Fisika LPPM

Volume 6 Issue 1, April 2021

SPEKTRA
Jurnal Fisika dan Aplikasinya

DOI: doi.org/10.21009/SPEKTRA
e-ISSN : 2541-3392

SPEKTRA: Jurnal Fisika dan Aplikasinya
Volume 6 Issue 1, April 2021
DOI: doi.org/10.21009/SPEKTRA.06100

Abstracting and Indexing:

Google Scholar	PKP|INDEX	Crossref	BASE
sinta Science and Technology Index	Indonesia OneSearch	ACADEMIA	Microsoft Academic Search
OpenAIRE	WorldCat	INTERNATIONAL Scientific Indexing	GARUDA Garba Rujukan Digital
MORAREF	Scilit		

Editorial Office

Program Studi Fisika Fakultas MIPA
Kampus A Universitas Negeri Jakarta
Gedung K.H. Hasyim Asyari Lt.10
Jalan Rawamangun Muka No.1
Rawamangun-Pulogadung Jakarta Timur, 13220

Reviewers (Mitra Bebestari)

EDITORIAL FOREWORD

SPEKTRA: Jurnal Fisika dan Aplikasinya is dedicated to all physics practitioners. The coverage of SPEKTRA includes: Instrumentation and Computational Physics, Material Physics, Medical Physics and Biophysics, Astrophysics, Theoretical Physics, Particle and Nuclear Physics, Environment Physics, Renewable Energy, and other fields related to the application of physics.

SPEKTRA Volume 6 issue 1 contains 8 papers: 1) The Development of Image Processing Method on The Automatic Reading System of The Glass Thermometer Using A Digital Camera; 2) The Data Acquisition Role on Static Test for Validation of RX320 Rocket Motor Design; 3) Seed Mediated Synthesis of Hexagonal S-Doped ZnO Nanorod and Its Physical Properties; 4) Increasing The Calcium Silicate Hydrate Amount in Reactive Powder Concrete Using Marble Powder; 5) Modification of Purun Tikus (Eleocharis Dulcis) as A Natural Fiber Composite Using KMnO4 and NaOH; 6) Simulation of Peak Ground Acceleration and Pseudo Spectral Acceleration of Palu Earthquake September 28th 2018; 7) The Bone Microstructure Identification Model Based on Backscatter Mode of Ultrasound; and 8) The Simulation of Granular Particle on Dry And Moisturized Porous Horizontal Surfaces.

Hopefully, SPEKTRA can be a reference for readers and researchers in developing physics and its application.

Jakarta, 30 April 2021

Editor-in-Chief,

Widyaningrum Indrasari

SPEKTRA: Jurnal Fisika dan Aplikasinya
Volume 6 Issue 1, April 2021

CONTENTS

SPEKTRA: JURNAL FISIKA DAN APLIKASINYA

UNIVERSITAS NEGERI JAKARTA

P-ISSN : 25413384 E-ISSN : 25413392 Subject Area : Science, Engineering

1 Impact Factor

450 Google Citations

S3 Current Acreditation

Google Scholar Garuda Website Editor URL

History Accreditation

2016 2017 2018 2019 2020 2021 2022 2023 2024 2025

Google Scholar Garuda

INCREASING THE CALCIUM SILICATE HYDRATE AMOUNT IN REACTIVE POWDER CONCRETE USING MARBLE POWDER

Authors : W Kushartomo, H Wiyanto, D Christianto Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 25-36, 2021

2021 0 cited S3 Journal

THE SIMULATION OF GRANULAR PARTICLE ON DRY AND MOISTURIZED POROUS HORIZONTAL SURFACES

Authors : D Muliyati, D Sumardani, F Bakri, H Permana, E Handoko, NLK Sari Spektra: Jurnal Fisika Dan Aplikasinya 6 (1), 71-88, 2021

2021 0 cited S3 Journal

SIMULATION OF PEAK GROUND ACCELERATION AND PSEUDO SPECTRAL ACCELERATION OF PALU EARTHQUAKE SEPTEMBER 28TH 2018

Authors : A Nasruroh, B Sunardi, MFH Hiola, H Subakti Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 49-60, 2021

2021 0 cited S3 Journal

THE BONE MICROSTRUCTURE IDENTIFICATION MODEL BASED ON BACKSCATTER MODE OF ULTRASOUND

Authors : U Umiatin, T Oktaviana, E Wijaya, R Riandini, F Yusuf Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 61-70, 2021

2021 0 cited S3 Journal

MODIFICATION OF PURUN TIKUS (ELEOCHARIS DULCIS) AS A NATURAL FIBER COMPOSITE USING KMnO4 AND NaOH

Authors : NH Haryanti, S Suryajaya, L Banowati, M Rahmah, A Safi'i Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 37-48, 2021

2021 0 cited S3 Journal

THE DEVELOPMENT OF IMAGE PROCESSING METHOD ON THE AUTOMATIC READING SYSTEM OF THE GLASS THERMOMETER USING A DIGITAL CAMERA

Authors : G Gianto, V Firmansyah, I Setiawan, A Rifani Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 1-8, 2021

2021 0 cited S3 Journal

SEED MEDIATED SYNTHESIS OF HEXAGONAL S-DOPED ZnO NANOROD AND ITS PHYSICAL PROPERTIES

Authors : Y Rati, AA Umar, Y Hamzah, AS Rini Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 19-24, 2021

2021 0 cited S3 Journal

THE DATA ACQUISITION ROLE ON STATIC TEST FOR VALIDATION OF RX320 ROCKET MOTOR DESIGN

Authors : S Setiadi, B Wicaksono, K Kurdianto, BH Jihad Spektra: Jurnal Fisika dan Aplikasinya 6 (1), 9-18, 2021

2021 0 cited S3 Journal

THE COMPATIBILITY OF MODEL FOR LOW SHEAR FLOW ANALYSIS IN DEVELOPING PLASTICIZED HTPB-BASED BINDER

Authors : A Restasari, LH Abdillah, R Ardianingsih, B Wicaksono, RS Budi Spektra: Jurnal Fisika Dan Aplikasinya 5 (3), 189-200, 2020

2020 1 cited S3 Journal

COMPARISON STUDY OF VERTICAL CYLINDER TANK DIAMETER MEASUREMENT BETWEEN STRAPPING AND OPTICAL METHOD

Authors : V Firmansyah, P Nugroho, HY Prihensa, A Muslim Spektra: Jurnal Fisika Dan Aplikasinya 5 (3), 231-238, 2020

2020 0 cited S3 Journal

View more ...

SURAT TUGAS
Nomor: 1083-R/UNTAR/PENELITIAN/III/2022

Rektor Universitas Tarumanagara, dengan ini menugaskan kepada saudara:

1. **WIDODO KUSHARTOMO, S.Si., M.Si., Dr.**
2. **HENNY WIYANTO, Ir., M.T.**
3. **DANIEL CHRISTIANTO, S.T., M.T.**

Untuk melaksanakan kegiatan penelitian/publikasi ilmiah dengan data sebagai berikut:

Judul	:	INCREASING THE CALCIUM SILICATE HYDRATE AMOUNT IN REACTIVE POWDER CONCRETE USING MARBLE POWDER
Nama Media	:	SPEKTRA
Penerbit	:	JURUSAN FISIKA UNJ
Volume/Tahun	:	6/2021
URL Repository	:	http://journal.unj.ac.id/unj/index.php/spektra/issue/view/1332

Demikian Surat Tugas ini dibuat, untuk dilaksanakan dengan sebaik-baiknya dan melaporkan hasil penugasan tersebut kepada Rektor Universitas Tarumanagara

01 Maret 2022
Rektor

UNIVERSITAS TARUMANAGARA REKTOR

Prof. Dr. Ir. AGUSTINUS PURNA IRAWAN

Print Security : 293cc5564a0a56720c1dd2add6c092e4

SPEKTRA: Jurnal Fisika dan Aplikasinya
Volume 6, Issue 1, April 2021
Homepage: doi.org/10.21009/SPEKTRA

Check for updates

DOI: doi.org/10.21009/SPEKTRA.061.04

INCREASING THE CALCIUM SILICATE HYDRATE AMOUNT IN REACTIVE POWDER CONCRETE USING MARBLE POWDER

Widodo Kushartomo*, Henny Wiyanto, Daniel Christianto

Civil Engineering Undergraduate Study Program, Faculty of Engineering, Universitas Tarumanagara, Jl. Let. Jend. S. Parman No. 1 Jakarta 11440, Indonesia

*Corresponding Author Email: widodo@untar.ac.id

Received: 5 December 2020
Revised: 11 February 2021
Accepted: 16 February 2021
Online: 28 April 2021
Published: 30 April 2021

SPEKTRA: Jurnal Fisika dan Aplikasinya
p-ISSN: 2541-3384
e-ISSN: 2541-3392

ABSTRACT

This research aims to make ultra high strength Reactive Powder Concrete (RPC) with marble powder as one of the components. The use of marble powder can increase Calcium Silicate Hydrate (CSH) and the strength of RPC. The research method used to achieve the objectives is experimental and divided into two steps. The first step is the characterization of a marble and micro silica powder mixture. Stoichiometry calculations are performed to determine the composition of the mixture. The test sample is made in the form of pellets consisting of a mixture of marble powder, micro silica, and water. The water content used is at 30% - 50%. Maintenance is carried out by immersion in water with the temperature of 20°C for 27 days and in steam at temperatures 200°C, 250°C, and 300°C with 2 atm pressure for 4 hours. Material characterization is carried out using X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The second step in this research is the RPC compressive strength test. The test sample is made in the form of a cube measuring 50 x 50 x 50 mm. This cube is a mixture of water, cement, micro silica, marble powder, sand, and superplasticizer. Material composition is arranged based on the characterization of the sample pellet test, and maintenance of the sample cube test is carried out as in the sample pellet test.

Keywords: CSH, RPC, strength, temperature, characterization

INTRODUCTION

The marble is a rock that resulted from a metamorphosis or a process made from limestone which contains carbonate. As a result of recrystallization of the structure from which the rock originates, it forms a new texture and grain regularity. Indonesian marble is estimated to be around 30-60 million years old. In Indonesia, the usage of marble is quite widespread. The use of marble can be categorized into two motifs: namely ordinario and staturio. Ordinario marble is usually used for manufacturing baths, tables, and walls, while staturio is often used for sculpture.

The processing and utilization of new marble use water, so it produces waste. This waste is accommodated in a pool (reservoir), which gradually settles then hardens. Marble waste can be used so as not to pollute the environment and economic value. Marble waste can be processed with dolomite as a mixture of building materials to reduce environmental pollution. The effects of using dolomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete were investigated. Test results indicate that the optimized assay of dolomite and waste marble powder as a replacement by weight of cement had the best compressive and flexural strengths [1].

Marble has the main content of the element calcium, which binds water to form compounds in the form of calcium hydroxide, chemically written as $Ca(OH)_2$. Calcium has several unique properties: chemically, calcium is alkaline. So, it quickly forms reactions with strong acids. Calcium in the calcium carbonate compound $CaCO_3$ releases carbon dioxide on heating to form calcium dioxide, which is usually called lime, and chemically written as follows [2].

$$\underset{\text{Calcium carbonate}}{CaCO_3} \longrightarrow \underset{\text{Calcium oxide}}{CaO} + \underset{\text{carbon dioxide}}{CO_2} \quad (1)$$

$$CaO + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{calcium hydroxide}}{Ca(OH)_2} \quad (2)$$

Reactive Powder Concrete (RPC) is a concrete composed of materials with microscopic particle sizes, such as cement, micro silica, quartz sand, quartz powder, and superplasticizer. RPC is concrete with excellent mechanical properties: the highest compressive strength ever achieved in making RPC ranges from 120.0 - 150.0 MPa, and the highest flexural strength ever achieved ranges from 20.0 - 30.0 MPa [3]. RPC is characterized by the use of cement and micro-silica in large quantities and does not use coarse aggregate. Because its materials have tiny particle sizes, RPC can be arranged in a compact and has a much better homogeneity when compared to concrete in general. Micro silica in RPC is a material mainly consisting of amorphous SiO_2. The SiO_2 content in micro silica reaches 98%, far more compared to volcanic ash, flying ash, or other pozzolanic material, which only ranges between 40% - 56% [4]. Micro silica has functioned as an activator for the occurrence of pozzolanic reactions with one of the cement hydration products, namely calcium hydroxide. It also functions to fill small voids in concrete.

Research conducted on RPC [3] still shows weaknesses, one of which is covered by quartz powder. Quartz Powder in the making of RPC has a function as a pore filler. In a tiny size, high pressure, and high temperature during RPC maintenance, quartz flour can react with C-S-H to form xonolite so that the compressive strength of RPC can increase significantly [5]. In Indonesia, quartz powder is not easy to get. In order to obtain it, imports from China, India, or Europe are needed, so sustainability in making RPC becomes a huge obstacle. This research will use marble powder instead of silica powder in the manufacturing of RPC. The first reason for using marble powder instead of silica powder in making RPC is that marble powder contains calcium as its main component. This calcium is expected to react with micro silica in the pozzolanic reaction to form calcium silicate hydrate compounds. The higher volume of calcium silicate hydrate is formed, the more the strength of RPC will increase, as explained above. Secondly, marble powder is a readily available material in Indonesia and a waste from marble production plants. Thus, marble powder waste as an RPC maker material can reduce environmental pollution [6].

RESEARCH METHOD AND MATERIALS

To achieve the objectives, the research method used in data collection is experimental research in which several tests, treatments, and characterization methods are carried out to determine the amount of calcium silicate formed based on the reaction between marble powder and micro silica, using the following research steps.

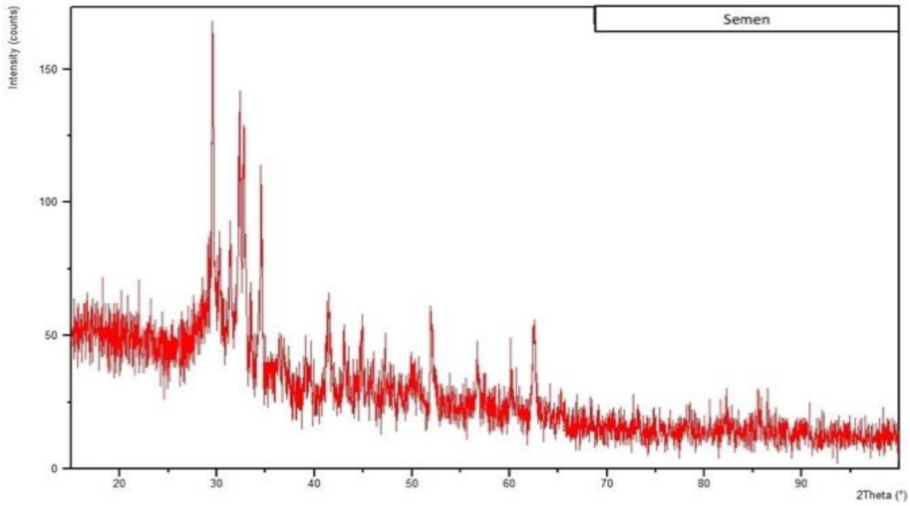
The material used in this research is cement, water, silica fume, marble powder, sand, and superplasticizer with a weight ratio of 1.00 : 0.20 : 0.25 : 0.15 : 1.10 : 0.03. Samples are made by mixing all materials into a mixer which is rotating at a speed of 1500 rpm. Samples were cast on the mold with a size of 5.0 cm x 5.0 cm x 5.0 cm and were treated by soaking in water at a temperature of 20ºC for 27 days, followed by treatment at 200ºC as mix-1; 250ºC as mix-2; and 300ºC as mix-3 in an autoclave for 4 hours and with 2 atm pressure. All samples were compared with a typical mix (without marble powder) examined using XRD, SEM, and compressive strength testing was performed.

Cement is used as a binding agent between the constituent RPC constituents. The cement used is portland cement type 1. Silica fume does not have atoms, has no common configuration, or is called amorphous. The size of the granules ranges between 0.1 - 0.2 µm. Silica fume contains 98% of SiO_2, with fineness of 20,000 m^2 / kg and density of 2,200 kg / m^3 [4]. The sand used is quartz sand, which has SiO_2 as a major composition, 150 µm - 600 µm grain size, zone 4 on grain grading, irregular shape, and hardness of 7 mohs. Marble mainly contains calcium, which binds water to form compounds in calcium hydroxide, chemically written as $Ca(OH)_2$. Each marble powder granule size ranges between 10µm - 40µm [6]. Superplasticizer is used to improve the workability of the mortar so that it can disperse the mortar well. The superplasticizer suitable for this research comes from polycarboxylate-based polymers.

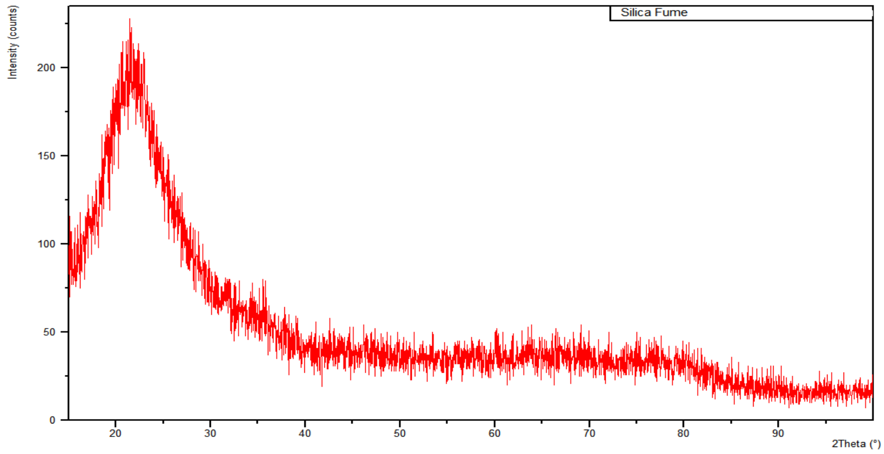
RESULTS AND DISCUSSION

XRD Characterization

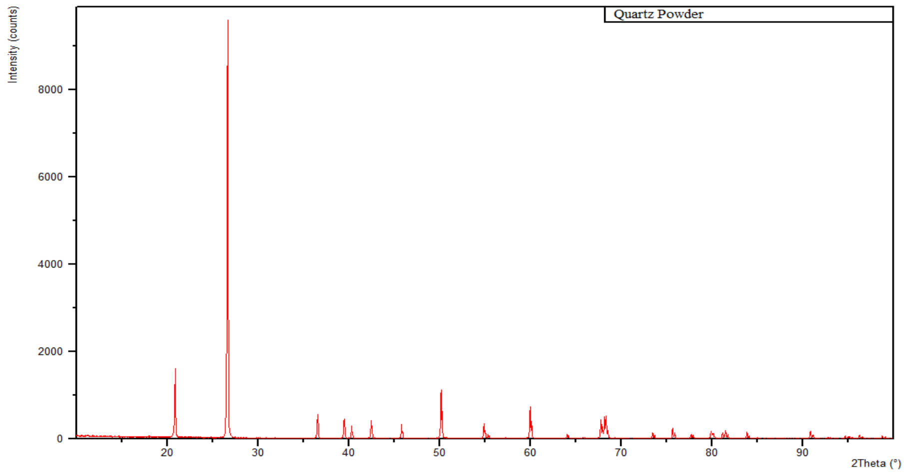
In the XRD spectrum of raw materials for cement, silica fume, and marble powder, as shown in FIGURE 1, the spectrum peaks at certain angles depict the mineral components contained therein. FIGURE 1a shows the mineral component of tricalcium silicate (C_3S) found in the diffraction angle 2θ = 32.15°, 32, 50°, 34, 37°, and 41.11°. The minerals in calcium silicate (C_2S) are present at the diffraction angle 2θ = 32.66°, 33.11°, and 41.63°. Tricalcium silicate is at the diffraction angle 2θ = 17.50°, 39.40°, and 44.57°, while the mineral component of calcium aluminoferrite (C_4AF) is at the diffraction angle 2θ = 34.38°, 50,56°, and 50.74° [7]. The four minerals are the main components of cement detected in the XRD spectrum. The XRD spectrum of Silica fume is shown in FIGURE 1b. This spectrum represents amorphous material, meaning that the silica fume of the atoms is not regularly arranged [4]. This amorphous material is very reactive to calcium hydroxide $Ca(OH)_2$ at room temperature, so it is widely used in the concrete industry. The XRD spectrum of quartz is presented in FIGURE 1c, which shows the crystalline spectrum of SiO_2 calcium silica with diffraction angles 2θ = 20.82°, 26.62°, and 36.52° [8]. By finding only three diffraction angles 2θ, the type of material can already be described.



1a.



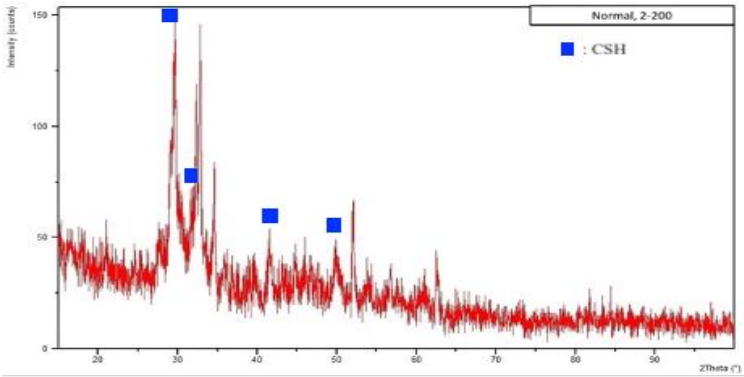
1b.



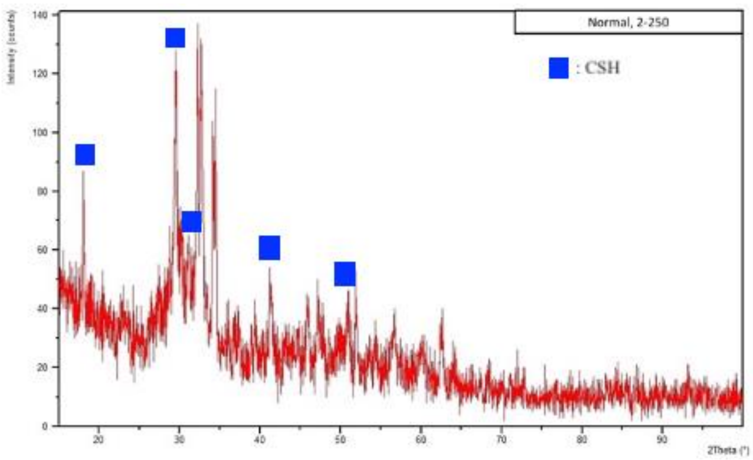
1c.

FIGURE 1. XRD Patterns of: a. Cement, b. Silica Fume, c. Silica sand.

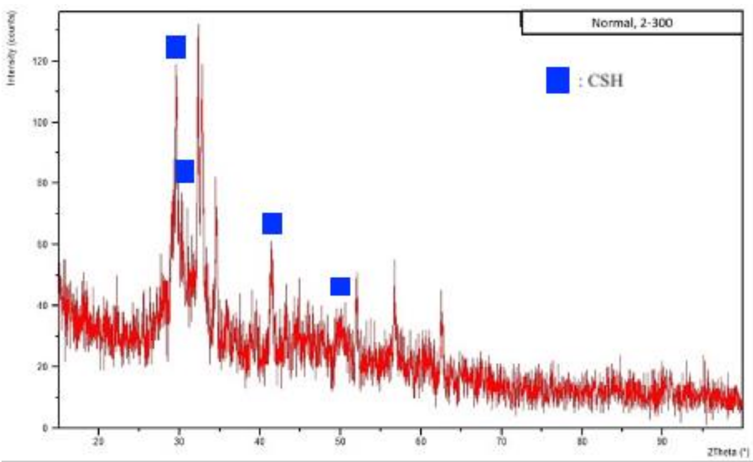
This research is conducted on concrete with typical composition, which means that the concrete is only composed of cement, water, silica fume, and superplasticizer. The XRD spectrum of concrete with a standard composition is shown in FIGURE 2. This spectrum clearly shows the presence of calcium silicate hydrate or known as (CSH) [9], at a diffraction angle of 2θ 16.9°, 29.2°, 32.0°, 42.7°, 49.8°.



2a.



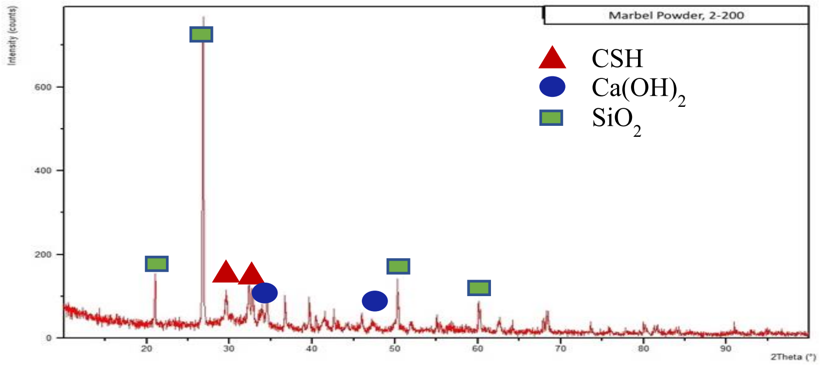
2b.



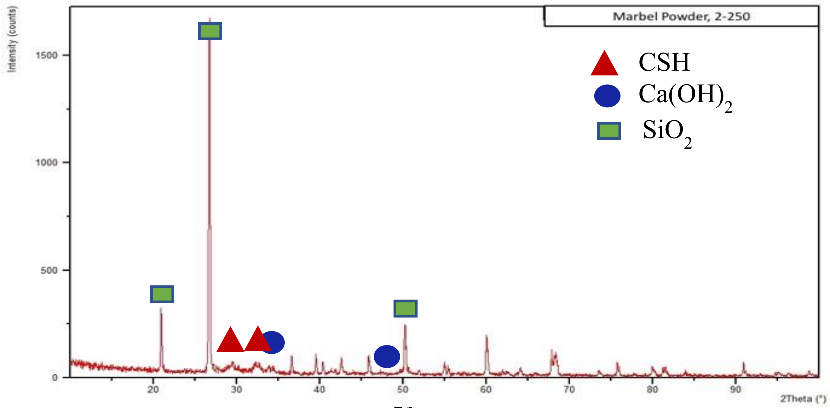
2c.

FIGURE 2. XRD Patterns of the standard mix at temperatures: a. 200°C, b. 250°C, c. 300°C.

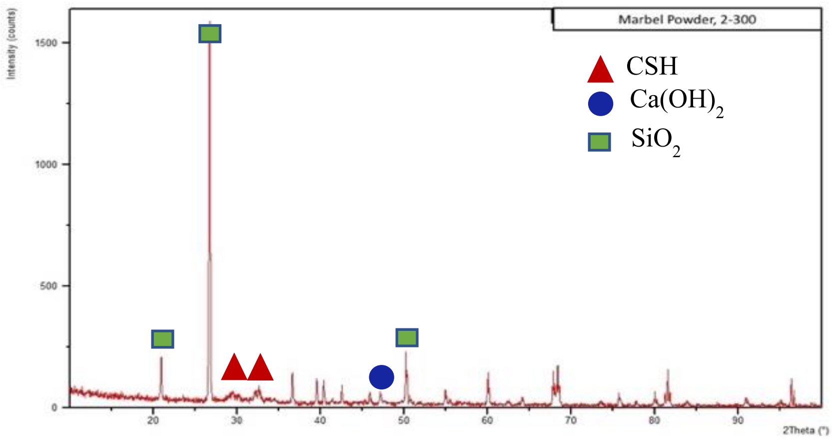
Examination using X-ray diffraction in mix-1, mix-2, and mix-3 samples is shown in FIGURE 3. In FIGURE 3, the intensity of the quartz spectrum dominates the appearance of other spectra, such as the CSH spectrum. However, the CSH spectrum is still evident in the position of the material. FIGURE 3a shows the CSH spectrum, which is much clearer when compared to the mix-2 spectrum of FIGURE 3b and the mix-3 spectrum of FIGURE 3c. This shows that maintenance using an autoclave at 200°C can increase CSH formation compared to maintenance at 250°C and 300°C. The appearance of the XRD spectrum in FIGURE 3 also shows the use of quartz flour in the process of making reactive powder concrete can increase the formation of CSH in concrete. CSH in concrete has a crucial function, which is to form strength. The CSH spectrum is not the same as the SiO_2 spectrum because CSH is a semi-crystal and not a pure crystal.



3a.



3b.



3c.

FIGURE 3. XRD Patterns of concrete sample: a. mix-1, b. mix-2, c. mix-3.

SEM Analysis

The formation and distribution of hydration products of hydrated cement paste with three different mix proportions are pictured below. The microstructure of the three mixes was examined and compared with the normal mix. The microstructure and strength properties of all three mixes were correlated based on the hydration products formed after 28 days. The reason behind the strength of the concrete was analyzed and explained based on the growth of hydration products in the microstructure of concrete mixes.

The SEM micrograph pictures in FIGURE 4 illustrate the microstructural variation during the hydration process and production of hydration products in Mix 1. The rate of hydration was sufficient to achieve the strength of concrete. C-S-H formation was complete. The development of chemical reaction between the portlandite from marble powder $Ca(OH)_2$ and silica in the silica fume results in the concrete having inadequate strength. In the SEM micrograph, the lower presence of ettringite was clearly evidenced in the micrograph, which leads to the increase of development and distribution of C-S-H gel in the hardened concrete.

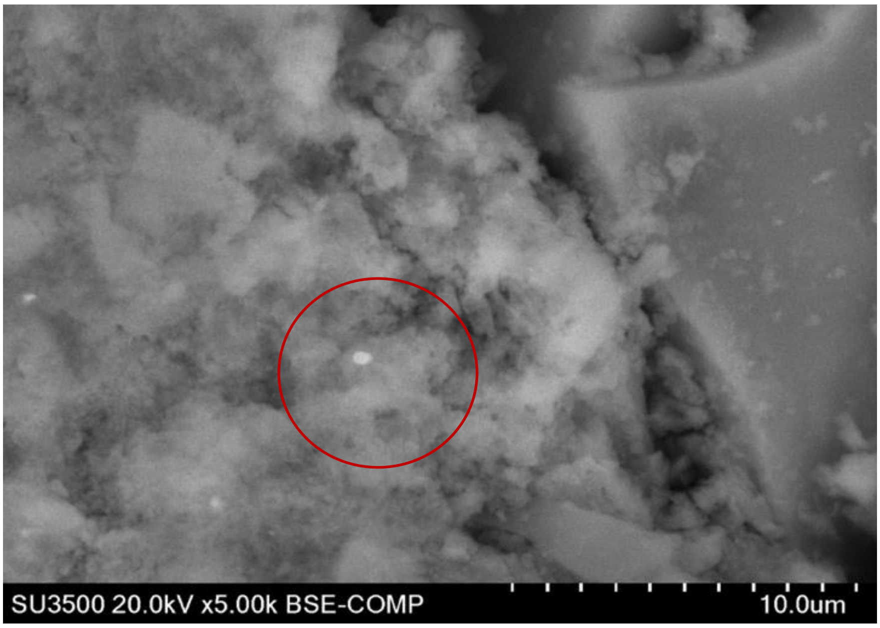


FIGURE 4. SEM Micrograph of Mix-1

The microstructure of the hydrated cement paste of Mix-2 was shown in FIGURE 5. The considerable strength obtained in this mix was due to the pozzolanic activity of silica fume. The chemical reaction of silica fume with the portlandite $Ca(OH)_2$ leads to the production of additional CSH gel, which was the main reason for the strength of this mix [10,11,12]. The rate of hydration process in Mix-2 was similar to the typical concrete mix, but the existence of mineral elements was quite different from Mix-3, which manipulates the strength of concrete curing temperature. Even though the strength of the concrete mix was not up to the anticipated level, it reached a considerable strength, which means it can also be used as a replacement for the normal concrete mix in certain concreting works.

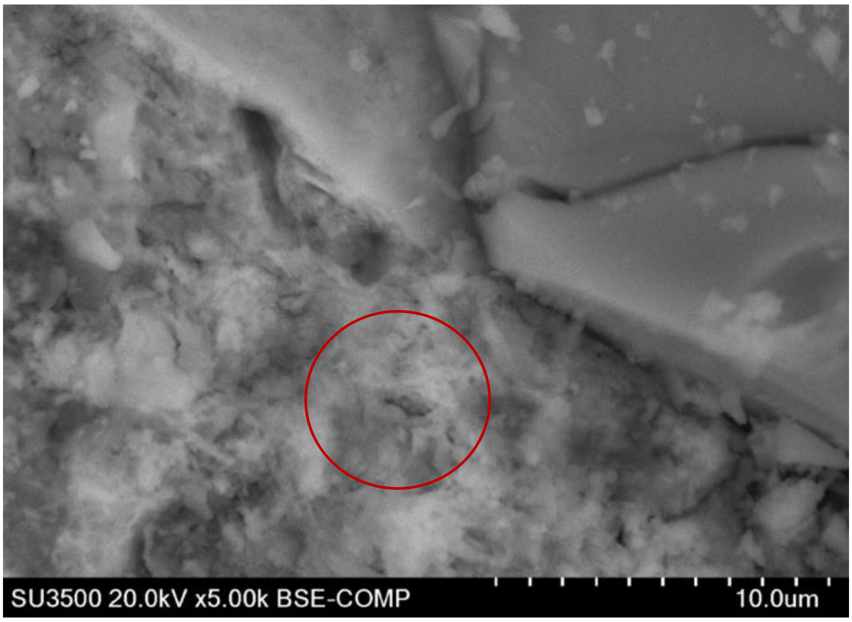


FIGURE 5. SEM Micrograph of Mix-2

In FIGURE 6, The SEM image of Mix-3 visualizes the microstructure of hydrated cement paste. From the SEM micrograph of the hardened concrete, the distribution of CSH was nearly decreased due to elevated curing temperature. In this mix, the range of CSH development was lower, which may be due to unreacted particles of marble powder present in the mix. The accumulation of other major mineral elements, such as Portlandite $Ca(OH)_2$ and Calcite ($CaCO_3$) crystals, are found in the microstructure of the mix. The main reason for the decrease in strength was the lack of hydration of particles, which is present in the hardened cement matrix. In other words, the amount of CSH formed is lower than in mix-1. The utilization of supplementary materials such as marble powder in the mix was unsuccessful because of the lack of chemical reaction between marble powder and the silica fume in curing temperature [6]. In this mix, due to the unreacted particles in the hardened cement paste, the strength of concrete mix was affected.

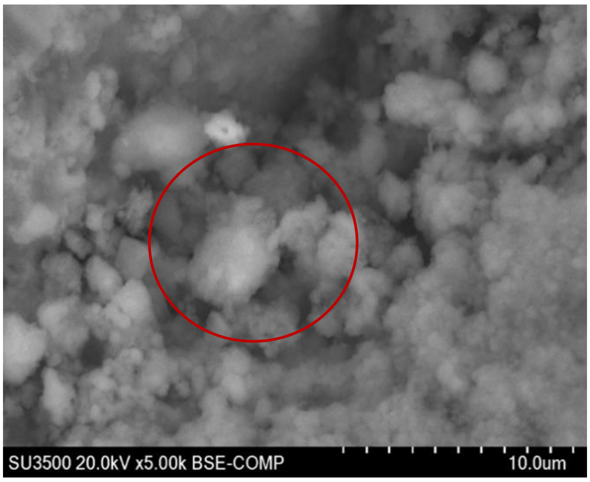


FIGURE 6. SEM Micrograph of Mix-3

Compressive Strength

Compressive strengths of four concrete mixes were determined after 28 days, and their comparison details are pictured in FIGURE 7. The concrete cubes were tested for compressive strength after 28 days of curing, and a higher value of compressive strength was obtained in Mix-1, which was slightly higher than mix-2. Even though Mix-3 did not reach the target strength, 50,0 MPa, it reached enough strength to be used as an alternative for the standard concrete mix in specific concreting works.

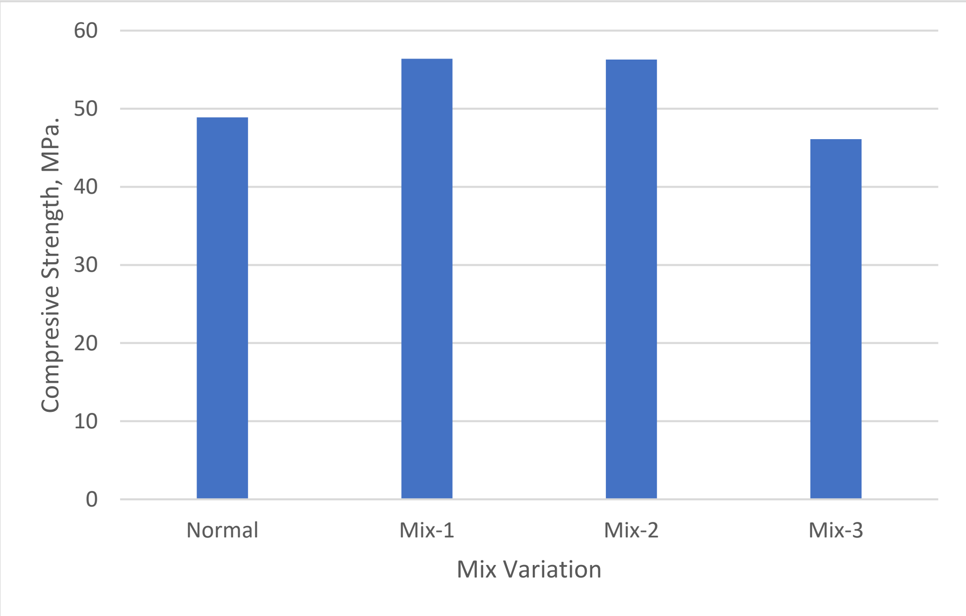


FIGURE 7. Concrete Compressive Strength

CONCLUSION

The conclusion obtained from the experimental study is that the addition of marble powder to reactive powder concrete (RPC) can increase the amount of calcium silicate hydrated (CSH). The increase in the amount of calcium silicate hydrated occurred due to the pozzolanic reaction between silica fume and marble powder. The rate of the pozzolanic reaction can be increased by applying pressure and increasing the temperature during the curing process.

Increasing the amount of hydrated calcium silicate in reactive powder concrete increases the compressive strength of the concrete. The increased amount of hydrated calcium silicate on RPC with the addition of marble trunks can be maximized if RPC is cured using an autoclave at a pressure of 2 atm and a temperature of 250°C for 4 hours.

REFERENCES

[1] Ali Ergun, “Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete,” Construction and Building Materials, vol. 25, no. 2, p. 806-812, 2011.

[2] S. Mindess and J. F. Young, “Cemen,” Concrete, Prentice-Hall, New Jersey, USA, 2002.

[3] W. Kushartomo *et al*., "Mechanical Behaviour of Reactive Powder Concrete with Glass Powder Substitute," EACEF5, *Procidia Engineering*, vol. 125, pp. 617-622, 2015.

[4] R. Maddalena, C. Hall, and A. Hamilton, "Effect of silica particle size on the formation of calcium silicate hydrate [C-S- H] using thermal analysis," Therm. Acta, vol. 672, pp. 142-149, 2019.

[5] W. Kushartomo *et al.*, "Pengaruh Penambahan Quartz Powder pada Reactive Powder Concrete terhadap Terbentuknya Kalsium-Silikat-Hidrat," *Jurnal Teknik Sipil-ITB*, vol. 20, no. 3, Dec 2013.

[6] P. J. Chavhan and S. D. Bhole, "To Study the Behaviour of Marble Powder as Supplementary Cementitious Material in Concrete," vol. 4, pp. 377-381, April 2014.

[7] K. L. Scrivener *et al*., "Quantitative Study Of Portland Cement Hydration By X-Ray Diffraction/Rietveld Analysis And Independent Methods," Cement and Conc. Research, vol. 34, iss. 9, pp. 1541-1547, Sept 2004.

[8] R. F. Zuo *et al*., "Mineralogical And Chemical Characteristics Of A Powder And Purified Quartz From Yunnan Province," De Gruyter, vol. 8, iss. 1, June 2017, DOI: 10.1515/geo-2016-0055.

[9] W. A. Hunnicutt, "Characterization Of Calcium-Silicate-Hydrate And Calcium-Alumino-Silicate-Hydrate," M. S. thesis, Dept. Civil Eng, Univ. of Illinois, Illinois, Urbana, 2013.

[10] A. Nonat, "The structure and stoichiometry of C-S-H," Cement and Concrete Research, vol. 34, iss. 9, pp. 1529-11534, Sept 2004.

[11] S. Y. Hong and F. P. Glasser, "Phase Relations in The CaO–SiO2–H2O System to 200 °C at Saturated Steam Pressure," IJIRS, Eng. Tech, vol. 6, iss. 6, June 2017.

[12] A. S. Adithya Saran and P.Magudeswaran, "SEM Analysis on Sustainable High-Performance Concrete," IJIRSET, vol. 6, no. 6, pp. 10237-10246, June 2017.