Organic Soil On Strength Properties Of Compressed Cement-Soil Block	166
25	Effect Of Base Isolator On The Structural Response Of Reinforced Concrete Multistoried Building Under Seismic Loads	174

TABLE OF CONTENTS cont.

CHAPTER	TITLE OF CHAPTERS	PAGE NO
26	Toner Used In The Development Of Foamed Concrete For Structural Use	184
27	Finite Element Simulation Of Damage In RC Beams	192
28	Seismic Performance Of Damper Installed In High-Rise Steel Building In Bangladesh	200
29	Characteristics Of Steel Fiber Reinforced Concrete With Recycled Coarse Aggregate	213
30	Finite Element Analysis Of A Strengthened Beam Deliberating Elastically Isotropic And Orthotropic CFRP Material	218
31	Compressive Strength Of Foamed Concrete In Relation To Porosity Using SEM Images	229
32	Predicting The Structural Performance Of Sandwich Concrete Panels Subjected To Blast Load Considering Dynamic Increase Factor	241
33	Partial Replacement Of Cement By Coffee Husk Ash For C-25 Concrete Production	258
34	Porosity, Permeability And Microstructure Of Foamed Concrete Through SEM Images	267
35	Some Mechanical Characteristics Of Concrete Reinforced With Dried Water Hyacinth And Quarry Dust As Fine Aggregates	282
36	Potential Use Of Cinder Gravel As An Alternative Base Course Material Through Blending With Crushed Stone Aggregate And Cement Treatment	290
37	Water Permeability And Chloride And Sulphate Resistance Of Rubberised Fibre Mortar	302
38	Case Study Of Structural Health Monitoring In India And Its Benefits	315
39	Comparing Compressive Strengths Of Layered And Random Placement Of Expanded Polystyrene Wastes In Quarry Dust Blocks	324
40	Experimental Study On Application Of Marble Waste As Conventional Aggregate For Base Course Materials	331
41	Evaluation Of The Performance Of Waste Marble Dust As A Mineral Filler In Hot-Mix Asphalt Concrete	349
42	Linear And Nonlinear Free Vibration Analysis Of Rectangular Plate Compressive Strength Of Mortar Containing Oil	367
43	Influence Of Oil Palm Spikelets Fibre On Mechanical Properties Of Lightweight Foamed Concrete	379
44	Experimental Study On Behavior Of Unprotected Foamed Concrete Filled Steel Hollow Column Under Fire	388

CHAPTER 16

CHARACTERIZATION OF EARLY POZZOLANIC REACTION OF CALCIUM HYDROXIDE AND CALCIUM SILICATE HYDRATE FOR NANOSILICA MODIFIED CEMENT PASTE

J.Z. Chong, N.M. Sutan* and I. Yakub

ABSTRACT

This study intends to investigate the early pozzolanic reaction of Nanosilica (nS) modified cement paste (NMCP) by the characterization technique of Calcium Hydroxide (CH) and Calcium Silicate Hydrate (C-S-H) using Fourier Transform Infrared Spectroscopy (FT-IR). NMCP samples were prepared with water-binder ratio of 0.50. nS of 5-15nm particle size were used as 1%, 3%, 5%, 7% and 10% replacement of cement by weight. All samples were cured in the concrete laboratory at daily room temperature (T) and relative humidity (RH) in the range of 18-28°C and 65-90%, respectively. Powdered samples were prepared and tested at day 1,7,21 and 28. It was found that characterization technique used were able to give satisfactory qualitative indication of pozzolanic reactivity of NMCP by the presence and absence of C-S-H and C-H that can indicate which replacement has higher pozzolanicity. NMCP exhibited a higher pozzolanic reactivity compare to conventional cement paste by which cement performance was enhanced.

Keywords: Nanosilica, CH, C-S-H, FT-IR, Cement Paste

INTRODUCTION

Concrete is the most widely used material in construction industry and consumes almost the total 90% cement production in the world. The consumption of large quantity of cement causes greenhouse effects to environment producing global warming issues. This is due to the emission of significant amount of carbon dioxide, CO₂ as by-product from the combustion of fuel fossil and calcination of limestone during its production. As much as 1.25 tonnes of CO₂ is emitted to produce every ton of cement and the CO₂ emission from cement industry is responsible 5% for the total global gas emissions of CO₂ [1]. One of the alternatives to reduce the amount of CO₂ emitted is reducing the amount of cement used in cement based material by partial replaced it with supplementary cementitious materials such as fly ash, ground granulated blast furnace slag, silica fume and natural pozzolans.

**Faculty of Engineering, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia.
Email: msnorsuzailina@unimas.my*

Introduction of nanotechnology in cement industry has the potential to reduce the amount of CO₂ emissions by partial replacement of cement in cement based material with nanoparticles. Previous research found that remarkable improvements in the mechanical and chemical properties of cementitious materials can be observed with incorporation of nanomaterial such as SiO₂, ZnO₂, Al₂O₃, TiO₂, carbon nanotubes, nanoclays, carbon nanofibers and other nanomaterial. In the recent development, the addition of nanosilica (nS) has attracted increasing interest because of its filling effect which improve the particle size distribution thus reduced the porosity and permeability of cement based materials in effect increase durability and sustainability [2]. The aspect that makes nS an excellent cement replacement material is due to its high pozzolanicity resulted in enhanced durability of cement based material. It has proven to be an excellent admixture for cement to improve strength and durability and decrease permeability [2]. Besides that, nS is also typically a highly effective pozzolanic material and addition of nS into cement paste will improved the microstructure of the paste and reduced calcium leaching as nS reacts with CH and form additional C-S-H gel [3]. Highly pozzolanicity of nS particles is due to its size which is typically 5 - 100 nanometers (nm) with specific surface area (SSA) in the 25 - 50 m²/g range and its fine vitreous particles approximately 1000 times smaller than the average cement particles.

According to ASTM C125 pozzolan is a siliceous and aluminous material which itself possesses little or no cementitious value but which will in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [4]. Pozzolanic reaction in cement system is the reaction of silica with Calcium Hydroxide (CH) formed during the hydration of the OPC. It produces additional Calcium Silicate Hydrate (C-S-H) which is the main constituent for the strength and density in the harden binder paste. The pozzolanic activity includes two parameters; the maximum amount of lime (CaOH₂) that pozzolan can react to and the rate of reaction. The rate of the pozzolanic activity is related to the surface area of pozzolan particles where higher surface area of pozzolan particle gives higher pozzolanic reactivity. Larsen investigated and analyzed pozzolanic reaction by monitoring the production of CH based on changing cement and admixture [5]. Through his findings in 1961, it was determined that the concentration of CH, commonly known as Portlandite, can be used to quantify the C-S-H formed in the same specimen. There should be a decrease in the amount of Portlandite in a given specimen based on addition of silica and maximum nominal size of the graded silica due the pozzolanic reaction [5]. The objective of this study is to investigate the early pozzolanicity of nS modified cement paste (NMCP) by monitoring the presence of crystalline form CH and its subsequent reduction in abundance with time as the pozzolanic proceeds to form more amorphous C-S-H gel.

MATERIALS AND METHOD

MATERIALS AND SAMPLE PREPARATION

Nanosilica (nS) used in this study was Silicon Dioxide Nanopowder (CAS 14808-60-7) of 5-15nm particle size (BET) with 99.5% silica purchased from Sigma-Aldrich, Germany. Cement used was Ordinary Portland Cement (OPC) (ASTM Type 1 recognized by ASTM C150) manufactured by Cahaya Mata Sarawak Cement Sdn. Bhd (CMS). The chemical and mineralogical characteristics of the OPC are given in Figure 1. NMCP samples were prepared with water-to-cement ratio (w/c) of 0.5 and 1%, 3%, 5%, 7% and 10% cement replacements by weight. Universal Containers 30ml (28 mm diameter , 85mm height) were used as moulds. All samples were cured in the concrete laboratory at daily room temperature (T) and relative humidity (RH) in the range of 18-28°C and 65-90%, respectively. Powdered samples were prepared from small samples collected from the demoulded samples.

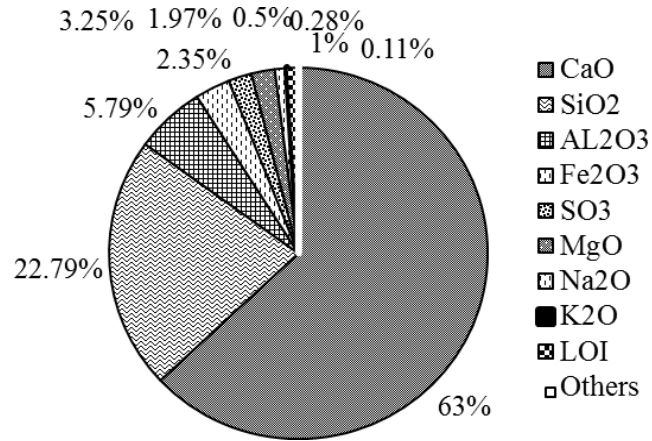


Figure 1: Chemical Composition of OPC

METHOD

Early pozzolanic reaction of Nanosilica Modified Cement Paste (NMCP) samples was analysed using characterization technique namely Fourier Transform Infrared Spectroscopy (FT-IR) at day 28. Test was performed on all samples with a Shimadzu Fourier Transform Infrared Spectroscopy (FT-IR) 81001 Spectrophotometer. The spectrum measurement method applied in this FT-IR study is Attenuated Total Reflection (ATR) method. Transmission infrared spectrum of each sample was recorded using a Fourier Transform Infrared Spectrophotometer (IRAffinity-1) in the region of 400 to 4000 cm^{-1} with 2.0 cm^{-1} resolution.

RESULTS AND DISCUSSION

Cement contains several chemical components with various functional groups, such as SiO_2 , SO_4 , H_2O , OH , and CO_3 , which are infrared active. The absorbed infrared wavelengths of the functional groups are dependent on the chemical surroundings of the group. Hence, there will be shifts of the absorption bands of the functional groups [6]. The main products of hydration, calcium hydroxysilicate of the C_2SH_2 and $\text{CSH}(\beta)$ types can be detected in the IR spectra from the ν_3 (Si-O) absorption band at 965–975 cm^{-1} and calcium hydroxide (CH) from the ν (OH) absorption band at 3640 cm^{-1} [7].

ANALYSIS SAMPLE WITHIN THE SAME PERCENTAGES OF NS REPLACEMENT WITH AGE DEVELOPMENT

Figure 2.1 to 2.5 showed the FT-IR spectrum for different percentages of nS replacement from day 1 to 28. When the hydration progresses from day 1 to 28, the CH band around 3630 cm^{-1} for 1%, 3%, and 5% NMCP shown a decrease in intensity (as shown in Figure 2.1B, 2.2B and 2.3B) which indicated that the CH contents were reduced with the age development. The trend of CH development is opposite if compared with control set.

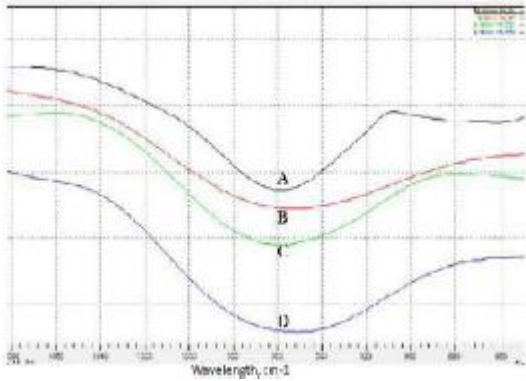


Figure 2.1A: C-S-H band of cement paste sample with 1% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

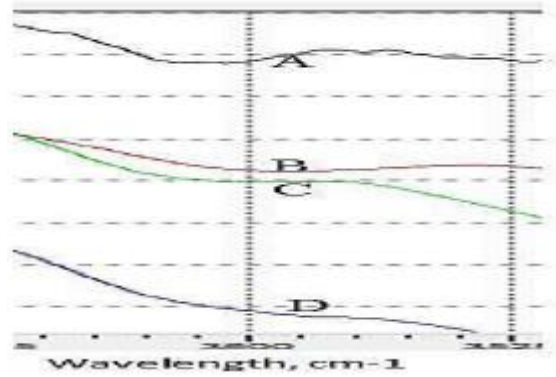


Figure 2.1B: CH band of cement paste sample with 1% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

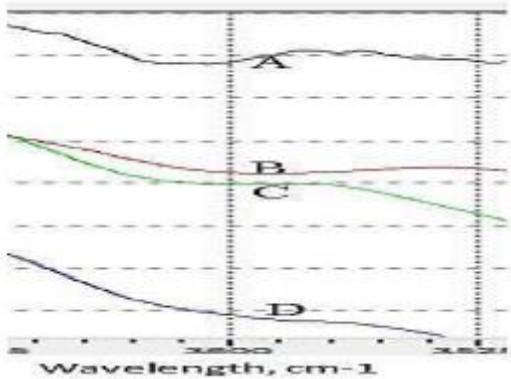


Figure 2.2A: C-S-H band of cement paste sample with 3% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

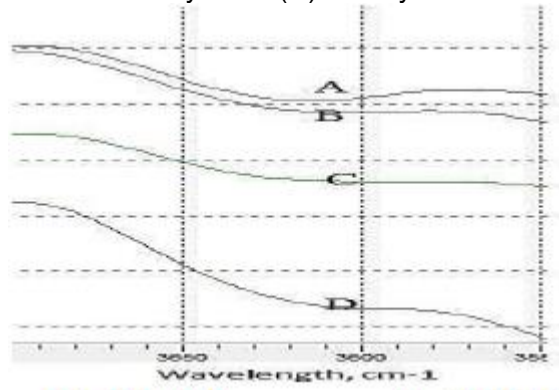


Figure 2.2B: CH band of cement paste sample with 3% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

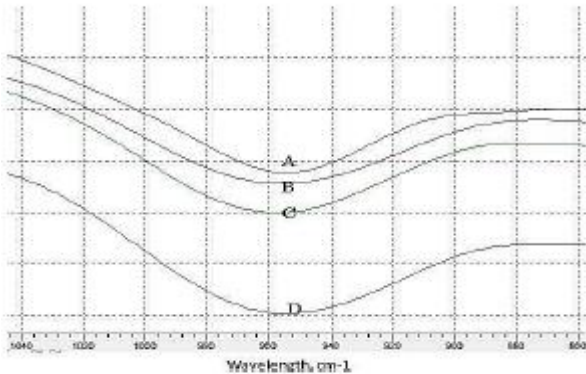


Figure 2.3A: C-S-H band of cement paste sample with 5% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

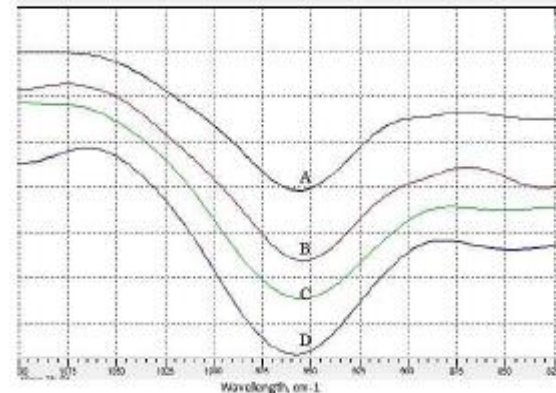


Figure 2.3B: CH band of cement paste sample with 5% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

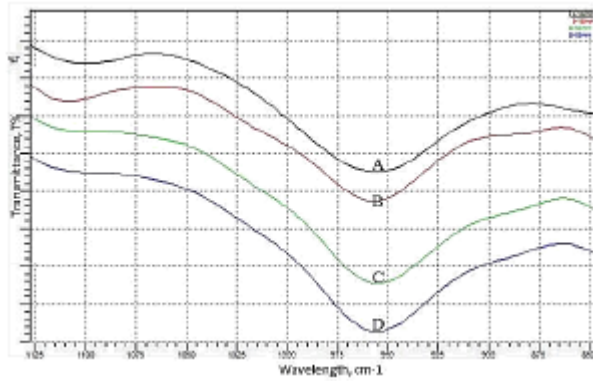


Figure 2.4A: C-S-H band of cement paste sample with 7% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

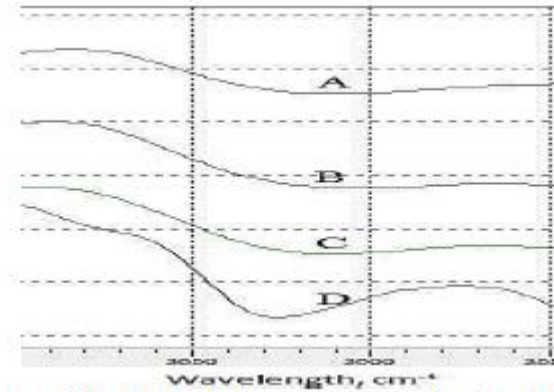


Figure 2.4B: CH band of cement paste sample with 7% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

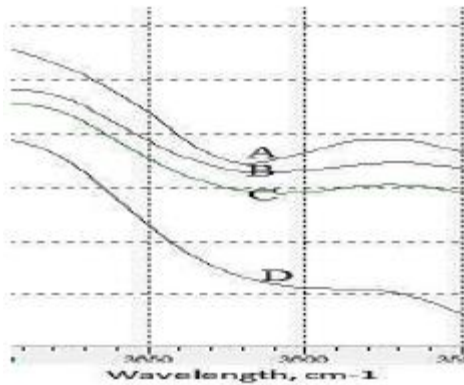


Figure 2.5A: C-S-H band of cement paste sample with 10% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

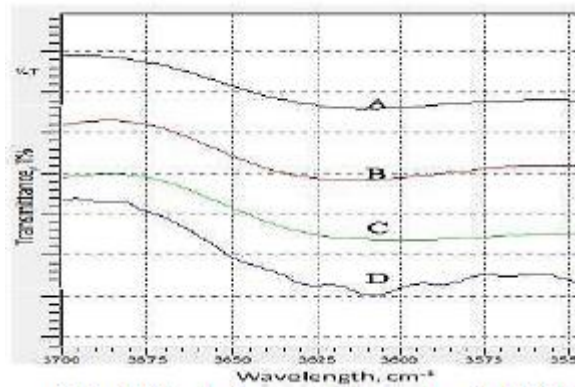


Figure 2.5B: CH band of cement paste sample with 10% NMCP at (A) 1 day (B) 7 days (C) 21 days and (D) 28 days

This phenomenon is due to the pozzolanic reaction of nS where nS reacts with CH to produce additional C-S-H. The CH band for 7% and 10% NMCP samples have shown an increasing intensity (as shown in Figure 2.4B and 2.5B). The increasing intensity of the CH band indicated that there was no reduction of the CH content in the sample. Therefore, pozzolanic reactivity did not occur for 7% and 10% NMCP. This may be due to the agglomeration of nS that prevented its participation in hydration reaction. The intensity of the C-S-H band increased as hydration progresses for all samples (as shown in figure 2.1A-2.5A). The C-S-H content for sample with 1%, 3% and 5% NMCP were more than 7% and 10% NMCP. This was due to the pozzolanic reactivity that produced an additional C-S-H that was purely from the cement hydration. As a summary, 1%, 3% and 5% NMCP showed pozzolanic reactivity and produced additional C-S-H to the cement sample. Meanwhile 7% and 10% NMCP did not show pozzolanic reactivity due to the agglomeration of nS.

COMPARISON BETWEEN SAMPLES WITH DIFFERENT PERCENTAGES OF NS REPLACEMENT AT DAY 28.

Figure 2.6 A and B showed comparison between samples with different percentages of nS replacement at day 28. The C-S-H band peak around 970 cm^{-1} for 1%, 3% and 5% NMCP samples (as shown in Figure 2.6A) have higher intensity compare to the control sample. The increasing trend of the C-S-H band indicated that there were more C-S-H produced in NMCP samples due to the pozzolanic reactivity of nS. The C-S-H band had shown the strongest intensity for the cement paste sample in 3% NMCP since it manifested the deepest and steepest downward peak for the C-S-H band as shown in Figure 2.6A. The 7% and 10% NMCP samples had low intensity in C-S-H band compare to the control sample. These indicated that there was lesser C-S-H produced in 7% and 10% NMCP sample. It can be concluded that, 3% was the optimum dosage for 5-15nm NMCP.

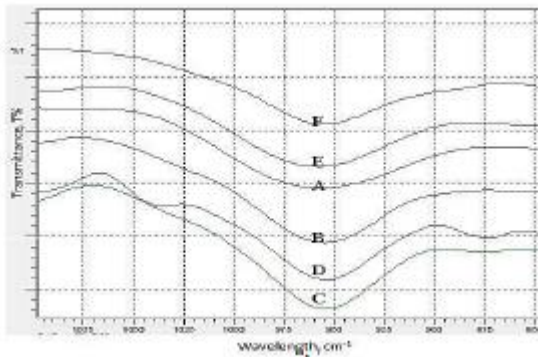


Figure 2.6A: C-S-H band around 970 cm^{-1} for (A) Control (B) 1% (C) 3% (D) 5% (E) 7% and (F) 10% NMCP sample at 28 day

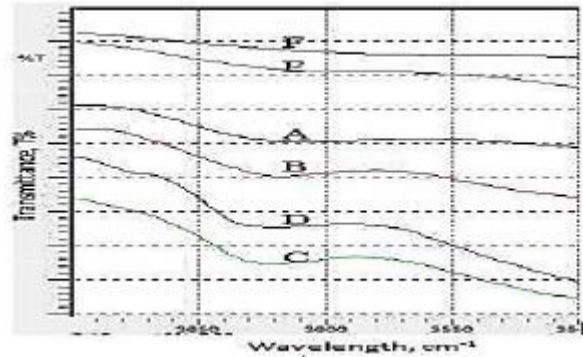


Figure 2.6B: CH band around 970 cm^{-1} for (A) Control (B) 1% (C) 3% (D) 5% (E) 7% and (F) 10% NMCP sample at 28 day

CONCLUSION

In conclusion, 1%, 3% and 5% NMCP samples have shown pozzolanic reactivity. The CH content in 1%, 3% and 5% NMCP samples decreased as the hydration progressed from day 1 day to day 28. The reduction of the CH is due to the pozzolanic reaction between nS and CH content in hydrated cement paste that produced additional C-S-H gel. Meanwhile 7% and 10% NMCP samples did not show pozzolanic reactivity due to agglomeration of nS that did not permit the nS to join the hydration process. Analysis done between samples with different percentages of nS replacement had found that the optimum dosage of nS by comparing the C-S-H content was 3%. Therefore, 3% NMCP was the optimum and the most effective percentage replacement that produced pozzolanic reactivity that can improve the microstructure of the cement system.

ACKNOWLEDGMENT

The research work reported in this paper has been funded by University Malaysia Sarawak (SGS/03(S113)/894/2012(26)).

REFERENCES

- [1] Malhotra, V.M, "Making Concrete Greener with Fly Ash", Concrete International, Vol.21, No.5, May 1999, pp.61-66
- [2] Sololev, K., (2009). Engineering of Silica nano particles for optimal performance in nano cement based materials: Nano Technology in Construction, Proceedings of the NICOM3, Prague, 139-148.
- [3] V . Ershadi; T. Ebadi; A.R Rabano; L. Ershadi; H. Soltanian. (2011). The Effect of Nanosilica on Cement Matrix Permeability in Oil Well to Decrease the Pollution of Receptive Environment. International Journal of Environmental Science and Development vol. 2.
- [4] American Society for Testing and Material (ASTM) C-125, Standard terminology relating to concrete and concrete aggregates.
- [5] Larsen, G. "Microscopic Point Measuring: A Quantitative Petrographic Method of Determining the Ca(OH)₂ Content of the Cement Paste in Concrete". Magazine of Concrete Research. 1961.
- [6] Ylemen, E.R., (2013) Early Hydration of Portland Cement – An Infrared Spectroscopy Perspective Complemented by Calorimeter and Scanning Electron Microscopy. Department of Chemical and Biological Engineering, Chalmers University of Technology, Gothenburg, Sweden 2013.
- [7] Conjeand, M., and Boyer, H. (1980), Some Possibilities of Raman Microprobe in Cement Chemistry, Cem. Concr. Res., 10:61.

The book is based on scientific and technological advances in various Structural Engineering and Construction Materials areas of Civil Engineering. It nurtures therefore the exchange of discoveries among research workforces worldwide including those focusing on the vast variety of facets of the fundamentals and applications within the Structural Engineering and Construction Materials arena. To offer novel and rapid developments, this book contains original contributions covering theoretical, physical experimental, and/or field works that incite and promote new understandings while elevating advancement in the Structural Engineering and Construction Materials fields. Works in closing the gap between the theories and applications, which are beneficial to both academicians and practicing engineers, are mainly of interest to this book that paves the intellectual route to navigate new areas and frontiers of scholarly studies in Structural Engineering and Construction Materials



e ISBN 978-967-2298-90-8



9 7 8 9 6 7 2 2 9 8 9 0 8