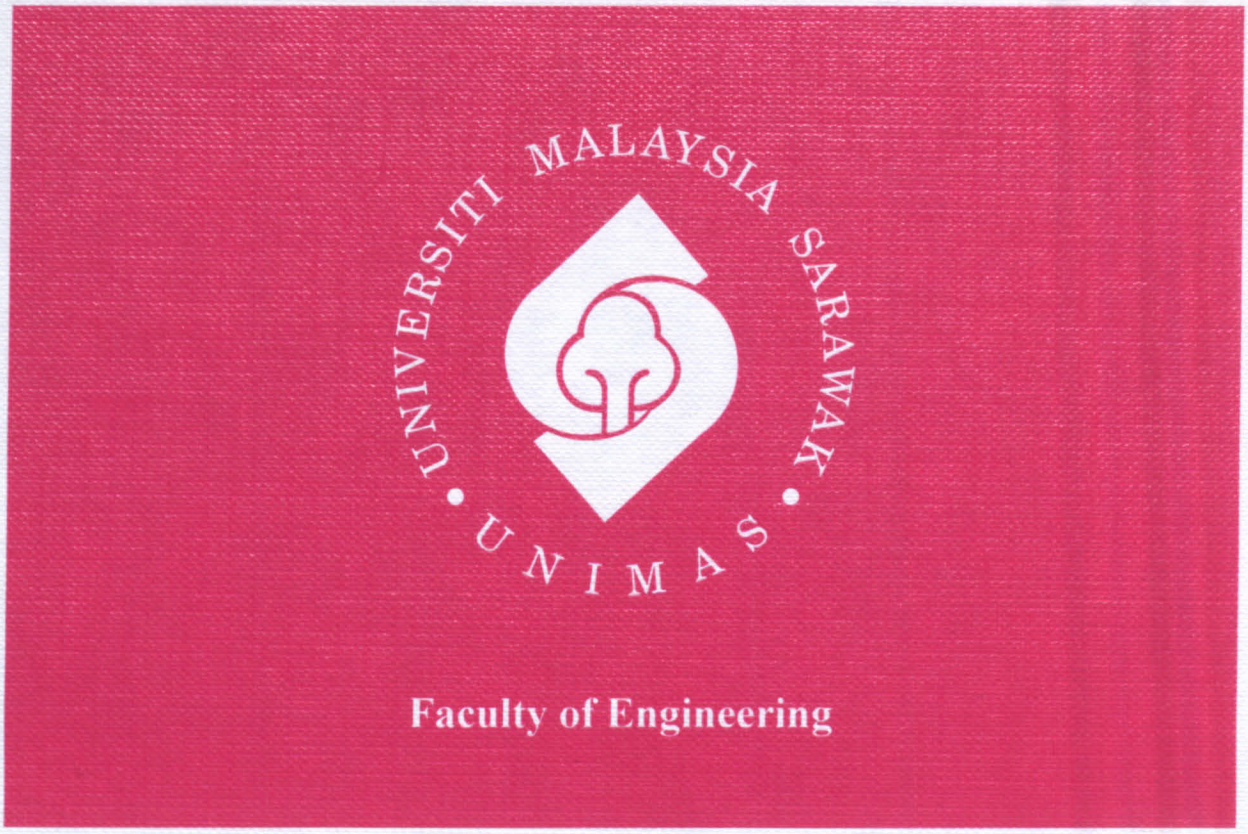

EXPERIMENTAL INVESTIGATION ON RHEOLOGICAL PROPERTIES OF SILICA FUME CEMENT PASTE AND ITS POTENTIAL APPLICATION IN GEOTECHNICAL ENGINEERING

Ting Aik Seng

Bachelor of Engineering with Honours
(Civil Engineering)
2020

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

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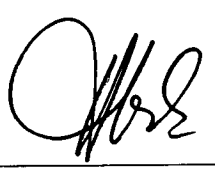

Dr Alsidqi Hasan
(Supervisor)

Date: 28/8/2020

EXPERIMENTAL INVESTIGATION ON RHEOLOGICAL PROPERTIES OF SILICA FUME CEMENT PASTE AND ITS POTENTIAL APPLICATION IN GEOTECHNICAL ENGINEERING

TING AIK SENG

This project is submitted in partial fulfilment of the requirements for the degree of
Bachelor of Engineering with Honours
(Civil Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2020

Dedicated to my beloved family, friends, lecturers and myself

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ABSTRACT

Silica fume is a waste material that has been produced in tonnes as industrial waste per year. Silica fume can be generalised as microsilica, and contain mainly amorphous silica with more than 85% of silica content depending on the origin of silica fume. Utilisation of silica fume has been well known in construction such as concrete industries and others due to the its physical properties. However, there is lack of studies of its application in geotechnical engineering. One of the important characteristics of silica fume is its rheology which related to many geotechnical applications such as cemented soil, soil column, temporary excavation support and others. Therefore, this study is focused to describe the laboratory research on the rheological properties of silica fume mixing with Ordinary Portland Cement (OPC) and water. The basic properties test was conducted on the silica fume before conducting the rheological and Unconfined Compression Strength (UCS) test. Rheological test was performed to evaluate the viscosity, γ and shear stress, τ of the silica fume cement paste. UCS test was performed to determine compressive and shear strength of the silica fume cement paste. In this research, the proportion of the cement are varying from 0 to 7.5% while the water/solid ratio varies from 0.1 to 0.3 to determine the rheological properties of the silica fume cement paste. The expected result is when the water/solid ratio increases, the viscosity and the shear stress decrease or vice versa and when the cement ratio increases, the viscosity and shear stress increase or vice versa. For the UCS test result, the expected result is when the water/ solid ratio increases, the compressive strength and shear strength decrease or vice versa. When the cement ratio increases, the compressive strength and shear strength increase or vice versa.

ABSTRAK

Asap silika adalah bahan buangan yang dihasilkan dalam jumlah ton sebagai sisa industri setiap tahun. Asap silika dapat digeneralisasikan sebagai mikrosilika, dan mengandung terutama silika amorf dengan lebih dari 85% kandungan silika bergantung pada asal asap silika. Penggunaan asap silika telah terkenal dalam pembinaan seperti industri konkrit dan lain-lain kerana sifat fizikalnya. Walau bagaimanapun, terdapat kekurangan kajian mengenai penerapannya dalam kejuruteraan geoteknik. Salah satu ciri penting asap silika adalah reologi yang berkaitan dengan banyak aplikasi geoteknik seperti tanah bersimen, tiang tanah, sokongan penggalian sementara dan lain-lain. Oleh itu, kajian ini difokuskan untuk menerangkan penyelidikan makmal mengenai sifat reologi pencampuran asap silika dengan simen portland biasa dan air. Ujian sifat asas dilakukan pada asap silika sebelum menjalankan ujian kekuatan mampatan rheologi dan ujian pemampatan. Ujiian reologi dilakukan untuk menilai kelikatan, γ dan tegangan hasil, τ dari pes simen asap silika. Ujian UCS dilakukan untuk mengetahui kekuatan mampatan dan ricih pes simen asap silika. Dalam penyelidikan ini, bahagian simen bervariasi dari 0 hingga 7.5% sementara nisbah asap air/silika berbeza dari 0.1 hingga 0.3 untuk menentukan sifat reologi dari pes simen asap silika. Hasil yang diharapkan adalah apabila nisbah air/pepejal meningkat, kelikatan dan tekanan hasil menurun atau sebaliknya dan ketika nisbah simen meningkat, kelikatan dan tegangan hasil meningkat atau sebaliknya. Untuk hasil ujian UCS, hasil yang diharapkan adalah apabila nisbah air/pepejal meningkat, kekuatan mampatan dan kekuatan ricih menurun atau sebaliknya. Apabila nisbah simen meningkat, kekuatan mampatan dan kekuatan ricih meningkat atau sebaliknya

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LIST OF ABBREVIATIONS AND NOTATIONS

ASTM	-	American Society for Testing and Materials
AASHTO	-	American Association of State Highway and Transportation Officials
BS	-	British Standard
CBR	-	California Bearing Ratio
CSA	-	Canadian Standards Association
EAFs	-	Electric Arc Furnaces
EDX	-	Energy Dispersive X-Ray
HRWR	-	High Range Water Reducers
IARC	-	International Agency for Research on Cancer
k	-	kilo
LL	-	Liquid Limit
m	-	Metre
Pa	-	Pascal
PL	-	Plastic Limit
PI	-	Plasticity Index
OPC	-	Ordinary Portland Cement
SEM	-	Scanning Electron Microscope
UCS	-	Unconfined Compressive Strength
USCS	-	Unified Soil Classification System
μ	-	micro

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The phrases silica fume, condensed silica fume and microsilica are always been used for describing the by-products of producing ferrosilicon and other metal alloys in smelting plants. (Panjehpour et al., 2011). In our study, the silica fume will be obtained from the Pertama Ferroalloys Sdn Bhd smelting plant in Samalaju Industrial Park, Bintulu. The earliest discovering of silica fume was in Norway, 1947. Many researches have been done due to the pozzolanic activity of silicon dioxide in silica fume. Nowadays, in some industrial countries such as Malaysia, China, United States, Africa, India, and others. Due to its widely use, silica fume has been standardized by American, European, and Asian.

Particles of silica fume are finer than particles of cement, fly ash and ground granulated blast-furnace slag. Silica fume is pozzolanic like volcanic ash since it is reactive. (Panjehpour et al., 2011). The surface area of silica fume is higher relative to other cementitious materials such as fly ash and cement due to the smaller size of silica fumes. The non-silica components in silica fume will determine the colour of silica fume and its colour ranges from light to dark grey. Due to the silica fume particles are finer than other cementitious materials, some problems that should be taken into account are transportation, dispersing consideration, and storage (Panjehpour et al., 2011). Regardless of the problem of particle size, silica fume occurs on different ways. There are three major different forms of silica fume, which are as produced silica fume, densified silica fume, and slurried silica fume.

Silica fume contains mainly amorphous silica and this indicating the silica fume is not a crystalline material. The majority of silica fume is silicon dioxide and is always exceeding 85%, according to the three standards which are American Society for Testing and Materials (ASTM), Canadian Standards Association (CSA), and American

Association of State Highway and Transportation Officials (AASHTO) while other trace contaminants such as cristobalite, carbon, aluminium, iron, calcium, magnesium, potassium and sodium also exists in silica fume but with a small quantity. Silica fume has been applied in concrete, geotechnical engineering field, and some rheological field on cement paste.

1.2 Problem Statement

The amount of waste materials produced from the industries and disposed into the landfills is increasing yearly. These scheduled waste materials are only discarded into the environment without any commercial return. One of the scheduled waste materials which is silica fume that is being produced in tones as industrial waste per year. Microsilica is typically considered as a nuisance dust and health issue such as irritation will be incurred due to high dust concentrations. Microsilica contains trace amount of less than 5 percent of crystalline silica which has been shown to cause silicosis. The International Agency for Research on Cancer (IARC) proved that silicosis is harmful to human health as it is a human carcinogen (Holland, 2005). Therefore, many researches have been to study the potential of silica fume to be used in construction industries, such as a partial replacement of cement by silica fume in concrete, the usage of silica fume in geotechnical engineering, and other construction developments to minimize the quantity of silica fume disposed in landfills sites.

For the past research, the silica fume is focusing more on the concrete but lack of geotechnical engineering application to soil. For the rheological field of silica fume, there is limited research has been conducted. Some research had been done such as the effect of rheological properties of silica fume cement paste such as plastic viscosity and yield point on the temperature, the rate and amount of heat evolved. Also, another study had been conducted which is effects of silica fume on rheological properties of asphalt cement. Based on the limited research done on the rheological properties of silica fume with cement paste, this research will be focus on the rheological properties of silica fume mixing with cement paste and its potential application in geotechnical engineering.

1.3 Project Significance

The finding of this study is important in order to identify the rheological properties of the silica fume cement paste in order to find the relationship of viscosity and shear stress of the silica fume cement paste. Based on the information study details, the rheological characteristics of silica fume cement paste can be done which eventually contributes in geotechnical engineering by reducing problems of excess silica fume in the future.

1.4 Aim and Objectives of Study

The purpose of this research is to assess the rheological properties of silica fume mixing with cement paste and compressive strength of silica fume cement paste. In order for achieving this aim, there are some objectives need to be completed.

i. To investigate and determine the basic properties of silica fume.
ii. To investigate the relationship of viscosity and shear stress of silica fume cement paste using HAAKE Viscotester 7 Plus for example the effect of cement and water/solid ratio on the silica fume cement paste.
iii. To determine and analyse the compressive and shear strength of the silica fume cement paste through Unconfined Compressive Strength (UCS) test.

1.5 Scope of Study

Investigation of rheological properties of silica fume cement paste and its potential application in geotechnical engineering can be conducted through some intensive laboratory testing.

Atterberg limits, specific gravity, sieve analysis, hydrometer tests will be carried out to determine the basic properties of the silica fume. Also, it is needed to classify the silica fume using Unified Soil Classification System (USCS). With the aim of revealing the microstructures of silica fume, Scanning Electron Microscope (SEM) test is also performed. Besides silica fume, the microstructures of fly ash and cement also will be performed using SEM in order to compare with silica fume. SEM images will be taken at Analytical Chemistry Laboratory, UNIMAS. Energy Dispersive X-Ray Analysis (EDX) also is performed at Analytical Chemistry Laboratory in order to see the distribution of element in silica fume.

With the intention of determining the rheological properties of the silica fume cement paste, the silica fume cement paste samples are prepared using different ratio of water and cement content. A dynamic shear rheometer tester will be used to investigate the rheological properties of silica fume cement paste. From the rheological tests of silica fume cement paste, the viscosity and elastic behaviour of the silica fume cement paste can be deduced. The Unconfined Compression Strength (UCS) test will be conducted on the samples after the rheological test is conducted to determine the compressive strength of the silica fume cement paste.

Throughout this research study, tests for determining the properties of silica fume, which are Atterberg limit, sieve analysis, specific gravity, hydrometer test, and UCS tests will be carried out Soil Mechanics and Geotechnical Laboratory. For the SEM and EDX test, the test will be conducted in the Analytical Chemistry Laboratory, UNIMAS. For determination of rheological properties of silica fume, the tests are carried out at the Highway Laboratory, UNIMAS.

1.6 Research Gap

This study concentrates on the rheological properties of silica fume cement paste which were obtained from Pertama Ferroalloys Sdn Bhd smelting plant in Samalaju Industrial Park, Bintulu. The rheological test of silica fume cement paste is important to apply in geotechnical engineering. The mix design of silica fume cement paste is varied in percentage of cement used and ratio of water/solid. The use of Ordinary Portland Cement is compulsory as it acts as the binder. The analysis on the percentage of cement used and water/solid ratio used in this study are carried out to determine the viscosity and shear stress of the silica fume cement paste. The physical characteristics of the silica fume such as specific gravity, moisture content, liquid limit, plastic limit, and particle size distribution will be determined and utilized in performing the rheological characteristics of silica fume. The experimental of Unconfined Compression Strength (UCS) test on the silica fume cement paste is carried out after curing in the air for 28 days for determination of the compressive and shear strength of silica fume cement paste.

1.7 Thesis Outline

This thesis consists of six chapters. Chapter 1 contains the summarising of introductory information addressing the issues of silica fume, aims, objectives, significance of study, scope of research, research gap and project schedule of this study. In Chapter 2, a theoretical background along with literature review on silica fume, its physical and chemical properties, importance and application of silica fume in concrete field. Most importantly, significance and sustainable use of silica fume in geotechnical engineering are also addressed. Besides, studies addressing the effect of rheological properties of using silica fume on the cement slurry and asphalt cement are also addressed. Chapter 3 contains the experimental procedures associated for the determination of using silica fume to determine the basic properties of silica fume, rheological properties of silica fume cement paste, and the unconfined compressive strength of silica fume cement paste in this thesis. Chapter 4 and 5 gives the results of the experiment, analysing, interpreting and discussions on the basic properties of silica fume, rheological properties of silica fume cement paste and the unconfined compression strength and shear strength of silica fume cement paste. The summarization of major findings of the experimental study also stated and emphasized in this chapter. Lastly, in Chapter 6, the conclusion is emphasized and the recommendations for the future research are addressed.

1.8 Project Schedule/Gantt Chart

A Gantt chart describes tasks to be carried out in chronological order to accomplish the goal of this project, which to come up with a set of laboratory tests and review of the laboratory test results. The Gantt Chart is shown in Figure 1.1.

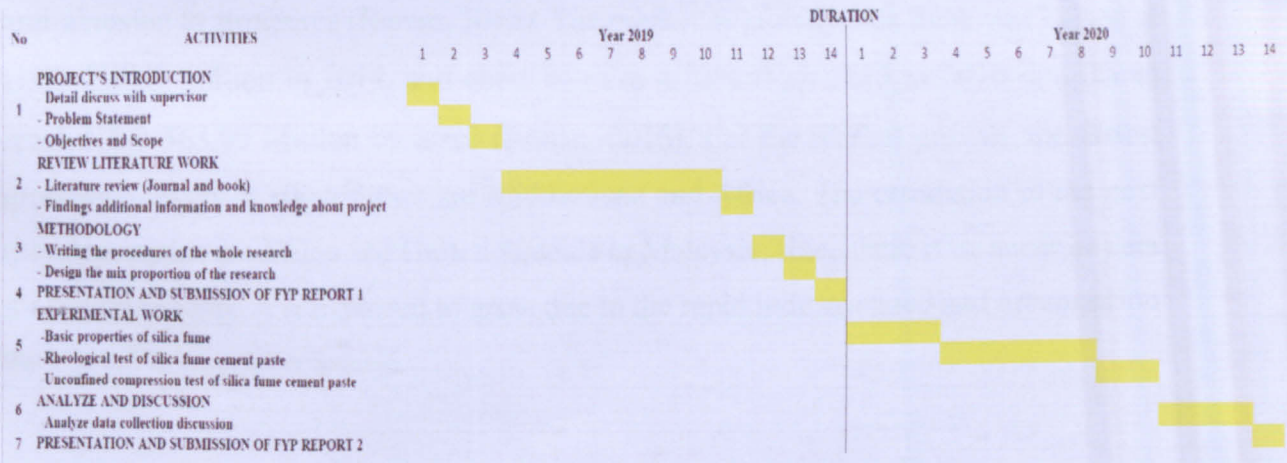

Figure 1.1: Gantt Chart