A STUDY ON SPENT COFFEE GROUND AS CEMENT ADMIXTURES

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ABSTRAK

Tujuan menjalankan kajian ini adalah untuk mengetahui sifat-sifat serbuk kopi yang terpakai dan kesannya sebagai bahan tambah memperlambatkan masa beku simen. Kajian ini bemula dengan menggunakan 0%, 0.2%, 0.4%, 0.6%, 0.8% dan 1.0% daripada serbuk kopi terpakai ditambah ke dalam campuran simen sebagai bahan pembantut simen. Bahagian pasir kepada simen dan air yang digunakan dalam bentuk campuran simen bagi kajian ini adalah 2.75 : 1.0 : 0.6 mengikut piawaian ASTM C1329-05. Sifat segar dan keras simen telah diuji iaitu ujian meja aliran, ujian Vicat dan ujian kekuatan mampatan dengan menggunakan saiz kiub 50mm x 50mm x 50mm. Kiub simen telah diletakkan dalam air untuk sembuh selama 3, 7, 28 dan 45 hari sebelum ujian kekuatan mampatan dijalankan. Ujian X-Ray Diffraction (XRD), ujian X-Ray Fluoescence (XRF) dan SEM EDX juga dijalankan dalam uji kaji uni untuk menentukan komposisi kimia yang terdapat dalam serbuk kopi terpakai dan mikrostruktur simen selepas penambahan serbuk kopi terpakai sebagai bahan pembantut simen. Hasil daripada ujian meja menunjukkan simen mengekalkan keupayaan alirannya dalam nilai piawaian selepas penambahan serbuk kopi terpakai di pelbagai peratusan seperti yang ditunjukkan. Selain itu, ujian Vicat juga menunjukkan simen yang telah ditambah dengan serbuk kopi terpakai dengan 0.6% berupaya membantut masa awal and akhir beku simen. Di samping itu, ujian kekuatan kemampatan simen menunjukkan simen serbuk kopi terpakai 0.6% memberi kekuatan mampatan yang tertinggi pada masa sembuh 45 hari, iaitu 42.857 MPa manakala simen kawalan hanya direkodkan pada 37.345 MPa. Simen serbuk kopi terpakai 0.6% mempunyai kukuatan kemampatan 14.76% lebih tinggi daripada simen kawalan. Ujian XRD dan XRF menunjukkan bahawa komponen utama yang terdapat dalam serbuk kopi terpakai terdiri daripada Kalium Oksida, Kalium Natrium, Kalsium Aluminium Chromium Oksida Silikat ,dan Tschortnerite. Sesungguhnya, puncak serbuk kopi terpakai terdapat pada 20.20^0 dan juga didapati mempunyai kandungan selulosa asli and selulosa hemi. Bilangan C-S-H yang lebih tinggi dalam simen serbuk kopi terpakai 0.6% berbanding simen kawalan telah membawa kekuatan mampatan yang lebih tinggi.

ABSTRACT

The purpose of carrying out this research is to find out the properties of spent coffee ground and its effect as cement retarding admixtures. The research started with using 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% of SCG being added into mortar mix as retarding admixtures. The proportion of sand to cement to water used in mortar mix design for this research is 2.75: 1: 0.6 according to the standard ASTM C1329-05. Fresh and hardened properties tests were carried out for this mortar mix, namely the flow table test, Vicat test and compressive strength test by using size 50mm x 50mm x 50mm cube. The mortar cubes were cured for 3, 7, 28 and 45 days. X-Ray Diffraction (XRD), X-Ray Florescence (XRF) and SEM EDX were also conducted in order to determine the chemical composition of the spent coffee ground and the microstructure of the mortar after the addition of spent coffee ground as retarding admixtures. The result of the flow table test shows the mortar maintain its flow ability within the standard values after the addition of SCG at various percentage. Moreover, the Vicat test of the SCG mortar shows that the mortar paste containing 0.6 % of SCG and above has retard the initial and final setting time of the mortar. In addition, the compressive strength test recorded that the compressive strength of 0.6 SCG mortar is highest compared to all other SCG mortar and also higher than the control mortar. The 0.6 SCG mortar compressive strength is recorded at 42.857 MPa whereas the control mortar is at 37.345 MPa, 14.76% higher than the control mortar. The XRD and XRF tests show that the major component in SCG are Potassium Oxide, Potassium Sodium Calcium Aluminium Chromium Oxide Silicate, and Tschortnerite. Indeed, the peak of SCG is at 20.2^0 and it is also found to highly content native cellulose or hemi cellulose. The higher number of C-S-H bond also observed in 0.6 SCG mortar compared to the control mortar, which results in higher compressive strength.

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LIST OF SYMBOLS

%	Percent
mm	Millimetre
mm^2	Millimetre square
ml	Milli litre
g	Gram
kg	Kilogram
kg/m^3	Kilogram per cubic metre
N/mm^2	Newton per square millimetre
MPa	Mega pascal
kN	Kilo newton
^oC	Degree Celcius
^{o}	Degree
kN/sec	Kilo newton per second
θ	Theta
$\geq$	Greater than or equal to
$\leq$	Less than or equal to
$\pm$	Plus or minus
x	Times
kx	Thousand times

LIST OF ABBREVIATIONS

2D	Two-dimensional
3R	Reduce, Reuse and Recycle
ASTM	American Society for Testing and Materials
BS	British Standard
MS	Malaysia Standard
C-S-H	Calcium Silicate Hydrate
EN	European Standards
OPC	Ordinary Portland Cement
SCG	Spent Coffee Ground

CHAPTER 1

INTRODUCTION

1.1 Introduction

There are a lot of waste being created each and every day all over the world, all of these waste products are causing a lot of problems to our environment. Therefore, many types of disposal system has been implemented to handle the waste being produced. Some of the most widely use disposal system in Malaysia are open-air landfills, illegal dumping and open burning. Due to fast pace of change in our society, the local authority face difficulties in improving the waste management system over the years. This causes most of the waste still ended up in landfills until today (Clean Malaysia, 2015).

In Malaysia, the amount of municipal solid waste is estimated to increase up to 31000 tons per day. Most of the waste produce is found to be high concentration of organic waste with high moisture content. The waste comprises 80% of food, paper, and plastics (Manaf et al, 2009).

The most adapted disposal system being use worldwide is landfill, especially in developing and poor countries. This is because landfill does not require a lot of technical skills and money. Although landfill method is cheap and easy to use, it will cause a lot of problems to our environment such as soil and groundwater contamination, unpleasant smell, the emission of greenhouse gases and the spreading of diseases by animals. Another problem that contributes to the environment pollution with landfill is leachate. Leachate may reach the surface of the ground and runoffs which causes pollution to water sources such as river or lake. The harmful substances are produced by the biological, chemical and physical degradation process in the landfill sites. (Ismail & Manaf, 2013) . Indeed, the only way to reduce and eliminate the problem cause by the waste is to utilize the waste. This can be done by adopting the 3R concept: Reduce, Reuse and Recycle.

One of the way to reduce the amount of landfills is through the reuse and recycling of the bulky waste. There are a lot of benefits of doing this, such as reduced environmental impact and avoid disposal and landfill. (European Week for Waste Reduction) Today, there are a lot of waste or byproducts from industry such as palm oil fuel ash and rice husk ash, has been reuse in construction field to reduce the use of the construction raw material and lower the construction cost. Coffee ground waste is the leftover produced from every cup of coffee made. Conventionally, coffee ground waste is known as being the waste, and useless. They are being disposed to the landfills without any treatment.

1.2 Background of Study

One of the most vastly used material in the construction field is concrete. Concrete is the mixture of different materials such as cement, coarse aggregates, fine aggregates and water. However, due to the different environment at the construction site, concrete are expected to have different properties in order to work well in the desired environment. In order to fulfill the requirements, admixtures usually being added to the concrete before or during the mixing process. There are a lot of admixtures with different functions being invented over the years to be use in the concrete industry. One of the admixtures is the retarder, it functions to slow down the rate of setting of concrete. By doing this, the concrete can stay fresh for a longer period of time before it gets hardened. Spent coffee ground (SCG) are rich in sugar content (Mussatto et al, 2012). The hydrolysis of spent coffee ground can also produce industrial important sugars which are glucose, galactose and mannose (Scully et al, 2016). As sugar can be use as one of the retarding admixture, the higher the amount of sugar, the longer the setting time of the mortar (Khan & Baradan, 2002). Therefore, spent coffee ground (SCG) might possess a good characteristic to be use as retarding admixtures.

1.3 Problem Statement

Coffee is one of the most famous drinks throughout the world, the production of coffee is more than 105 million tons yearly. It is among one of the most traded commodities worldwide (Murthy & Naidu, 2012). Coffee drink is made from grinding the coffee bean and brew it with hot water with a ratio of 8-20g of coffee beans per 100ml of water (Farah, 2012). However, coffee beans only can be brew once before it is discarded. This signifies that the coffee industry produced a lot of waste yearly due to the discarding of the used coffee ground.

In Malaysia, the disposal of waste is considered as one of the largest factor that contribute to the environmental problems and continue to increase. The commonly used method for waste disposal is by landfills. Most of the landfills in Malaysia are non-sanitary landfills which are without proper engineering plan and effective in handling the waste (Moh & Manaf, 2017). In order to reduce the environmental problem, the waste products which is the spent coffee grounds (SCG) have to be utilize for this research.

1.4 Objective

If spent coffee ground (SCG) can be develop to be the retarder admixture, which usually is a waste product and available in abundance. It would be a milestone achievement for the construction industry.

The main objective of this research is to study the feasibility and utilizing the used coffee ground as the retarder admixture in concrete production and construction industry. In order to achieve the required outcome, the objectives of this research are summarized as follows:

i. To determine the characteristic of the spent coffee ground (SCG) in terms of the elements or compound that are suitable to be used as retarder admixtures.

ii. To determine the mechanical properties of the mortar under the effect of the spent coffee ground (SCG) as retarder admixtures.

1.5 Scope of Work

The scope of work in this research is aligned with the objectives. A preliminary analysis will be conducted before doing the laboratory works for the used coffee ground which includes X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and Energy-Dispersive X-Ray Spectroscopy (SEM EDX). These tests are to find out the characteristics of the used coffee ground to be used as the retarder admixtures. Numerous of mortar cubes were produced by different percentages of the spent coffee ground. The percentage of the used coffee ground ranges from 0.2%, 0.4%, 0.6%, 0.8%, and 1.0% of used coffee ground as retarder admixtures.

The used coffee ground is collected and dried with oven at 60 ^{o}C for 48 hours before it is used as retarder admixtures. All of the mortar cubes that has been casted will be undergoes water curing process before the cubes were taken for further analysis. For the mortar mix design, the proportion of sand to cement to water used is 2.75 : 1 : 0.6 according to the standard ASTM C1329-05.

The specimens will undergoes mechanical tests. Flow Table Test was chosen to test the consistency of the fresh mortar complying with ASTM C 1437. Vicat Test is used to test the setting time of the cement mortar which complying with ASTM D 1525 was also carried out. For Compression Strength Test, the cubes casted were 50mm x 50mm x 50mm which complying with BS 1881 : Part 116. All the specimens were tested at the age of 3, 7, 28, and 45 days.

1.6 Research Significance

Concrete is one of the most significant resources that are very much needed in the construction industry, the usage of concrete is 11 billion metric tons yearly worldwide (Imbabi et al, 2013). Thus, in today construction industry, requires different types of concrete, therefore, admixtures are being used to modify the properties of concrete so that it is suitable for different situation (Albayrak et al, 2015). Therefore, in order to identify more potential material to be used as concrete admixtures, analysis should be carried out to identify the potential materials.

Concrete retarders are used to increase the setting time of the concrete, and maintain the freshness of the concrete for placing (Kumar & Rao, 1994). There are a number of material that are suitable to be used as concrete retarders namely Mono Calcium Phosphate, Sugar, Citric acid and others (Singh & Garg, 1997). Indeed, spent coffee ground (SCG) is found that contain high amount of sugars that is suitable to be used as the material for concrete retarders admixtures (Mussatto et al, 2011). Cement can be retarded using the admixtures material which contain lignosulfates, carbohydrates and sugar derivatives by altering the hydration mechanism of the cement (Nalet & Nonat, 2016).

In addition, the concrete retarders found in the market is very costly, which often results with a higher cost of the concrete (Mbugua et al, 2016). Therefore, spent coffee ground (SCG) as the waste product from coffee drinks production, can be analyzed and fulfill the functions as the concrete retarders as well as reduce the production cost of the concrete with retarder admixtures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss about the literature review of the function of SCG as retarding admixtures, general characteristic, the effect of the retarding admixtures, and the properties of the mortar.

There are a lot of utilization of SCG in the industry such as Biotechnology, Food Science and Chemical Engineering. This indicates that SCG waste is produced in mass and the waste have to be utilize. A lot of studies have been done to SCG in order to explore for more usage and its value after brewing for coffee drink.

However, there are not a lot of cement material studies done by adapting SCG into the cement materials. Therefore, there are a lot of opportunities for the researchers to carry out studies on SCG and find out the values of SCG that can be used for cement materials.

2.2 Industrial by product as cement admixtures

There are a lot of by product that are being generated from all sorts of industry activities. The coffee industry generate spent coffee ground as the by products which are only used once to brew the coffee drink as every 1 kg of dry coffee powder may produce up to 2kg of wet spent coffee ground (Martinez-saez et al., 2017). So, there are a lot of spent coffee ground that are being produced each and every year be it locally or globally.

Cement admixtures are widely being used in the construction industry. Cement admixtures are being added into cement mix to produce cement mix which have better properties or changes the properties of the cement according to the specifications required. Therefore, there are a lot of researches being carried out to find out more material that are suitable to be used as cement admixtures which can change the properties of the cement accordingly. One of the admixtures being widely used is the cement retarder, it can stop or control the hydration of cement for desirable period (Paolini & Khurana, 1998). The function of the cement retarder is to retard or prolonged the setting time of the cement. This is very important in the construction industry which deal with hot weather or environment or the transportation of cement mix to the construction site is very far away, cement retarder is added to the cement mix to keep the cement mix fresh and prolonged the setting time of the cement mix.

Indeed, more than 8 million tons of coffee beans are consumed each and every year lead to this industry generate tons of by product each and every year worldwide (Liu et al, 2017). This by product is readily available locally too which is a good source of raw material to be develop as admixtures. Other than that, most of the SCG available are free of charge as they are usually being discarded as waste product. This can greatly reduce the raw material costs of developing SCG as retarding admixtures.

2.3 Mortar

Mortar is produce by mixing cement, sand and water. There are different mixing ratio of the materials depending on the properties of the mortar needed. Other than that, the water cement ratio have to be at least 0.5 as this will produce a higher strength mortar (Singh et al, 2015).

In this research, spent coffee ground is added to the mortar as cement admixtures. The SCG is added to retard the setting time of the mortar. However, the properties of the mortar which are the flow ability, setting time and compressive strength have to be tested after the addition of the spent coffee ground.

The mortar mix that are being used in this research is Type N mortar which a mixing ratio of sand to cement to water is 2.75 : 1 : 0.6. The mortar standard is based on ASTM C 1329-05, with a water cement ratio of 0.6, the mortar is expected to be able to exhibit good flow ability.

Figure 2.1 Well-Mixed Mortar

2.3.1 Cement

Cement is a product which exist in powdery form that are made with lime and clay based materials. Cement is used as a binder in the construction industry. It is used to produced mortar and concrete in the construction industry.

The most commonly used cement in construction industry is Ordinary Portland Cement (OPC), whereas the main chemical composition of cement are calcium, silicon, aluminum, and iron. It is manufactured by grounding clinker with small amount of gypsum.

Figure 2.2 Cement powder

2.3.2 Fine aggregate

For mortar production, the most commonly used fine aggregate is mining sand and river sand. Fine aggregate is the size of the aggregate is less than 4.75mm up to a minimum size of 0.075mm.

In this research, the production of mortar uses river sand as the fine aggregate. The size of the fine aggregate can be determined from sieve analysis.

Figure 2.3 Fine aggregate

2.3.3 Water

Water is one of the most important material that are needed in mortar production. Water is added to cement in order for the chemical reaction to occur. The chemical reaction that occurs when water is added to cement powder is the hydration process. The hydration process enable cement to exhibits its binding properties.

Therefore, the amount of water added to the cement to produce mortar is also very crucial. There must be sufficient amount or water for complete hydration process. On the other hand, too many water added to the mix will reduce the strength of the mortar. Thus, we have to determine the amount of water needed accordingly.

In addition, insufficient water that are being added to the mix will cause incomplete hydration process, the cement will harden and become brittle. This will greatly reduce the strength of the mortar.

The source of water is also very important as this will directly affect the quality of water that are being supplied. The quality of the water will affect the hydration process together with the final strength of the mortar. Normally, the water that are adopted for mixing is the tap water that are supplied by the local authority.

Figure 2.4 Water

2.4 Spent coffee ground

Coffee is the second largest traded commodity with estimated of 9.34 million tons of production every year spent coffee ground is generated from coffee (Liu et al., 2017). Spent coffee ground is produced from the coffee industry after brewing which contains a lot of organic compounds such as fatty acid, lignin, cellulose, hemicellulose and other polysaccharides which are valuable compounds (Pujol et al., 2013). Usually, they are discarded after brewing the coffee drink for once, and underutilized, being exposed at landfills or a small amount are being used as compost (Yang et al., 2016).

This contribute to the generation of large quantities of spent coffee ground as waste each and every year worldwide. It is reported that there are 6 million tons of spent coffee ground produced each year (Ballesteros et al, 2014).

There a lot of chemical compound that is found in the SCG. These chemical compound includes glucose, hemicellulose, lignin, fat, protein, nitrogen, carbon and others (Ballesteros et al, 2014). This signifies that there are chemical components which can be extracted from SCG and be useful in the industry.

Sugar is able to slow down the hardening and prolonged the setting time of the cement with no adverse effect on the cement paste (Abalaka, 2011). It is found that SCG is rich in sugar (Mussatto et al., 2011). For a material suitable to be used as retarding admixtures for cement, it has to be with high sugar content (Khan & Baradan, 2002). Therefore, SCG has the potential to be developed as the retarding admixtures for cement. Retarding admixtures is very important in the construction industry to improve workability and prolonged setting time of cement (Bhatty, 1987).

Figure 2.5 Spent coffee ground

2.5 Method of characterization been used

The method of characterization that are being used for the used coffee ground are X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and Energy-Dispersive X-Ray Spectroscopy (SEM EDX).

The X-Ray Diffraction (XRD) test is an analytical technique use to determine the phase of the crystalline substances for a particular material. It shows the ordered structure of the crystalline region of the material being tested (Zhao et al., 2007). The material have to be finely ground, homogenized and average bulk composition is determined. The XRD can determine the characterization of the crystalline materials and the identification of fine grained minerals which are too fine to be determine by naked eyes.

The X-Ray Fluorescence (XRF) test is an analytical technique which is capable of determining the qualitative and quantitative of material composition. XRF determine the material composition by X-Rays emitted from the fluorescence. The X-Ray emitted is unique for specific elements, therefore, we are able to tell the elements which are found in the material.

In addition, the Energy-Dispersive X-Ray Spectroscopy (SEM EDX) is also being used for surface imaging to study the microstructure of the cement mortar. With different magnification level, SEM EDX can be used to study the surface of the mortar such as cracks, pores and identify the components. These components can be identified by surface imaging are cement, sand and C-S-H gel. This can gives a picture of the structures of the mortar after the addition of SCG.

Figure 2.6 XRD Test Machine

Figure 2.7 XRF Test Machine

Figure 2.8 SEM EDX Surface Imaging Machine

2.6 Application of spent coffee ground

There are more and more application of spent coffee ground today. One of the most commonly known application is to use as fertilizer for the plants. One of the benefit of SCG as fertilizer is that it adds organic material to the soil which improves drainage, water retention and aeration in the soil. SCG is neutral, so it will not affect the acidity level of the soil. Composted spent coffee ground has also proven to be able to increase growth of horticultural plant in specific soil type (Hardgrove & Livesley, 2016).

In the Biotechnology research, researchers study on ways to extract sugar from spent coffee ground. Due to the high sugar content in SCG, through the bioconversion process, sugar can be extracted from SCG. However, the process have to be conducted under controlled conditions (Mussatto et al., 2011).

Another studies in the Biotechnology is to produce ethanol from spent coffee ground. The SCG undergoes fermentation to produce ethanol. The spent coffee ground which is rich in sugar, can be used as substrate in fermentation process (Mussatto et al., 2011).

For a Biotechnology research, spent coffee ground is used as a substrate by extracting the oil from it to produce polyhydroxyalkanoates, which is a type of biodegradable and biocompatible polymers (Obruca et al, 2015).

Spent coffee ground can also be fermented by colon microbiota to produce short-chain fatty acid with the ability to prevent inflammation. This is able to protect those inflammatory diseases such as bowel disease and rheumatoid arthritis (López-barrera et al, 2016).

Spent coffee ground is also being used to produce activated carbon by adding Zinc Chloride as activating agent. The caffeine content is a very important component which enhance the reaction as a catalyst (Kante et al, 2012). In order to reduce the environmental impact, spent coffee ground is also being developed to adsorb or to amend heavy metal that contaminated the water or soil (Kim et al, 2014).

In addition, spent coffee ground is also being use for biodiesel production. This is due to the high oil content found in the spent coffee ground which can be recovered and be used for biodiesel. Biodiesel is a biodegradable fuel that can be used of added to the diesel fuel. The oil in used coffee ground is extract with isopropanol for higher recovery and lower cost (Caetano et al, 2012).

Spent coffee ground is being used as non-structural embankment fill material. The spent coffee ground properties is tested with geotechnical engineering and chemical tests. It is suitable to be used on the road embankment which do not sustain high traffic loadings as this will help to reduce the spent coffee ground waste from landfills .

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, there will be information about the properties of the materials and also the laboratory work involved to test the concrete specimens. The laboratory work involved is to test the mechanical properties of the mechanical properties of the concrete. For the series of laboratory works involved, is based on the British Standard (BS) and American Society for Testing and Materials (ASTM) to determine the mechanical properties of the concrete.

3.2 Materials and properties

The raw materials that are being used in this research are readily available locally. They include the Ordinary Portland Cement (OPC), fine aggregate the river sand, tap water and the used coffee ground from Starbucks Coffee Malaysia as the retarder to the mortar. The percentage of the used coffee ground that are being added to the cement mortar mix as retarder are 0.2%, 0.4%, 0.6%, 0.8% and 1.0% respectively. The details of the materials and laboratory works will be provided further under the following section.

3.2.1 Cement

The most common type of cement powder that is being used in the mortar production is the Ordinary Portland Cement (OPC), therefore, OPC ASTM Type 1 is being used in the research. The cement powder that is provided in this research is YTL Cement Orang Kuat as shown under Figure 3.1. The further information about the chemical composition and the physical properties of the cement powder is shown under Table 3.1.

Figure 3.1 YTL cement Orang Kuat

Table 3.1 Chemical composition and physical properties of OPC

Tests	Units	Specification MS 522-1: 2007 (42.5 N)	Test Results
		Chemical composition	
Insoluble residue	%	≤ 5.0	0.4
Loss on ignition (LOI)	%	≤ 5.0	3.2
Sulfate content (SO_3)	%	≤ 3.5	2.7
Chloride (Cl^-)	%	≤ 0.10	0.02
		Physical properties	
Fineness (according to Blaine	m^2/kg	-	345
Setting time (initial)	mins	≥ 60	130
Soundness	mm	≤ 10	1.0
Compressive strength (mortar prism; 1:3:0.5)	MPa	≥ 10	29.7 (2days)
	MPa	≥ 42.5; ≤ 62.5	48.9 (28 days)

Adapted from (YTL Cement, 2017)

3.2.2 Fine aggregate

The most commonly used fine aggregate is the mining sand and the river sand in concrete production. In this research, the laboratory work will use the river sand as the find aggregate that is shown under the Figure 3.2. The sand will be tested with sieve analysis test to determine its fineness modulus (BS 812: Part 103).

Figure 3.2 Fine aggregate

3.2.3 Water

Water is the most important material for the production of mortar. The cement, together with enough amount of water undergoes hydration process to create Calcium Silicate Hydrate Gel (C-S-H gel). The quality of the water being used in the mortar production is also very important. This is because some water sources may content contaminants which will affect the strength of the mortar and may cause corrosion to the reinforcement bars for reinforced concrete production. Due to these reasons, the water that are being used for mortar production must be from uncontaminated source and clean. Some of the commonly found contaminants in the water are acid, alkali, oil, sugar, silt and other elements which are detrimental to the mortar production. In this sense, drinkable water is a suitable water source that can be used in the mortar production. For this research, the water source that is being adopted is from the tap water supplied from Jabatan Bekalan Air Pahang.

3.2.4 Spent coffee ground

The used coffee ground in this research is being supplied by the Starbucks Coffee Malaysia that is showed under Figure 3.3. The used coffee ground is collected from the outlets and mix together. Then, it is dried under room temperature and oven dried for 24 hours at 60 ^{o}C, the temperature is maintained at 60 ^{o}C or less is because higher temperature may causes the organic component to deplete (Etim, Umoren, & Eduok, 2016). The used coffee ground has already been grinded and can be used without further processing. After the collection of the used coffee ground, it has to be put under air dry in 2 days before sending it for oven dry. This is due to the moisture in the used coffee ground, as fungi will start to grow if not process within a short period of time and contaminated the used coffee ground. Used coffee ground contains plenty of components, one of the highest component found is sugar (Mussatto et al., 2011).

Figure 3.3 Spent coffee ground

3.3 Spent coffee ground mortar preparation

The mixing of the mortar is according to the standard ASTM C1329-05, which is the type N mortar. The mix proportion of sand to cement to water for this mix design is 2.75 : 1 : 0.6. For producing the mortar cubes with size 50mm x 50mm x 50mm, the volume of mortar needed is small. So, the mixing is carried out by using mortar mixer in the laboratory only.

In order to obtain a uniform mortar mix, the following procedures are being used. The fine aggregates are first poured into the mixing plate, then followed by the spent coffee ground and cement powder. The materials are then well-mixed with the spade for 2 minutes. After this, three quarter of the water needed for the mix is added and mix together for another 2 minutes. Lastly, add the remaining water into the mix and mix manually again for another 2 minutes. The mixes are then casted into respective steel molds under the shade. The compaction of the mortar was done according to the BS 1881: Part 108. The used coffee ground mortars that are being produced in laboratory scale is being shown under Figure 3.4.

Figure 3.4 Spent coffee ground mortar

3.4 Curing regimens

Curing is essential for the mortar because it is a measurement to prevent the mortar from losing its moisture and keeping the mortar under a suitable temperature range. A proper curing can enhance the mortar in strength gaining. Therefore, the curing process can reduce the drying shrinkage, at the same time it hardens until it gained enough strength to resist the shrinkage cracking.

Under this research, the curing method that has been adopted is the full water curing method, which is shown under Figure 3.5. Table 3.2 shows the labeling of the concrete specimens so that it will be clear during the laboratory works later. For the water curing method, all the concrete specimens will be fully immersed in the water curing pond until the day for testing. The temperature of the water that is being used for the water curing was 24 ± 3 ^{O}C.

Table 3.2 Naming of mortar specimens with different admixtures percentage

Water Curing
0 SCG
0.2 SCG
0.4 SCG
0.6 SCG
0.8 SCG
1.0 SCG

Figure 3.5 Full water curing for specimens

3.5 Properties of fresh mortar

The test included in testing the fresh concrete is the Vicat test (ASTM C 191) and Flow Table Test (ASTM C 1437). The Vicat Test was carried out to determine the setting time of the mortar mix by using the Vicat needle. The flow table test was carried out to determine the flow value of the fresh mortar. By doing this test, the flow ability of the fresh mortar can be determined..

3.5.1 Vicat test

The identification of the setting time of the fresh mortar is important to study the effect of the used coffee ground as the retarder admixture. The identified setting time is very important in deciding the optimum amount of used coffee ground to be added into the mix so as to obtain the required setting time. This also contribute to the others aspects when doing a concrete mix, such as the mixing duration, time to transport, place and compact the concrete effectively.

During the test, it must be ensure that the mould is supported by the non-absorptive plate. Before the fresh mortar is being placed into the mould, the fresh mortar is made into a ball shape and toss for 6 times from one hand to another. After filling the fresh mortar into the mould, the excess mortar is levelled and removed. The set up of the laboratory work is as shown under Figure 3.6.

The sample is remained in moist condition for 30 minutes after the fresh mortar is being placed, without being disturbed. After 30 minutes, the test starts by lowering the needle until it touches the mortar surface. The set screw is tightened and the indicator is set. Then the rod is released quickly by unscrew the set screw. The reading is recorded and this step is repeated for a few times at different locations. The initial setting time of the mortar sample is when the average penetration of 10mm or less. Whereas for the final setting time is taken when the vicat needle do not penetrate into the paste.

Figure 3.6 Vicat Test

3.5.2 Flow table test

In addition, the flow table test is carried out to determine the consistency of the fresh mortar. The consistency check can determine the flow ability of the concrete with the addition of the used coffee ground as admixtures. This will provide us with the information of the workability of the mortar.

The flow table was cleaned and placed on the flat surface. After that the mould will be placed at the center of the table top as shown in Figure 3.7. The fresh mortar are added into the mould by three layers and each layer with 20 times of tamping by using a tamping rod. This is to ensure the uniform filling of the mould.

Next, the upper mould is leveled to remove the excess fresh mortar. After that, the table is dropped immediately with a drop height of 12.5mm. This process is repeated for 25 drops in 15 seconds.

Figure 3.7 Flow Table apparatus

3.6 Characterization

The characterization of the analysis includes X-Ray Diffraction test (XRD), X-Ray Fluorescence test (XRF), and Field Emission Scanning Electron Microscope (FESEM) were carried out to investigate the properties of the used coffee ground. Therefore, FESEM is carried out to understand more about the behavior of the specimens after the addition of the used coffee ground as retarder admixtures. The further information about the tests will be discuss in the subtopics.

3.6.1 X-Ray Diffraction (XRD)

X-Ray Diffraction (XRD) is a very effective analytical technique in analyzing the phase identification of the crystalline material and the unit cell dimensions also will be provided. Before the material is being analyzed, it has to be finely ground, homogenized and determine the average bulk composition. The scan speed of the XRD is set to be 1.00 seconds with 0.2^o between 20^o and 80^o for the spent coffee ground. The scan axis was 2 thetas as to have a better analysis of the spent coffee ground. XRD was used to identify the crystalline structure and qualitative compositions for the oven dried spent coffee ground.

3.6.2 X-Ray Fluorescence (XRF)

X-Ray Fluorescence (XRF) was the test to identify the chemical composition of the used coffee ground. X-Ray Fluorescence is an analytical instrument that is being used to detect the chemical composition of the solid, liquid includes the sample in powder form. This is a non-destructive test that could be used in a variety of elements ranges from sodium to uranium that are able to provide the concentration up to 100%. In this research, XRF is being used to analyze the chemical composition of the used coffee ground so that it can be used as the retarder admixtures in the mortar.

3.6.3 Energy-Dispersive X-Ray Spectroscopy (SEM EDX)

The purpose of SEM EDX being used in this research is to find out the clear resolution about the microstructure of the mortar. Thus, the microstructure in the mortar is unable to be seen by naked eyes. By using the surface imaging function provided by SEM EDX as shown in Figure 3.8, the microstructure of the mortar can easily be determined.

By using the surface imaging, the mortar sample needed to be cut by using diamond cutter for suitable size. The surface imaging of SEM EDX uses the magnification level of 200x, 1kx, 2.5kx, 5kx and 10kx. Different magnification level are able to show different surface image. In addition, the surface imaging of mortar focus on identifying the surface microstructure such as cracks and pores. On the other hand, the identification of material can be carried out too. The material identification includes cement, sand, CSH gel and others.

Figure 3.8 SEM EDX machine set up

3.7 Mechanical properties

In order to figure out the mechanical properties of the mortar, we have to carry out destructive laboratory test. The destructive test that has been chosen to test the mechanical properties of the mortar cube is the compressive strength test.

3.7.1 Compressive strength test

The compressive strength test was carried out according to the British Standard (BS 1881 : Part 116). Before carrying out the test, the surface of the compressive strength machine should be wipe clean to be free from grits or any substances which were to in contact with the platens of the machine. This measurement is taken to ensure that the loading applied will be even throughout the whole surface of the mortar cubes. The size of the mortar cube being prepared is 50mm x 50mm x 50mm as shown under Figure 3.9. The specimens will be put under loadings and the maximum loads will be recorded. Other than that, the type of failure and the surface appearance of the cubes will be observed as well. The compressive strength of the cubes were calculated using Equation 3.1. The testing of the cubes are taken at age of 3, 7, 14, 28, 45 days. There will be there specimens for each age of the cubes, in order to obtain the average data for a more accurate results. Figure 3.10 showed the compression machine that is being used to carry out the compressive strength test with 1.00 kN/s loading rate and start load of 5.00 kN, and stop load of 10%.

$$fc = \frac{P}{A} \qquad \textit{Equation 3.1}$$

Fc = Compressive strength of the mortar specimens (MPa)

P = Maximum loading recorded from the compressive strength test (N)

A = Average surface area of the specimen (mm^2)

Equation 3.1 : Formula to calculate Compressive Strength

Figure 3.9 Mortar mould 50mm x 50mm x 50mm

Figure 3.10 Compression test machine

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discuss the result of the laboratory testing that have been carried out based on the methods that are being presented in the methodology chapter. The fresh and hardened properties of the mortar and the chemical composition of the samples are being tested and results are being recorded. The tests that have been carried out on the fresh mortar are flow table test and Vicat test whereas for the hardened mortar is the compressive strength test. In addition, XRD, XRF and SEM EDX tests are being carried out to test the chemical composition of the samples. The samples that are being used to carry out the chemical composition tests are the SCG and the mortar cube samples. The results recorded from the laboratory works regarding different amount of admixtures added are being discussed in this chapter.

4.2 Fresh and hardened properties results of SCG mortars

The properties of the fresh SCG mortar in this research project are determined by flow table test and Vicat test. Furthermore, the properties of the hardened mortar are determined by the compressive strength test. All the results from the laboratory works will be presented by using tables and graphs in the sub-chapters. The nomination of the SCG mortar cube samples with different parameters are showed in Table 4.1.

Table 4.1 Naming of Mortar Cube Samples

Mortar Cube	Composition
0 SCG	0% of spent coffee ground
0.2 SCG	0.2% of spent coffee ground
0.4 SCG	0.4% of spent coffee ground
0.6 SCG	0.6% of spent coffee ground
0.8 SCG	0.8% of spent coffee ground
1.0 SCG	1.0% of spent coffee ground

4.2.1 Flow Table Test

After the mixing process has been completed, the fresh mortar are being tested. The flow value of the fresh mortar are being obtained by measuring the distance of x and y direction after the fresh mortar spread on the plate of the apparatus. The results of the flow table test, which measure the consistency of the fresh mortar are recorded and tabulated in Table 4.2. For flow table test, the amount of water for gauging should be able to give flow value at 105 ± 5% (Kondraivendhan & Bhattacharjee, 2015).

From the results recorded in this laboratory work, the 0.4 SCG, 0.6 SCG and 0.8 SCG mortar paste is recorded at 110% which are the same as the standard flow value of 110%.The flow value of 0 SCG, 0.2 SCG and 1.0 SCG are 115%, 113% and 114% respectively. The results are slightly higher than the standard flow value which is 110%.

This could be caused by the addition of SCG reduced the water content in the mortar, thus the workability of the mortar is improved. The similar results also recorded by (Chandra et al., 2013) which mentioned that the mortar is more workable when the water content is reduced due to addition of material. This is indicates by the 1.0 SCG mortar when the percentage of SCG added to the mortar is 1% of cement weight. However, the addition of SCG do not affect the flow ability of the mortar. The mortar still maintain the flow value within the deviation range of 5% as shown in Figure 4.1.

Table 4.2 Summary of flow value result

Mortar Cube	Flow Value (%)
0SCG	115
0.2SCG	113
0.4SCG	110
0.6SCG	110
0.8SCG	110
1.0SCG	114

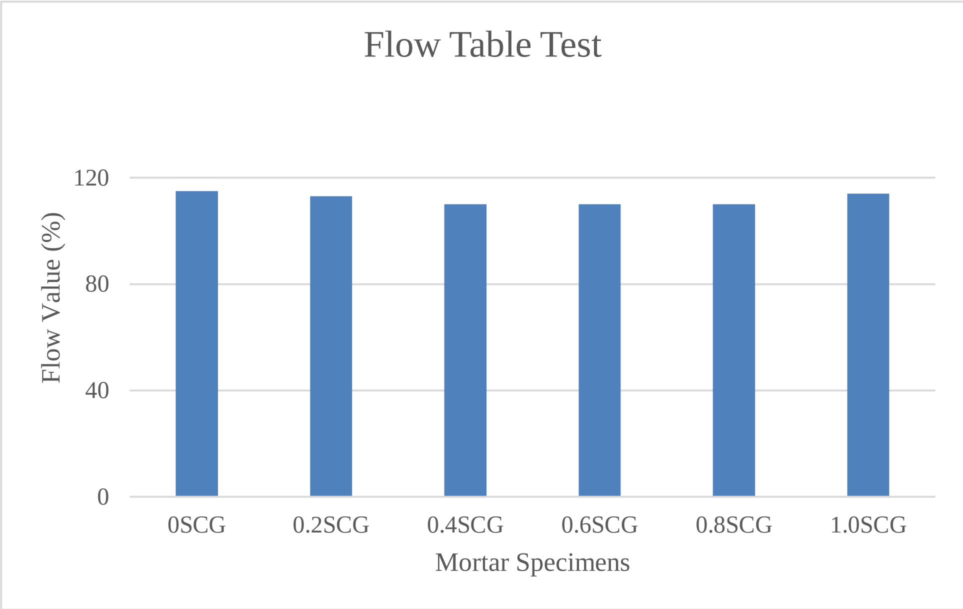

Figure 4.1 Bar chart of flow table test

4.2.2 Vicat Test

Vicat test also has been carry out to determine the setting time of the SCG mortar samples. Vicat test also known as setting time test, which are aimed to determine the initial and final setting time of the SCG mortar. Vicat test was conducted after the mixing of the fresh mortar is completed. The initial setting time and final setting time is observed and recorded. The initial setting time mentioned is the time when the penetration is 10mm or less is recorded while final setting time is the time when the mortar has completely lost its plasticity.

It is recorded in Table 4.3 that the 0.6 SCG, 0.8 SCG and 1.0 SCG mortar has longer initial setting time compared to the 0SCG mortar. The initial setting time of the 0SCG mortar is recorded at 180 minutes whereas 0.6 SCG and 0.8 SCG are recorded at

210 minutes and 200 minutes respectively. However, the 1.0 SCG mortar shows the longest initial setting time which is 240 minutes. From the results recorded in this research project, it shows that the addition of 0.6 % of SCG of cement weight onwards causing the cement to retard compared with the 0SCG mortar, which is the control mortar mix. This might be due to the chemical composition of the SCG which retards the mortar. It is recorded that SCG are sugar-rich compound which has the ability to retard the mortar. (Ballesteros et al., 2014) Hence, the higher the percentage of the SCG being added into the mortar mix, the longer the initial setting time.

The final setting time of the cement mortar is when it lost all of its plasticity. It was recorded that in this research, the 0.6 SCG, 0.8 SCG and 1.0 SCG mortar takes longer of final setting time compared to 0SCG, the control mortar final setting time. The final setting time of the 0SCG mortar is recorded at 220 minutes whereas the final setting time of 0.6 SCG, 0.8 SCG are recorded at 260 minutes and 250 minutes respectively.

However, the final setting time of the 1.0 SCG mortar is the longest among all which is recorded at 270 minutes. Based on the bar chart being presented below, it can be seen that the addition of SCG of 0.6 %, 0.8 % and 1.0 % of cement weight increased the initial setting time by 30 minutes, 20 minutes and 60 minutes compared to the control mortar initial setting time whereas for final setting time increase by 40 minutes, 30 minutes and 50 minutes compared to the control mortar final setting time. BS 12 (1978) suggested that the initial and final setting time of mortar to not be more than 45 minutes and 10 hours (Utsev & Taku, 2012) where SCG mortar passes this criteria. As a conclusion, the increasing of the percentage of SCG being added into the mortar are able to retard the mortar by increasing the initial and final setting time of the mortar.

Table 4.3 Summary of Vicat Test result

Specimen	Initial Setting Time (Minutes)	Final Setting Time (Minutes)
0 SCG	180	220
0.2 SCG	150	200
0.4 SCG	130	180
0.6 SCG	210	260
0.8 SCG	200	250
1.0 SCG	240	270

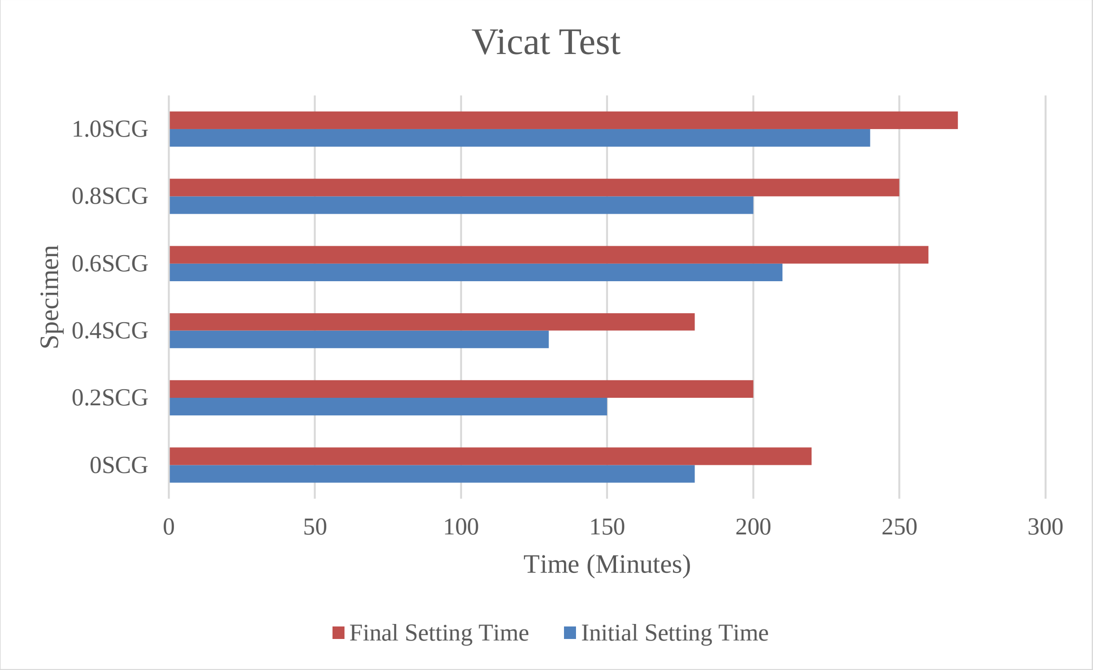

Figure 4.2 Bar chart of summary of Vicat Test

4.2.3 Compressive Strength Test

The compressive strength of the samples are determined after 3,7,28 and 45 days of water curing. In this research project, three cube samples were tested to get the average results reading and then recorded for a more accurate result. Table 4.4 shows the results for compressive strength of SCG mortar with different percentage of SCG added into the mix by cement weight. On the other hand, Figure 4.2 represented the graph of compressive strength at a different curing time.

Table 4.4 Summary of compressive strength results

Mortar Cube	Compressive Strength (MPa)			
	3 Days	7 Days	28 Days	45 Days
0 SCG	26.828	37.032	35.756	37.345
0.2 SCG	23.782	31.126	28.640	36.257
0.4 SCG	22.628	26.532	27.246	40.388
0.6 SCG	22.906	25.687	31.461	42.857
0.8 SCG	20.836	22.529	28.631	34.159
1.0 SCG	19.285	22.791	28.887	40.413

From the data presented from Table 4.4, the compressive strength for 0 SCG mortar, also the control mortar is the highest among all at 3 days, recorded at 26.828 MPa. The compressive strength however shows a decreasing trend 23.782 MPa, 22.628 MPa, 22.906 MPa, 20.836 MPa and 19.285 MPa for 0.2 SCG, 0.4 SCG, 0.6 SCG, 0.8 SCG and

1.0SCG respectively after SCG were added as admixtures. This shows that the early strength of the mortars are weaker compared to the control mortar. This is because the increasing percentage of SCG being added into the mortar will weaken the early strength due to the changes in water cement ratio as the addition of SCG into the cement mix will cause the water cement ratio to decrease as the SCG will absorb the water. This condition will weaken the hydration process of the cement results in lower early strength of SCG mortar in early stage (Teo et al., 2014). As hydration of cement will be affected by the water content in the design mix, the higher the water content, the higher the rate of hydration of cement, since the water content is reduced by the addition of SCG, the rate of hydration of cement is reduced as well. This causes the early strength development rate is lower.

Furthermore, at the age of 28 days, the compressive strength of control mortar still the highest but shows a slight decrease or almost constant compared to compressive strength 28 days, recorded at 35.756 MPa. The compressive strength of 0.2 SCG, 0.4 SCG, 0.6 SCG, 0.8 SCG and 1.0 SCG recorded at 28.640 MPa, 27.246 MPa, 31.461 MPa, 28.631 MPa and 28.887 MPa respectively. Indeed, the compressive strength of 0.6 SCG mortar shows a highest compressive strength among all the SCG mortar excluding the control mortar. This also imply a higher hydration rate in 0.6 SCG mortar compared to the others.

At the age of 45 days, the compressive strength of 0.6 SCG mortar is the highest compared to all the specimen. The compressive strength is recorded at 42.857 MPa, compared to control mortar, which only have compressive strength of 37.345 MPa at the same curing age. This is due to the mineral composition of SCG which consist of some pozzolanic material (Ballesteros et al., 2014) which brought pozzolanic effect to the mortar and results in the increases of the compressive strength at 45 days.The early strength of the mortar are weaker compared to the control mortar as the pozzolanic reaction does not takes place, this is because the lower rate of hydration results in slower production of calcium hydroxide, as pozzolanic reaction only starts after the calcium hydroxide being produced (Ikpong & Okpala, 1992). The proportion of 0.6 % of SCG being added into the mortar design mix is the optimum amount, which gives the highest compressive strength at the curing age of 45 days.

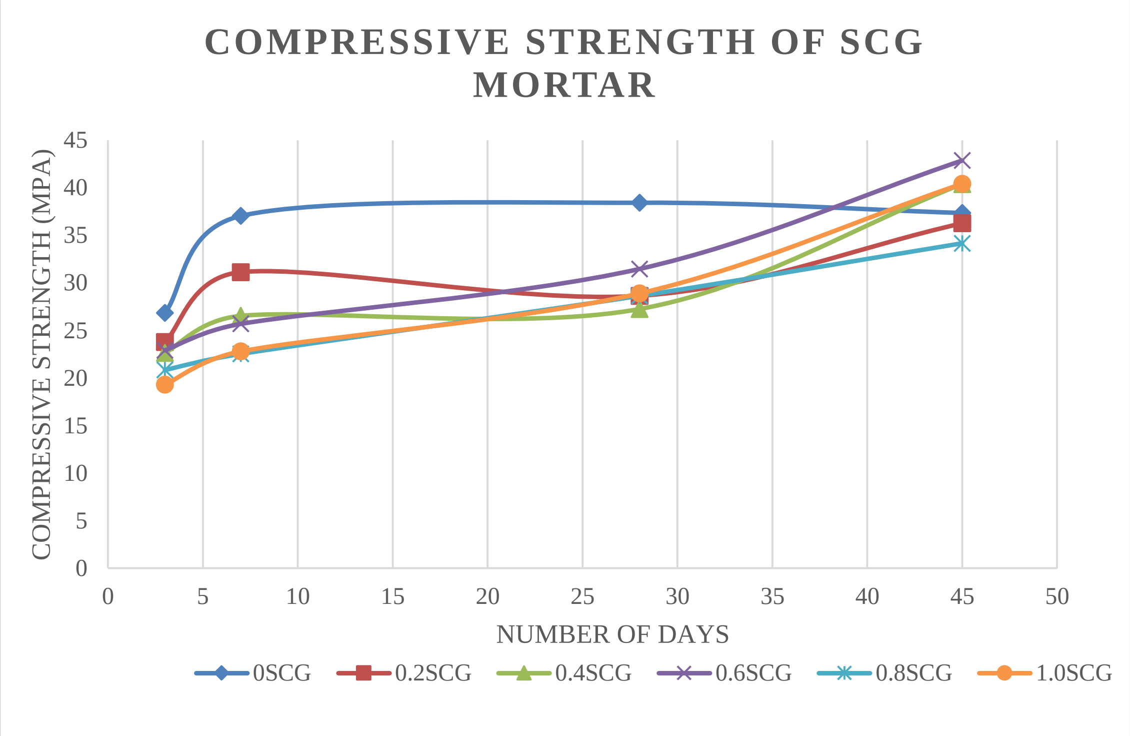

Figure 4.3 Development of Compressive Strength

4.3 Chemical composition result

The chemical composition test is carried out to study the chemical composition and properties of an unknown material. Therefore, chemical test is conducted in this research to find out the chemical composition and properties of the SCG samples and mortar cubes samples add with SCG. The tests which are carried out to determine the chemical composition and properties are the X-Ray Diffraction (XRD), X-Ray Florescence (XRF) and Energy-Dispersive X-Ray Spectroscopy (SEM-EDX). The chemical properties of SCG and the mortar added with SCG are tested in this research project. The results of the tests are presented as below.

4.3.1 X-Ray Diffraction (XRD)

XRD test is carried out to determine the chemical composition of the SCG. The results of the XRD test is presented with a 2D diffraction pattern graph which scattering peaks obtained from the test. From the graph, if shows the major elements which are found in the SCG sample. From the graph, the higher the intensity, the higher the number of the elements found in the SCG sample.

The results from the XRD test found that SCG mainly content of Potassium Oxide, Potassium Sodium Calcium Aluminium Chromium Oxide Silicate, and Tschortnerite. According to (Dai et al., 2016), the peak of SCG is at 20.2^0 and it is found to highly content native cellulose or hemi cellulose. From the graph obtained, SCG exhibit crystalline properties which is responsible for a higher tensile strength which is less accessible to chemical attacks (Ballesteros et al., 2014).

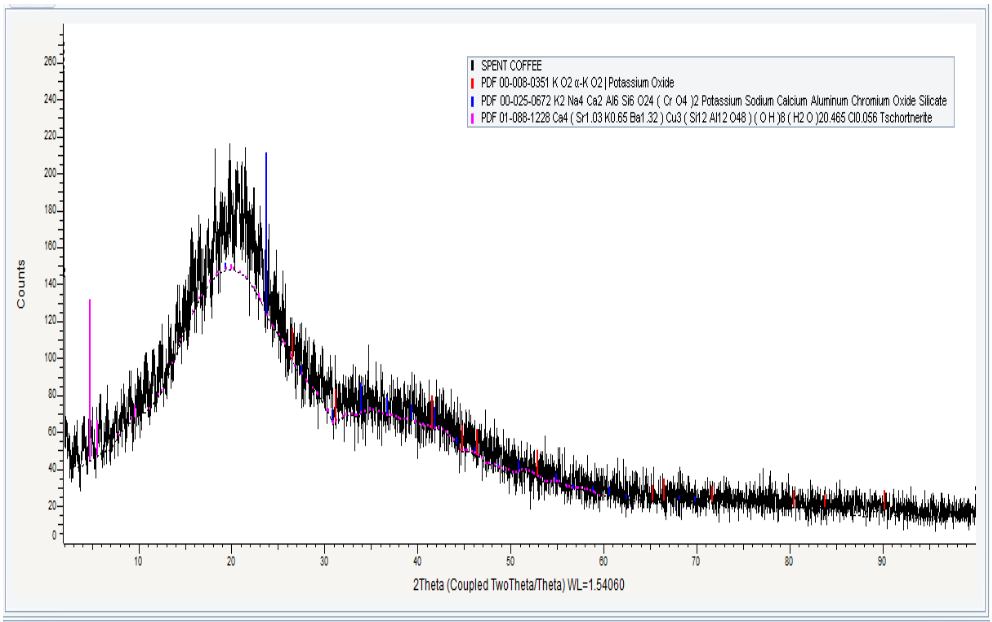

Figure 4.4 XRD pattern of SCG

4.3.2 X-Ray Fluorescent (XRF)

The XRF test is carried out to determine the chemical composition of SCG for instance the elements and the oxides in the SCG samples. The content of element in SCG samples are presented in Table 4.5. The result shows that the SCG samples mainly consists of Potassium (K), Calcium (Ca), Phosphorus (P), Sulphur (S), Iron (Fe), Silicon (Si), Magnesium (Mg), Molybdenum (Mo), Copper (Cu), Manganese (Mn), Zinc (Zn), Aluminium (Al) and Rubidium (Rb). Among all the elements, the highest proportion of the element found in the SCG sample is Potassium which accounts for 1.81 %. From the XRF results, it is also found that the SCG sample has a very low content of Silicon, which only accounts for 0.10%. It is also recorded that the SCG has sugar which polymerized into cellulose and hemicellulose structures which can exhibit properties and function as a retarder for mortar (Ballesteros et al, 2014).

Table 4.5 XRD test of element in SCG

Sample	SCG
Element	Percentage (%)
Potassium (K)	1.81
Calcium (Ca)	0.66
Phosphorus (P)	0.26
Sulphur (S)	0.21
Iron (Fe)	0.21
Silicon (Si)	0.10
Magnesium (Mg)	0.04
Molybdenum (Mo)	0.04
Copper (Cu)	0.03
Manganese (Mn)	0.03
Zinc (Zn)	0.03
Aluminium (Al)	0.02
Rubidium (Rb)	0.01

Moreover, the XRF results of the oxides of the SCG is presented in Table 4.6. The XRD result showed that the highest oxide content found in SCG is potassium oxide, which is 2.18 %. The oxides content found to be more than or equal to 0.20 % are calcium oxide, phosphorus pentoxide, sulphur trioxide, iron oxide and silicon dioxide. In addition, it can be determined from the results that the SCG has less composition of inorganic oxides such as silicon dioxide, iron oxide and alumina. Those inorganic oxides such as silicon dioxide, alumina and iron oxide are considered as hard substances (Aku et al, 2013). Hence, SCG are considered as soft substances as the addition will deteriorate the strength of mortar.

From the XRF results obtained, it can be concluded that the SCG consists of high sugar content and exhibit the properties to be use as a retarding admixtures for the mortar. As an overall, the result obtained from the XRF test is matched with the result from XRD test.

Table 4.6 XRD test of oxides in SCG

Sample	SCG
Oxide	Percentage (%)
Potassium Oxide	2.18
Calcium Oxide	0.92
Phosphorus Pentoxide	0.59
Sulphur Trioxide	0.52
Iron Oxide	0.30
Silicon Dioxide	0.22
Magnesium Oxide	0.07
Molybdenum Oxide	0.05
Copper Oxide	0.04
Manganese Oxide	0.04
Zinc Oxide	0.03
Aluminium Oxide	0.03
Rubidium Oxide	0.01

4.3.3 Energy-Dispersive X-Ray Spectroscopy (SEM EDX)

SEM EDX is carried out to determine the behaviour of the mortar under the addition of SCG by providing a high resolution image on the mortar sample. In this research project, the control mortar and 0.6 SCG mortar at the curing age of 45 days are analysed by SEM-EDX analysis. The image for the microstructure of the samples are obtained at different magnification levels such as 200x, 1 kx, 2.5 kx, 5 kx and 10 kx.

Figure 4.5 shows the SEM EDX image of the control mortar at 200x, 1 kx, 2.5 kx, 5 kx and 10 kx. It is found that the control mortar has two types of particles which are the angular particles which represent the sand and the spherical particles which represent the cement or CSH (Mindess & Diamond, 1992). The micrograph in Figure 4.5 (a) showed that there are a few pores on the surface of the control mortar which can affect the compressive strength if the number of pores is high. Meanwhile, Figure 4.5 (b) showed that there are a lot of angular particles with different sizes. Figure 4.5 (c) and (d) showed that the cement particles are covering the angular particles which are seen to consists of needle-like protruding structures. The needle-like structures is clearly shown in Figure 4.5 (e). The needle like protruding structures is the particles being produced after the hydration of cement which produced the C-S-H bond between cement and sand in the mortar (Ylmén et al., 2009).

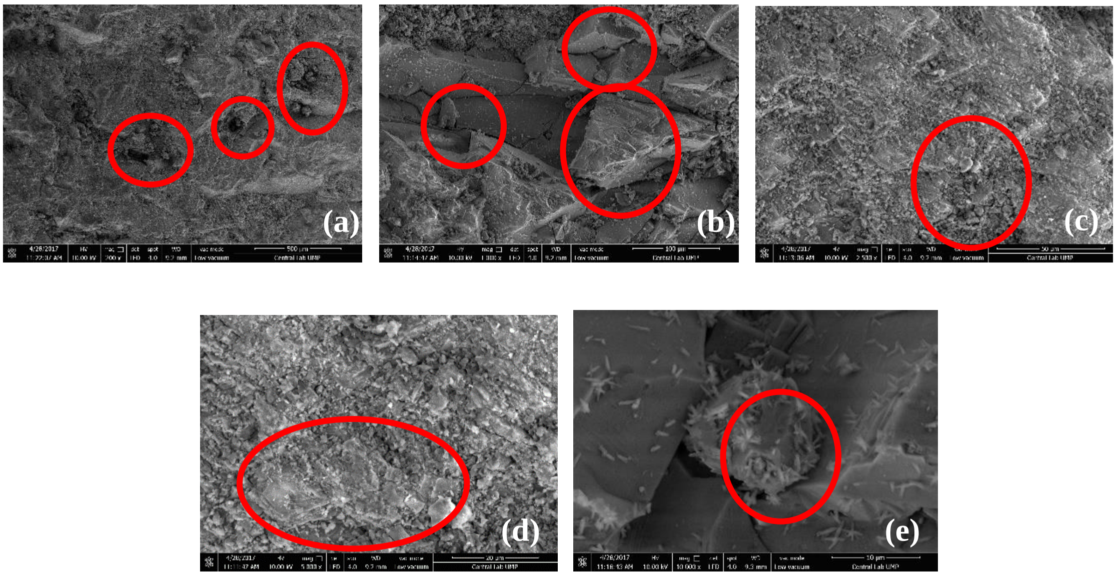

Figure 4.5 SEM EDX image of control mortar at (a) 200x (b) 1 kx (c) 2.5 kx (d) 5kx (e) 10kx

Figure 4.6 present the images from the SEM EDX on 0.6 SCG mortar at different magnification levels. It can be observed that there are no pores on the surface of the 0.6 SCG mortar at the age of 45 days curing under Figure 4.6 (a). This can be the reason that the compressive strength of the 0.6 SCG mortar is higher than the control mortar at the age of 45 days.

Besides that, in Figure 4.6 (c), (d) and (e) shows the number of needle-like structures is higher compared to the control mortar. This indicates that the C-S-H bond between the cement and the sand is more compared to the control mortar, which results in higher compressive strength. Other than that, the addition of SCG also promote the pozzolanic activity in the mortar due to the content of pozzolanic material found in SCG. SCG contained pozzolanic elements which favours pozzolanic activity in the mortar which contributes to the higher compressive strength to the SCG mortar (Ballesteros et al, 2014).

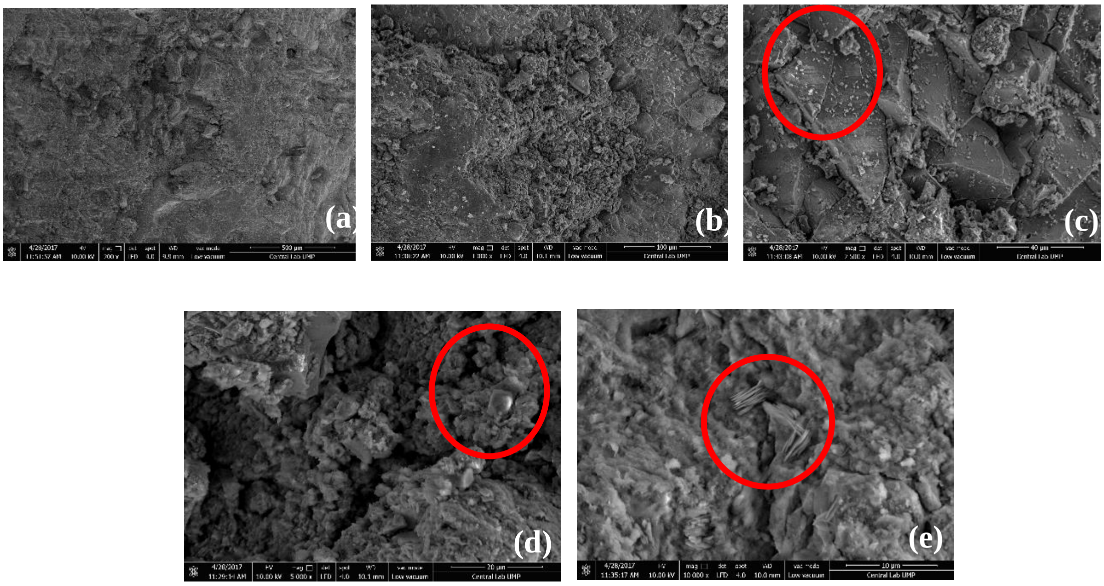

Figure 4.6 SEM EDX image of 0.6 SCG mortar at (a) 200x (b) 1 kx (c) 2.5 kx (d) 5 kx (e) 10 kx

4.4 Summary

Based on the results from the flow table test, it can be concluded that the addition of the SCG as admixtures in the mortar mix do not affect the flow ability of the mortar. The mortar samples after the addition of SCG still able to maintain it flow ability within the standard flow of 110 %. For flow table test, the amount of water for gauging should be able to give flow value at 105 ± 5%. (Kondraivendhan & Bhattacharjee, 2015).

Based on the results from Vicat test, the addition of SCG in the mortar as admixtures has retarding effect to the mortar. The 0.6 SCG, 0.8 SCG and 1.0 SCG mortar sample shows a longer initial and final setting time compared to the control mortar. The initial setting time of the control mortar is recorded at 180 minutes whereas for 0.6 SCG, 0.8 SCG and 1.0 SCG mortar is recorded at 210 minutes, 200 minutes and 240 minutes respectively. On the other hand the final setting time of control mortar is 220 minutes whereas for 0.6 SCG, 0.8 SCG and 1.0 SCG mortar is recorded at 260 minutes, 250 minutes, and 270 minutes respectively. Therefore, it can be concluded that the addition of SCG as admixtures are able to retard the setting time of the mortar. The higher the percentage of SCG being added into the mortar mix, the greater retarding effect that is presented in the mortar results in a longer initial and final setting time of the mortar.

According to the results from compressive strength test, it can be concluded that the addition of SCG as cement admixtures will decrease the early strength of the mortar. The higher the percentage of the SCG is added, the lower the early compressive strength. However, it is also recorded that the addition of SCG mortar favor the development of later compressive strength of the mortar. At the age of 45 days curing, it is found that the 0.6 SCG mortar has the highest compressive strength compared to all the samples including the control mortar. The compressive strength for 0.6 SCG mortar at 45 days curing age is recorded at 42.857 MPa whereas the control mortar is recorded at 37.345 MPa, the compressive strength of 0.6 SCG mortar is 14.76 % higher than the control mortar.

Moreover, the chemical composition test from XRD shows that the SCG mainly contain of Potassium Oxide, Potassium Sodium Calcium Aluminium Chromium Oxide Silicate, and Tschortnerite. According to Dai et al (2016), the peak of SCG is at 20.2^0 and it is found to highly content native cellulose or hemi cellulose. From the graph obtained, SCG exhibit crystalline properties which is responsible for a higher tensile strength which is less accessible to chemical attacks (Ballesteros et al, 2014). The result shows that the SCG samples mainly consists of Potassium (K), Calcium (Ca), Phosphorus (P), Sulphur (S), Iron (Fe), Silicon (Si), Magnesium (Mg), Molybdenum (Mo), Copper (Cu), Manganese (Mn), Zinc (Zn), Aluminium (Al) and Rubidium (Rb). Among all the elements, the highest proportion of the element found in the SCG sample is Potassium which accounts for 1.81 %. From the XRF results, it is also found that the SCG sample has a very low content of Silicon, which only accounts for 0.10%. The XRD result also showed that the highest oxide content found in SCG is potassium oxide, which is 2.18 %. The oxides content found to be more than or equal to 0.20 % are calcium oxide, phosphorus pentoxide, sulphur trioxide, iron oxide and silicon dioxide. It can be concluded that the SCG consists of high sugar content and exhibit the properties to be use as a retarding admixtures for the mortar. As an overall, the result obtained from the XRF test is matched with the result from XRD test.

Lastly, the SEM EDX test shows that the control mortar consists of needle-like protruding structures which are the product after the hydration of cement. This creates C-S-H bond between cement and sand particles which promotes better bonding to the mortar resulting in better compressive strength. However, the SEM EDX test for 0.6 SCG mortar shows a higher number of needle-like protruding structures compared to the control mortar. This indicates that the 0.6 SCG mortar has higher number of C-S-H bonds which results in a higher compressive strength compared to the mortar. In addition, SCG also contains pozzolanic materials which also promotes pozzolanic effect to the mortar (Ballesteros et al, 2014)

From all the tests that has been conducted in this research project, it can be summarize that the addition of SCG into the mortar as admixtures retards the setting time of the mortar. It also reduce the early strength of the mortar but the compressive strength still increases as the age increase and eventually exceed the compressive strength of control mortar at age 45 days of curing. Hence, more research project need to be conducted to find out the potential use of the SCG as cement admixtures.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter review the finding of this research based on the laboratory works results obtained. The results recorded from the laboratory works are based on the objectives being stated earlier on which is to determine the potential use of SCG as retarding admixtures in mortar. By that, tests are carried out to determine the characteristics of SCG in terms of the elements that are suitable to be used as retarding admixtures in mortar.

In addition, the fresh and hardened mortar properties are also being tested to find out the effect on the fresh and hardened mortar after the addition of the SCG in the mortar mix. Furthermore, the chemical composition of SCG is also tested to figure out the chemical properties of the material.

All of the specimens are subjected to 3, 14, 28 and 45 days of water curing before tests for hardened mortar properties are being carried out.

5.2 Conclusions

This research project is carried out to determine the chemical and mechanical properties of the mortar after addition of SCG as retarding admixtures. From the results recorded from the laboratory works, few conclusions can be made as followings:

1. The results recorded from the flow table test showed that all the mortar paste has acceptable flow value which that the flow values are recorded between 110 ± 5%. This also implies that the addition of SCG in the mortar do not affect the flow ability of the fresh mortar compared to the control fresh mortar.

2. The addition of SCG in mortar as cement admixtures has retarded the setting time as compared with the control mortar which caused by the retarding effect of SCG as a retarding admixtures. The initial setting time and final setting time showed an increasing trend where the time required for the SCG mortar paste to set is increased with the increasing amount of SCG being added into the mortar mix.

3. The compressive strength of the hardened mortar added with SCG is tested for 3, 7, 28 and 45 days curing time. The results obtained from the compressive strength test shows that the addition of spent coffee ground decrease the strength of the mortar. The higher the percentage of SCG added, the lower the strength. However, the development of compressive strength at 28 days and 45 days of curing time, the compressive strength of 0.4 SCG, 0.6 SCG and 1.0 SCG mortars show sharp increasing trend and appeared to be higher than control mortar at 45 days of curing time.

4. Based on the XRF test being conducted for the spent coffee ground, it was found that the spent coffee ground consists a small quantity of Silicon, Iron, Aluminium, Phosphorus, Calcium, Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3), Iron Oxide (Fe_2O_3), Phosphorus Pentoxide (P_2O_5), Calcium Oxide (CaO) and Sulphur Trioxide (SO_3) which promote pozzolanic activity.

5. Based on the XRD test being conducted for the spent coffee ground, the spent coffee ground mostly consists of

6. Based on the SEM-EDX test that has been conducted, it is found that the surface of the mortar of 0.6 SCG mortar has less pores compared to the control mortar. The needle–like structure which is the C-S-H bond formed in lumps discovered in 0.6 SCG mortar contribute to a better bonding for particles which results in a higher compressive strength than the control mortar.

7. Based on the results from all the laboratory works, we can conclude that the spent coffee ground has shown retarding effect which is potentially use as retarding admixtures. It also has achieved suitable strength for structural use. However, more research and laboratory works has to be carried out to explore more properties of mortar under the effect of spent coffee ground and the retarding ability of spent coffee ground before it can be fully utilize in construction industry.

5.3 Recommendation for future research

This research is carried out mainly to find out the potential of the SCG as retarding admixtures for mortar. The experimental work conducted were to find out the chemical properties and mechanical properties of the mortar under the addition of SCG as retarding admixtures. However, more research and studies should be conducted in order to figure out more potential use of the SCG in construction field. The recommendations for the future studies are as follows:

i. The study of incinerate or microwave SCG in order to reduce the organic composition in SCG.

ii. The study of oven dry SCG at 100 ^{0}C as retarding admixtures in mortar to the retarding effect for mortar and mechanical performance of SCG mortar.

iii. The study of extraction of sugar compound from SCG to enhance the effect of the SCG as retarding admixtures for mortar.

iv. The study of the durability properties of mortar under the effect of SCG as retarding admixtures.

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APPENDIX A

RESULT FOR FLOW TABLE TEST

Mortar Cube	Flow Value (%)
Control	115.30
0.2SCG	112.96
0.4SCG	110.19
0.6SCG	110.03
0.8SCG	109.86
1.0SCG	114.32

APPENDIX B

RESULT FOR VICAT TEST

Vicat test for control mortar (220 minutes)

Time	Penetration (mm)		
1225	-	-	-
1255	0	0	0
1325	0	0	0
1355	0	0	0
1425	19	0	16
1455	2	3	4
1505	4	2	2
1515	0	1	1
1525	0	0	1
1535	0	0	0

Vicat test for 0.2% SCG mortar (200 minutes)

Time	Penetration (mm)		
1039	-	-	-
1109	0	0	0
1139	0	0	0
1209	20	18	0
1239	13	10	15
1309	3	4	4
1339	1	1	0
1349	2	1	1
1359	0	0	1
1409	0	1	0
1419	0	0	0

Vicat Test for 0.4% SCG mortar (180 minutes)

Time	Penetration (mm)		
1146	-	-	-
1216	0	0	0
1246	0	0	0
1316	0	0	13
1346	13	15	9
1416	5	5	3
1426	2	1	2
1436	0	1	1
1446	0	2	1
1456	0	0	1
1506	0	0	0

CONTINUED

Vicat test for 0.6% SCG mortar (260 minutes)

Time	Penetration (mm)		
1223	-	-	-
1253	0	0	0
1323	0	0	0
1353	0	0	0
1423	18	16	20
1453	14	15	16
1523	11	8	7
1553	3	2	2
1603	3	1	2
1613	2	1	1
1623	0	0	1
1633	0	0	1
1643	0	0	0

Vicat test for 0.8% SCG mortar (250 minutes)

Time	Penetration (mm)		
1339	-	-	-
1409	0	0	0
1439	0	0	0
1509	0	0	0
1539	0	0	20
1609	19	20	0
1639	12	18	10
1709	10	9	12
1739	2	4	3
1749	3	2	2
1759	3	3	1
1809	0	1	0
1819	0	0	1
1829	0	0	0

CONTINUED

Vicat test for 1.0% SCG mortar (270 minutes)

Time	Penetration (mm)		
0941	-	-	-
1011	0	0	0
1041	0	0	0
1111	0	0	0
1141	0	0	0
1211	14	13	19
1241	12	11	14
1311	11	10	7
1341	3	2	2
1351	1	1	1
1401	0	1	0
1411	0	0	0

APPENDIX C

RESULT FOR COMPRESSIVE STRENGTH TEST

Compressive strength for control mortar

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0SCG3-A	275.29	50 x 50	2500		28.676	26.828
0SCG3-B	277.61	50 x 50	2500		27.411	
0SCG3-C	278.27	50 x 50	2500		24.396	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0SCG7-A	280.35	50 x 50	2500		37.478	37.032
0SCG7-B	279.54	50 x 50	2500		37.832	
0SCG7-C	278.04	50 x 50	2500		35.785	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0SCG28-A	279.43	50 x 50	2500		38.705	38.422
0SCG28-B	280.58	50 x 50	2500		40.716	
0SCG28-C	278.85	50 x 50	2500		35.846	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0SCG45-A	278.53	50 x 50	2500		37.330	37.345
0SCG45-B	279.42	50 x 50	2500		37.367	
0SCG45-C	-	-	-	-	-	

CONTINUED

Compressive strength for 0.2% SCG mortar

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.2SCG3-A	276.82	50 x 50	2500		23.447	23.782
0.2SCG3-B	276.97	50 x 50	2500		23.150	
0.2SCG3-C	277.88	50 x 50	2500		24.750	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.2SCG7-A	278.60	50 x 50	2500		31.728	31.126
0.2SCG7-B	276.19	50 x 50	2500		31.114	
0.2SCG7-C	274.57	50 x 50	2500		30.537	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.2SCG28-A	273.30	50 x 50	2500		28.174	28.640
0.2SCG28-B	273.14	50 x 50	2500		29.123	
0.2SCG28-C	269.50	50 x 50	2500		28.623	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.2SCG45-A	276.76	50 x 50	2500		36.548	36.257
0.2SCG45-B	275.62	50 x 50	2500		34.855	
0.2SCG45-C	271.25	50 x 50	2500		37.367	

CONTINUED

Compressive strength for 0.4% SCG mortar

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.4SCG3-A	279.88	50 x 50	2500		23.391	22.628
0.4SCG3-B	278.98	50 x 50	2500		21.624	
0.4SCG3-C	276.97	50 x 50	2500		22.870	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.4SCG7-A	268.53	50 x 50	2500		27.467	26.532
0.4SCG7-B	272.98	50 x 50	2500		26.524	
0.4SCG7-C	271.08	50 x 50	2500		25.606	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.4SCG28-A	274.75	50 x 50	2500		24.341	27.246
0.4SCG28-B	278.69	50 x 50	2500		29.830	
0.4SCG28-C	267.00	50 x 50	2500		27.568	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.4SCG45-A	281.62	50 x 50	2500		39.730	40.388
0.4SCG45-B	281.75	50 x 50	2500		41.275	
0.4SCG45-C	280.59	50 x 50	2500		40.158	

CONTINUED

Compressive strength for 0.6% SCG mortar

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.6SCG3-A	269.15	50 x 50	2500		22.759	22.906
0.6SCG3-B	270.19	50 x 50	2500		22.846	
0.6SCG3-C	276.46	50 x 50	2500		23.112	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.6SCG7-A	274.43	50 x 50	2500		26.555	25.687
0.6SCG7-B	271.89	50 x 50	2500		25.734	
0.6SCG7-C	273.50	50 x 50	2500		25.271	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.6SCG28-A	274.29	50 x 50	2500		32.826	31.461
0.6SCG28-B	270.50	50 x 50	2500		31.428	
0.6SCG28-C	274.70	50 x 50	2500		30.128	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.6SCG45-A	275.42	50 x 50	2500		42.968	42.857
0.6SCG45-B	275.29	50 x 50	2500		42.745	
0.6SCG45-C	-	-	-	-	-	

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Compressive strength for 0.8% SCG mortar

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.8SCG3-A	273.87	50 x 50	2500		19.037	20.836
0.8SCG3-B	275.26	50 x 50	2500		22.089	
0.8SCG3-C	272.59	50 x 50	2500		21.382	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.8SCG7-A	272.77	50 x 50	2500		21.549	22.529
0.8SCG7-B	272.20	50 x 50	2500		23.429	
0.8SCG7-C	272.73	50 x 50	2500		22.610	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.8SCG28-A	271.12	50 x 50	2500		27.020	28.631
0.8SCG28-B	274.22	50 x 50	2500		29.905	
0.8SCG28-C	264.60	50 x 50	2500		28.967	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
0.8SCG45-A	269.63	50 x 50	2500		33.310	34.159
0.8SCG45-B	271.35	50 x 50	2500		34.855	
0.8SCG45-C	270.88	50 x 50	2500		34.312	

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Compressive strength for 1.0% SCG mortar

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
1.0SCG3-A	271.60	50 x 50	2500		19.484	19.285
1.0SCG3-B	271.74	50 x 50	2500		18.330	
1.0SCG3-C	274.47	50 x 50	2500		20.042	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
1.0SCG7-A	275.20	50 x 50	2500		22.632	22.791
1.0SCG7-B	276.02	50 x 50	2500		22.107	
1.0SCG7-C	270.83	50 x 50	2500		23.633	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
1.0SCG28-A	274.11	50 x 50	2500		29.681	28.887
1.0SCG28-B	273.99	50 x 50	2500		23.578	
1.0SCG28-C	264.31	50 x 50	2500		33.403	

Sample	Weight (g)	Dimension (mm)	Area (mm^2)	Maximum Load (N)	Ultimate Strength (N/mm^2)	Average Ultimate Strength (N/mm^2)
1.0SCG45-A	278.00	50 x 50	2500		40.605	40.413
1.0SCG45-B	276.86	50 x 50	2500		40.475	
1.0SCG45-C	273.94	50 x 50	2500		40.158	

APPENDIX D

PHOTO OF LABORATORY PREPARATION

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PHOTO OF LABORATORY PREPARATION