SPENT BLEACHING EARTH ASH (SBEA) AS SILICA FUME REPLACEMENT IN TERNARY BLENDED CONCRETE

SUFFIAN BIN ABDUL KARIM

FACULTY OF ENGINEERING UNIVERSITI MALAYSIA SABAH

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ABSTRACT

Spent Bleaching Earth Ash (SBEA) is a sustainable product recycled from spent bleaching earth (SBE). It is recently used as a blended cement. In particular, ternary blended concrete incorporating SBEA and silica fume was studied with different percentages of SBEA replacing silica fume in the mix design. The physical and chemical characteristics of SBEA, silica fume and cement were analyzed. The effect on engineering properties of partially substituting silica fume with SBEA in trinary blended concrete was also studied. Lastly, the optimum percentage replacement of SBEA used in the ternary blended concrete is done. The mix design was based on the JKR mix design standard for M30 grade concrete, which was then altered by replacing 13% cement with silica fume. Silica fume is then replaced with 20%, 40%, 60%, 80% and 100% with SBEA. Three major experiments were done to test this concrete's engineering properties: workability, compressive and density test. It was found that SBEA had almost similar fineness to cement powder, with a specific gravity of 1.97 for SBEA, 3.23 for silica fume and 3.17 for cement. SBEA consists mainly of silica (SiO2), and the value of SiO2, aluminium oxide (Al2O3), and iron oxide (Fe2O3) combination was 69.15% which is more than 50%. According to the ASTM C618 standard, SBEA could be categorized in the Class C pozzolan. The primary crystalline phase of SBEA was α-quartz, while x-ray diffraction (XRD) of silica fume was found to exhibit generally amorphous characteristics, and the primary crystalline phases of the cement powder were alite, belite, portlandite, and gypsum. Based on the micrograph image, SBEA possesses some relatively spherical, irregular-shaped, and agglomeration of its particles, silica fume particle is spherical and has a smooth surface area. Cement particles are observed to have an irregular shape and come in different sizes. The conventional cement was substituted with 13% silica fume by cement mass. The compressive strength of concrete containing different percentages of SBEA replacing silica fume was determined and found that the early curing age of concrete compressive strength was not affected by the replacement of SBEA but observed to take a turn in the late curing age, where 40% of SBEA replacement show the highest compressive strength, 70.02 MPa. The workability shows that an increase of SBEA percentages replacement illustrates better workability and density of all the mix designs is not far from each other, with S4 mix design being the highest. In short, the best design to be implemented in the construction industry is the S4 mix design with the highest compressive strength and acceptable workability and density.

ABSTRAK

ABU TANAH PELUNTUR TERPAKAI (SBEA) *SEBAGAI PENGGANTIAN WASAP SILIKA DALAM KONKRIT CAMPURAN TERNARY*

Abu Tanah Peluntur Terpakai (SBEA) ialah produk mampan yang dikitar semula daripada tanah pelunturan terpakai (SBE). Ia baru-baru ini digunakan sebagai simen campuran. Khususnya, konkrit campuran terner yang menggabungkan SBEA dan wasap silika telah dikaji dengan peratusan berbeza SBEA yang menggantikan wasap silika dalam reka bentuk campuran. Ciri-ciri fizikal dan kimia SBEA, wasap silika dan simen telah dianalisis. Kesan ke atas sifat kejuruteraan menggantikan separa wasap silika dengan SBEA dalam konkrit campuran trinari juga telah dikaji. Akhir sekali, penggantian peratusan optimum SBEA yang digunakan dalam konkrit campuran ternary dilakukan. Reka bentuk campuran adalah berdasarkan piawaian reka bentuk campuran JKR untuk konkrit gred M30, yang kemudiannya diubah dengan menggantikan 13% simen dengan wasap silika. Asap silika kemudiannya digantikan dengan 20%, 40%, 60%, 80% dan 100% dengan SBEA. Tiga eksperimen utama telah dilakukan untuk menguji sifat kejuruteraan konkrit ini: kebolehkerjaan, ujian mampatan dan ketumpatan. Didapati bahawa SBEA mempunyai kehalusan yang hampir sama dengan serbuk simen, dengan graviti tentu 1.97 untuk SBEA, 3.23 untuk wasap silika dan 3.17 untuk simen. SBEA terdiri terutamanya daripada silika (SiO2), dan nilai gabungan SiO_2, aluminium oksida (Al_2O_3), dan oksida besi (Fe_2O_3) adalah 69.15% iaitu lebih daripada 50%. Menurut piawaian ASTM C618, SBEA boleh dikategorikan dalam pozzolan Kelas C. Fasa kristal utama SBEA ialah α-kuarza, manakala pembelauan sinar-x (XRD) wasap silika didapati menunjukkan ciri-ciri umumnya amorfus, dan fasa kristal utama serbuk simen ialah alit, belite, portlandit, dan gipsum. Berdasarkan imej mikrograf, SBEA mempunyai beberapa zarah yang agak sfera, berbentuk tidak sekata, dan aglomerasi zarahnya, zarah wasap silika adalah sfera dan mempunyai luas permukaan yang licin. Zarah simen diperhatikan mempunyai bentuk yang tidak sekata dan mempunyai saiz yang berbeza. Simen konvensional telah digantikan dengan wasap silika 13% dengan jisim simen. Kekuatan mampatan konkrit yang mengandungi peratusan berbeza SBEA menggantikan wasap silika telah ditentukan dan mendapati bahawa umur pengawetan awal kekuatan mampatan konkrit tidak terjejas oleh penggantian SBEA tetapi diperhatikan untuk mengambil giliran pada usia pengawetan lewat, di mana 40% daripada Penggantian SBEA menunjukkan kekuatan mampatan tertinggi, 70.02 MPa. Kebolehkerjaan menunjukkan bahawa peningkatan peratusan penggantian SBEA menggambarkan kebolehkerjaan yang lebih baik dan ketumpatan semua reka bentuk campuran tidak jauh antara satu sama lain, dengan reka bentuk campuran S4 adalah yang tertinggi. Ringkasnya, reka bentuk terbaik untuk dilaksanakan dalam industri pembinaan ialah reka bentuk campuran S4 dengan kekuatan mampatan tertinggi dan kebolehkerjaan dan ketumpatan yang boleh diterima.

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LIST OF ABBREVIATION

SBEA	-	Spent Bleaching Earth Ash
SBE	-	Spent Bleaching Earth
SF	-	Silica Fume
FA	-	Fly Ash
OPC	-	Ordinary Portland Cement
XRF	-	X-Ray Fluorescence
XRD	-	X-Ray Diffraction
SEM	-	Scanning Electron Microscope
SCM	-	Supplementary Cementing Materials
CSH	-	Calcium Silicate Hydrate

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Cement was a critical industrial product that was produced commercially all over the world. Cement, combined with aggregates and watered, creates the ubiquitous concrete used in buildings, roads, bridges, and other constructions. Despite its low embodied energy, the magnitude of cement manufacturing was concerning, considering that cement production accounted for 7-10% of total carbon dioxide emissions globally and was the third most significant contributor to greenhouse gas emissions, according to Chen *et al.* , (2010). With the cement sector developing at a pace of roughly 5% per year, according to Hossain (2011), more rigorous CO_2 reduction measures had been necessary to maintain cement emissions.

Many cement and concrete manufacturing initiatives reduce CO_2 emissions throughout the manufacturing process. By substituting part of the pure cement in, a cement-based combination with alternative pozzolanic material, which had the potential to operate as a cement-like binder, the percentage of pure cement in the mixture may be lowered. Industrial wastes such as fly ash slag, a byproduct of the coal power sector, silica fume, and rice husk ash all had the added advantage of being pozzolana that would otherwise go to landfills. While every ton of pozzolana effectively saves one ton of cement, technical limitations often limit the proportion of cement that may be substituted.

When concrete is in a fresh state, there are several benefits to employing pozzolana components. The first and most important aspect is its workability. Pozzolana cement also lowers the rate of slump loss in concrete compared to conventional cement (Bendapudi *et al.*, 2011), especially under hot weather conditions like in Malaysia. There is also bleeding, a sort of segregation in which part of the water in the concrete mix rises to the surface of new concrete. Pozzolana cement decreases bleeding by having a higher volume of particles and lower water content for given workability, according to Khan *et al.* (2014). This also aids in the blocking of bleed water conduits. Pozzolana cement aids in the production of more cohesive concrete that is less prone to segregation and bleeding.

Nevertheless, when concrete is hardened, pozzolana cement provides other benefits. Shannag (2000) states that at 28 days, the strength and rate of strength growth of concrete prepared using pozzolana cement will be comparable to that of regular concrete. Pozzolana cement concrete has a lower modulus of elasticity at early ages and a slightly greater modulus at later ages than regular concrete. Because pozzolana cement is finer than ordinary cement, it improves paste volume and reduces bleeding, resulting in enhanced contact and a better bond with steel (Sabet *et al.*, 2013). Pozzolana cement hydration is slower than regular cement hydration, resulting in slower heat production and reduced internal stresses in concrete. Pozzolana cement in concrete aids in the reduction of drying shrinkage and plastic shrinkage.

Correspondingly, ternary concrete is a blend of three distinct cementitious elements. The optimal supplemental cementitious proportions for ternary blends, like any concrete mixture, will be determined by the intended use of the concrete, building needs, and seasonal factors. Cold weather, like any concrete, may affect early strength increase and mixture proportions and may need minor changes to ensure worksite performance.

In this ternary concrete, the researched materials are silica fume and Spent Bleaching Earth Ash (SBEA). silica fume is produced as a byproduct of the production of silicon metal or ferrosilicon alloys. One of the most practical applications for silica fume is in concrete. It is a highly reactive pozzolan due to its chemical and physical characteristics. Research done by Khedr (1994), concrete with silica fume may be solid and long-lasting. Silica fume is available from concrete additive manufacturers and, when requested, is easily applied throughout the concrete manufacturing process, placing, finishing, and curing silica-fume concrete need specific care from the concrete contractor.

Globally, crude palm oil refinery plants create roughly 2 million tons of spent bleaching earth (SBE) (Huang *et al.*, 2010). Malaysia is well-known for producing a large quantity of palm oil fruits. To make refined palm oil, bleaching earth is added during the pretreatment process, which involves the degumming and bleaching of crude palm oil. SBE is a byproduct of the crude palm oil refining process. in Malaysia, SBE from refinery plants is often disposed of in landfills. One of the recovered products from SBE is Spent Bleaching Earth Ash (SBEA) which is one of the primary materials in this study after silica fume.

Pozzolana is a way to reduce the application of cement by partially replacing it. Silica fume is one of the best pozzolanas made up its name in the construction industry. Mixing this material with SBEA in ternary blended concrete is an effort to achieve better concrete performance. With that, this research aims to explore the impact of partly replacing silica fume for SBEA in trinary mixed concrete to determine the best SBEA replacement percentage to be utilized in ternary blended concrete.

1.2 Problem Statement

As one of the primary components in this research, silica fume must be considered in actual application since several problems must be overcome when dealing with this substance. Silica fume concrete is too viscous to work with and is difficult to apply. it is difficult to clean the surface. Silica fume necessitates a large quantity of water and must be combined with a superplasticizer. Finally, a study by Wu *et al*. (2017) reported that silica fume increases the autogenous shrinkage of the cement slurry, and the quantity of inclusion exceeds 5%, increasing the danger of cracking. Producing fractures in mortar and concrete is simple, mandating concrete care. With all of this, there has been a lack of studies to overcome or decrease the issue of creating this ideal concrete mix.

On the other hand, Spent Bleaching Earth Ash (SBEA) is still in short supply regarding utilization and implementation methods in Sabah Malaysia. This is related to a lack of study on this material's suitability for usage as a partial substitute for cement in binary mixed concrete, particularly ternary blended concrete. As a result, the feasibility of SBEA to be used in ternary blended concrete is unknown. Therefore, the first problem encountered in this research is determining the physical and chemical properties of this material, SBEA and determining the categorization of the pozzolana materials provided by Gamalux Oils Sdn. Bhd. company is critical to the advancement of this study.

The key challenge with this study is determining the best or optimal mix of ternary concrete, which consists of three (3) main substances: cement, silica fume, and the main emphasis, SBEA, with the hope that this mix design can minimize the disadvantages created by silica fume such as reducing the shrinkage rate, by partially replacing it by SBEA. This is the most difficult challenge because there is no record of this ternary mix concrete design on this material. The manufacturing of this ternary concrete takes time since it takes time to discover the best mix design based on lab work.

1.3 Objective of Study

The aim of this research is to investigate on how to incoperating the Spent Bleaching Earth Ash (SBEA) as partial replacement of silica fume in ternary blended concrete. The objectives of this research are:

1. To determine the physical and chemical properties of SBEA, silica fume and Cement.
2. To investigate the effect on engineering properties of partially substituting silica fume with SBEA in trinary blended concrete.
3. To identify the optimum percentage replacement of SBEA to be used in the ternary blended concrete.

1.4 Scope of Study

This research is evolving around the primary material, the Spent Bleaching Earth Ash, provided by the local production industry, Gamalux Oils Sdn Bhd. This material will be studied in the laboratory at Universiti Malaysia Sabah to determine its physical and chemical characteristics, which is the pozzolanic reaction. This is done by conducting sieve analysis, specific gravity test, X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) analysis. This was utilized to classify the characteristics of its pozzolana.

The next step in the research is to create a ternary blended concrete design mix using cement, silica fume, and SBEA as the main ingredients as the optimal percentages of silica fume, which is 13% cement replacement, is replaced with SBEA by 20% increment up until fully replaced; 0%, 20%, 40%, 60%, 80% and 100%. The replacement is the manipulated variable while the cement amount is constant. The literature review optimum silica fume as partial replacement in blended concrete becomes the basis for the ternary concrete design mix.

The central emphasis observation is workability in its fresh state, compressive strength after curing, and also its density. This will be assessed through the slump test, the compressive strength and density testing, respectively. The optimal proportion of SBEA replacing silica fume is underlined as one of the study goals at the conclusion.

1.5 Significant of Study

This optimal ternary concrete mix design will contribute to manufacturing by providing a higher quality concrete building. It will assist manufacturers with its engineering qualities, which is the strength of the material, by comparing the mix percentage and density against the compressive strength and workability of this ternary concrete. Because of its high strength in transferring loads from the building with higher capacity and loadings, this can undoubtedly add value to the construction.

1.6 Thesis Outline

This study will use SBEA as a silica fume substitute in ternary concrete. The pattern of this research has been discussed in the first chapter, the introduction. This chapter has the following elements: background of research, problem statement, aim of the investigation, scope of work, importance of the study, and summary. This factor all affected the direction of the investigation as well as the extent of the investigation.

Preliminary research will be completed in Chapter 2. The first step in starting a research project is to do a literature review. This step is accomplished by studying previous journals and publications related to this dissertation. Past research from the year 2018 to the year 2022 was evaluated using various sources in order to get relevant information on the present state. ScienceDirect, Google Scholar, Elsevier, Research Gate, Academia, and Scopus have been selected as the data collection medium for quantitative studies worldwide, particularly in Malaysia. This website is fully accessible via the medium provided by the University.

In Chapter 3, the foundation of the whole research framework will be outlined. The goal of this research is to provide opinions on how to mix a ternary concrete using silica fume and SBEA as the primary ingredients in the construction industry. This chapter will go over the flow planning of the method that is being used in this research.

1.7 Summary

Essentially, Chapter 1 focuses on this study's introduction, scope, and relevance and how it will steer the research to provide beneficial and remarkable results after the goals have been met. This chapter emphasizes the primary scale on how to reach the goal of this study through various methods and observations of this ternary blended concrete composed of cement, silica fume, and SBEA. The uses and exposure of these materials will be examined further in Chapter 2 literature review.

CHAPTER 2

LITERATURE REVIEW

2.1 Silica Fume

The silicon and ferrosilicon industries produce silica fume as a byproduct. At temperatures up to 2000°C, the reduction of high-purity quartz to silicon creates SIO2 vapours, which oxidize and condense in the low-temperature zone to microscopic particles of non-crystalline silica. Non-crystalline silica is found in 85–95% of byproducts of silicon metal and ferrosilicon alloys with a 75% or higher silicon concentration. The byproduct of producing a ferrosilicon alloy containing 50% silicon has a substantially lower silica concentration and is less pozzolanic. As a result, the SIO2 concentration of silica fume is connected to the kind of alloy formed, according to Thomas (2013). The schematic diagram of silica fume manufacturing is shown in Figure 1.1. Micro silica, condensed silica fume, volatilized silica, and silica dust are all names for silica fume. The colour of silica fume is either excellent white or grey.

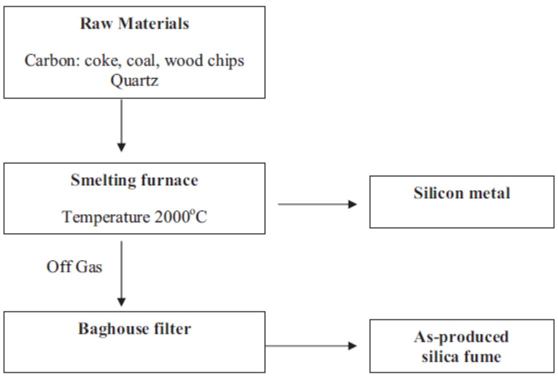

Figure 2.1 : Schematic Diagram of Silica Fume Production
Source : Siddique, R. (2011)

Byproducts recovered from the exhaust gases of ferrosilicon, silicon, and other metal alloy smelting furnaces are often referred to as micro silica, condensed silica fume, and silica fume. However, Koksal *et al*. (2008) state that the words silica fume and micro silica are used for high-quality condensed silica vapours in the cement and concrete industries. European standards have used the phrase silica fume. Silica fume was first identified in Norway in 1947 when environmental controls began screening furnace exhaust gases. Most of these vapours were finely comprised of silicon dioxide in a high proportion. Because the pozzolanic reactivity of silicon dioxide was widely known, several investigations were conducted on it, as reviewed by Baali (2009).

Over 3000 publications on silica fume and silica fume concrete have been published. Silica fume, in accordance with AASHTO M 307 or ASTM C 1240, may be used as a material for extra cementations to boost strength and longevity, according to Bhanja (2005). According to the Florida Department of Transportation (2004), the amount of cement replacement with silica fume should range between 7% and 9% by mass of cementation materials.

2.1.1 Overview of Silica Fume as Partial Replacement in Cement

As studied by Babu *et al*. (1995), because of its finely dispersed condition and a high proportion of amorphous silica, condensed silica fume has proven to be the most effective, if not necessary, pozzolanic additive for the construction of extremely high strength concretes and concretes of very high durability. In recent years, using pozzolanic admixtures in conjunction with chemical admixtures has enabled concrete technologists to adapt concretes for various specialized needs. For concrete applications, silica fume is recommended to meet certain minimum specifications such as a SIO_2 content of at least 85%, a spherical shape with several primary agglomerates with particle sizes ranging from 0.01 to 0.3 microns, an amorphous structure, and a shallow content of unburnt carbon.