EFFECT OF FLY ASH AS PARTIAL CEMENT REPLACEMENT ON WORKABILITY AND STRENGTH ON WATER CURED LIGHTWEIGHT CONCRETE

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ABSTRAK

Abu terbang yang dihasilkan dari loji kuasa arang batu dilupuskan sebagai sisa pencemaran alam sekitar. Penggunaan simen dalam pembinaan menyebabkan pelepasan gas rumah hijau yang dihasilkan daripada pengeluaran simen. Ia juga bukan persekitaran yang mesra alam dan mahal untuk pembinaan di era ini. Di samping itu, batu dandang minyak kelapa sawit merupakan hasil sampingan sampah pengilangan minyak sawit yang menyebabkan peningkatan kawasan pembuangan sampah. Dalam kajian ini, kajian ini menyiasat kesan abu terbang sebagai penggantian simen separa pada kebolehkerjaan, kekuatan mampatan dan lentur pada air konkrit ringan sembuh. Lima jenis campuran dengan pelbagai peratusan abu terbang sebagai kandungan penggantian simen separa digunakan. Campuran pertama ialah 0% daripada tindakan abu terbang sebagai spesimen kawalan dan yang lain mengandungi 10%, 20%, 30% dan 40% kandungan abu terbang. Kekuatan mampatan dan kekuatan lentur ditentukan pada 7, 14 dan 28 hari. Penemuan menunjukkan kekuatan meningkat apabila peratusan abu terbang meningkat. Kekuatan mampatan tertinggi ialah 10% abu terbang yang digunakan dalam konkrit. Trend yang sama diperhatikan dalam keputusan lenturan. Abu terbang menjadi bahan pozzolanic menyebabkan reaksi pozzolanic dalam campuran konkrit yang meningkatkan jumlah C-S-H gel. Akibatnya, konkrit menjadi lebih padat dan lebih kuat.

ABSTRACT

Fly ash generated from coal power plant is disposed as environmental polluting waste. The use of cement in construction cause the greenhouse gas emission that produces from the cement production. It is also not eco-friendly environment and costly for construction in this era. In addition, palm oil boiler stone is a waste by-product of palm oil milling that causes the increasing of dumping area. In this study, this research investigates the effect of fly ash as partial cement replacement on workability, compressive strength and flexural on water cured lightweight concrete. Five types of mixes with various percentage of fly ash as partial cement replacement content were used. The first mixes are 0% of fly ash act as control specimen and the others contains 10%, 20%, 30% and 40% of fly ash content. The compressive strength and flexural strength were determined at 7, 14 and 28 days. Findings show that strength is increasing as a percentage of fly ash used increase. The highest compressive strength is 10% of fly ash used in concrete. Similar trend were observed in flexural strength result. Fly ash being a pozzolanic material causes pozzolanic reaction in concrete mix which increases amount of total C-S-H gel. As a result, the concrete become denser and stronger.

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LIST OF SYMBOLS

kg	Kilogram
m^3	Meter
MPa	Mega pascal
%	Percentage

LIST OF ABBREVIATIONS

LWC	Lightweight Concrete
LWAC	Lightweight Aggregate Concrete
POBS	Palm Oil Boiler Stone
OPC	Ordinary Portland Cement
OPEFB	Oil Palm Empty Fruit Bunches
OPS	Oil Palm Shell

CHAPTER 1

INTRODUCTION

1.1 Introduction

Lightweight concrete (LWC) is a special concrete which weigh lighter than conventional concrete. There are three types of LWC, which are lightweight aggregate concrete, aerated concrete, and no-fines concrete. LWC has a lower modulus of elasticity, higher inelastic strains and lower coefficient of thermal expansion. In addition, LWC has more continuous contact zone between the aggregate and the paste, and more water in the pores of aggregate for continued internal curing when compared to normal weight concrete. LWC has lower thermal expansion than ordinary concrete and can reduce the cost of material used for construction.

Malaysia is one of the largest producers and exporters of palm oil products to various corners of the world (Kanadasan, 2014). One of the top product is Palm Oil Boiler Stone (POBS) act as LWC. The processing phase of palm oil products accumulate too much causes the disposal site to be limited. POBS was obtained from the by-product of palm oil milling (Bashar, 2014) and a waste by-product from the incineration process of oil palm shells and fibers (Mohammed, 2011). The waste product such as POBS causes pollutions such as air pollution during the milling stage of palm oil production and land pollution where the dumping of palm oil boiler stone has increase the degradation of land. Utilization of POBS in concrete production did not only solves the problem of solid waste disposal but also helps to conserve natural resources (Bashar, 2014).

Another waste product that comes from coal industry is fly ash which is a fine powder that is a by-product of burned pulverized coal in the electric generation power plant. The ash contains aluminous and siliceous materials will form the same compound with Portland cement if added with water and lime. Improve workability, contribute to strength development and hence consider an effective cementitious component of concrete found in fly ash (Islam, 2010). The use of fly ash as an eco-friendly product as a by-product produces low energy. The benefits of using fly ash are to reduce the problems of cracking, permeability and bleeding. It also can be a cost-effective replacement for Portland cement because it may reduce the amount of cement when fly ash added to concrete. Finally, it gives benefits for our environment.

1.2 Problem Statement

Due to the growing of economy with fast development in this era, the usage of cement is increasing. Increasing usage of large quantities of cement may cause problems to the consumers. Cement is a broad energy commodity industry and leads to the release of large amounts of greenhouse gases (Chowdhury, 2015). Fly ash is also a waste product that produces from coal industry that causes air pollution. In addition, palm oil boiler stone (POBS) is also a waste from palm oil mill industry. The dumping of palm oil boiler stone has increased the degradation of land and affecting groundwater sources.

1.3 Objective of Study

The objective of the study is as follow:

a) To investigate the effect of fly ash as partial cement replacement on the workability of Palm Oil Boiler Stone lightweight aggregate concrete.

b) To investigate the effect of fly ash as partial cement replacement on compressive strength of Palm Oil Boiler Stone lightweight aggregate concrete.

c) To investigate the effect of using the different percentage of fly ash as partial cement replacement towards the flexural strength of Palm Oil Boiler Stone lightweight aggregate concrete.

1.4 Scope of Research

This test is conducted to determine the effect of fly ash as partial cement replacement towards workability and strength of lightweight concrete. In this thesis, there are five samples of mix that were casted, which were 0% that act as a control concrete specimen, 10%, 20%, 30% and 40% of fly ash as a substitute for the cement. The difference percentage of fly ash as partial cement replacement was to investigate the strength of concrete. There is two type of specimens conducted for curing regime namely beam that was conducted to test flexural strength and cube that was conducted to test compressive strength of concrete. In addition, slump test was conducted to test the workability of the concrete. To get the accurate result, the test will be repeated three times and within 28 days.

1.5 Significance of Research

Utilization of fly ash as partial cement replacement has many significant environmental benefits. Fly ash use conserves natural resources and materials. Use of fly ash can avoid landfill disposal. The use of fly ash as a substitute for cement also reduces air pollution. Meanwhile, the use of palm oil boiler stone (POBS) can also help to reduce the use of landfill that affects the groundwater sources. This can keep the groundwater sources safe.

1.6 Layout of Thesis

This report consists of five chapters. Chapter one introduces the issue investigated in this research highlighting problem statements and outlining objective to be achieved. The scope of research and contribution of the study is also included in this section. The chapter ends with the layout of the thesis. Chapter two discusses the utilization of POBS and fly ash in concrete production. This includes the review of basic properties and application of LWAC. Define the workability and strength of concrete and the review of these issues presented in this chapter.

Chapter three discusses the methodologies used in this study. In this section reported the preparation of mix ingredients and the apparatus used in conducting the experiment. The detail explanation about design mix of the concrete will present in this chapter. In chapter three also discuss the testing procedure adopted. Chapter four mainly presents and discusses the laboratory results of POBS lightweight aggregate concrete incorporated with fly ash. Data that has been analysing and form of graph for workability and strength test result are present in this chapter.

Chapter five concludes the whole study. Based on the result obtained from the testing the respective objectives listed are drawn in this conclusion. The recommendations for future study have been the list in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Concrete is one of the most important materials that contribute to construction in the world. To produce concrete, natural resources such as cement, sand, stone, water and so on were used, which is high in demand in the concrete industry. According to Saha (2017), almost 7% of greenhouse gas emission produced from the cement production because the process makes the cement produce a large amount of carbon dioxide. Conventional concrete using Ordinary Portland Cement (OPC) causes a lot of problems especially to the mass concrete (Ahmad et al., 2014). From this problem, substitution of waste material is the best alternatives way to achieve sustainable development in the concrete industry.

Malaysia industry produces many by-products. Malaysia coal industry generate waste material name fly ash that can be used as a partial cement replacement. They generate millions of tons of waste and produces waste material such as fly ash that is produced in Tanjung Bin Power Plant, Johor. Another waste product that is added to the concrete is Palm Oil Boiler Stone (POBS) that is from palm oil industry. Palm oil boiler stone is produced from burning of solid wastes in boiler combustion process that come from Palm Oil Industry Lepar Hilir, Pahang.

2.2 Fly Ash

Coal fly ash is a material that is being mainly composed of nearly perfect spheres of Al-silicate glass that disserves applications making use of such properties, rather than to be used as an inert filler (Nugteren, 2007). Fly ash comprised of the non-combustible mineral portion of coal and it is generated from the coal combustion process. Efficient recycling and resource recovery from coal fly ash has been a major topic of current international research interest that aimed at achieving sustainable development of human society from the viewpoints of energy, economy, and environmental strategy (Hui et al., 2009). These particles solidify as microscopic, glassy spheres that are collected from the power plants exhaust before they can fly away hence the products name fly ash (Islam, 2010).

Fly ash is known to be a good pozzolanic material for use in concrete. Additionally, it can increases strength development, and later ages, reducing corrosion of reinforcing steel and generally improves resistance to chemical attack. The successful application of fly ash will not only reduce the cement consumption but also eliminate the waste disposal costs (Saha, 2017). Utilization of waste material like fly ash gives more benefit and helps to conserve natural resources.

2.2.1 Fly Ash from Malaysia Coal Industry

Fly ash is a waste material derived from the burning of coal in power generating plants. It generates problems of discarding as well as environmental degradation, due to its nature of causing air and water pollution on a large scale (Nadesan & Dinakar, 2017). Many coal industries like TNB Kapar in Selangor, Tanjung Bin Power Plant in Johor, Sri Ulu Langat Palm Oil in Selangor generate a large amount of fly ash. Generation of fly ash was the increase from year to year and such waste would contribute to environmental pollution if left unmanaged.

2.2.2 Characteristic of Fly Ash

Fly ash sample enriched predominantly in silica, alumina and iron oxides fall under the category of F. The major mineral crystalline phase identified in the ash sample is quartz and mullite (Kaushal, 2017). Due to pozzolanic activity, low water demand reduced bleeding in the concrete, hence, fly ash has been adopting widely in the construction industry. Pozzolanic materials are known as the cementitious material that commonly silica or alumina and silica that was classified by their chemical and mineralogical composition and particle characteristic (Bayuaji, et al., 2016). It has the ability to convert calcium hydroxide to calcium silicate hydrate gel (C-S-H).

Fly ash also can improve the workability and compressive strength of the concrete. The strength development of fly ash depends on its chemical and physical properties. The chemical characteristics of fly ash are secondary, although the post-compaction cementation provided by some high-calcium fly ash is likely to prove beneficial (Ahmaruzzaman, 2010). Fly ash composed of fine particle size distribution exhibits compressive strength comparing to the ordinary fly ash and have the positive impact on shrinkage mitigation (Saha, 2017). It also was shown to reduce the heat of hydration and the risk of thermal cracking. Table 2.1 shows the chemical composition of cement and fly ash (Saha, 2017).

Table 2.1 The chemical composition of cement and fly ash

Parameter	OPC (%)	Fly Ash (%)
SiO_2	20.29	76.34
Al_2O_3	5.48	14.72
Fe_2O_3	2.85	3.69
MgO	1.24	0.54
SO_3	2.49	0.11
CaO	63.11	0.6
Na_2O	0.29	0.19
K_2O	0.45	0.96
Cr_2O_3	0.02	-
P_2O_5	0.17	0.1
SrO	0.05	-
TiO_2	0.27	0.61
Mn_2O_3	0.08	0.07
ZnO	0.04	-
LOI	3.39	0.53

Source: Saha (2017)

2.2.3 Utilization of Fly Ash

Coal based thermal plants generating a large amount of fly ash as a by-product from its combustion. With increasing the environmental awareness, utilization of fly ash has become an attractive alternative to disposal (Kaushal, 2017). Shrinkage of concrete that applies to fly ash depends on its fineness and water requirements. In addition, fly ash concrete showed higher permeable void and the void content increased with the increment of the fly ash. The use of fly ash in concrete also increases the porosity of the concrete. Besides that, fly ash can reduce the heat of hydration and the risk of thermal cracking due to its pozzolanic activity. The reaction of fly ash gives a great contribution to the properties development of concrete. This is because fly ash particle is finer comparing to Portland cement as the fly ash had a higher specific surface area than portland cement. The use of fly ash in replacing the cement greatly contributes to the reduction of environmental pollution that has been the cause of pollution especially air pollution. Table 2.2 shows the utilization of fly ash as a replacement in concrete.

Table 2.2 The utilization of fly ash as a replacement in concrete

SOURCES	RESEARCH AREA
Toniolo and Boccaccini (2017)	Fly ash (FA) is the most used and suitable waste material in geopolymerization
Rafieizonooz, Mirza, Salim, Hussin, and Khankhaje (2016)	Fly ash as the replacement for sand and cement
Abbasa, Saleema, Kazmib, and Munirb (2017)	Production of sustainable clay bricks using waste fly ash.

From the properties of fly ash, it can be as the additive agent in a soil that improves nutrients. This will leads to moderate the environment and economic impacts disposal fly ash by creating new probabilities for its more utilization (Kaushal, 2017). The results demonstrate that the strength of fly ash containing concrete improves more slowly but more strongly with aging than their fly ash free counterparts. An optimum fly ash replacement ratio exists where the maximum compressive strength of fly ash containing concrete can be achieved, and the maximum strength for the specimens aged 28 days and above is higher than of fly ash free concrete (Kaushal, 2017). Use fly ash can also decrease the corrosion by hindering chloride penetration as well as decreasing the content of free chloride.

In addition, fly ash is an environmentally friendly alternative to ordinary Portland cement as it is an industrial by-product (Moffatt et al., 2017). The use of fly ash can help to reduce air pollution because it easily carries by the wind. The use of fly ash as replacement of cement give more advantage which are can save the environmental problem and to keep the natural resources . This is because the production of cement emitted a massive carbon dioxide and it is a continuous increase in its use all over the world. Figure 2.1 shows the comparison of the environmental impact of all scenarios (Huang and Lo, 2017).

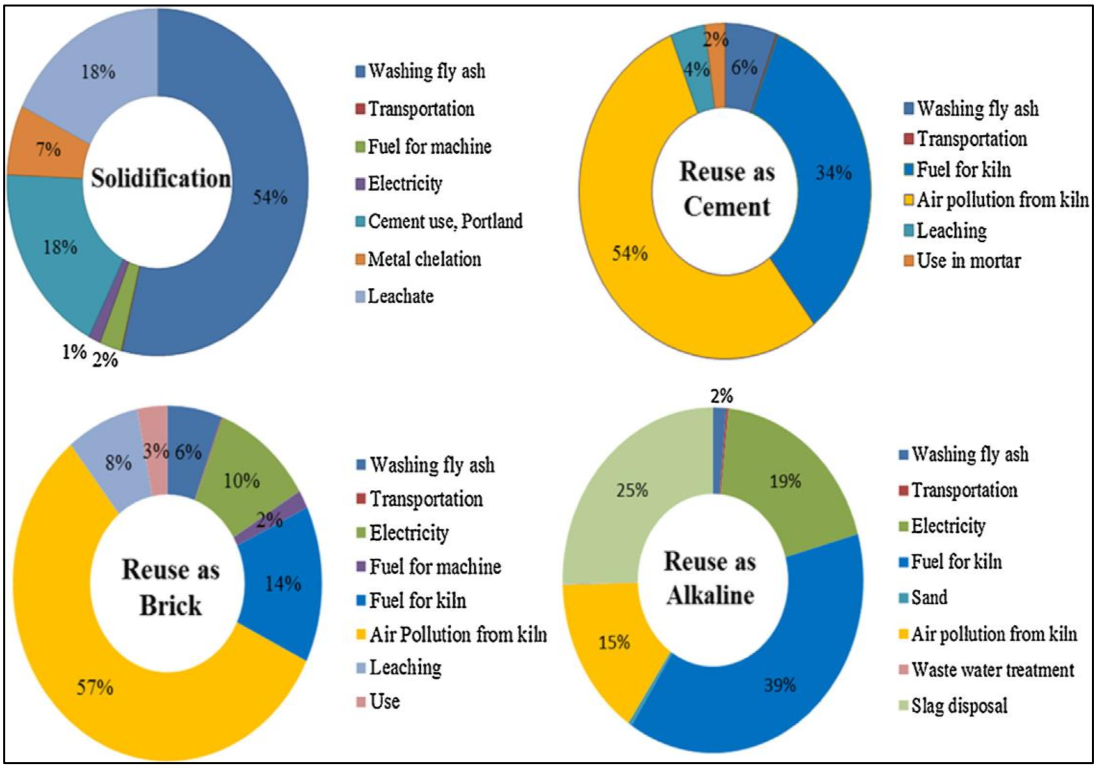

Figure 2.1 Environmental impact distributions for all scenarios

Source: Huang and Lo (2017).

2.3 Waste from Malaysia Palm Oil Industry

The Palm Oil Tree in Malaysia originated from West Africa that is growing wild and later developed into an agricultural crop. Palm oil industry becomes one of the main Malaysian commodities as indicated in Ninth Malaysian Plan (RMK9) (Ahmad et al., 2014). Under this plan, Malaysia's focus on the biotechnology industry is to generate a large number of agricultural products to be export to overseas. The main commodities listed are industrial palm oil. The rapidly expanding palm oil production will produce by-products that are usually considered as rising waste disposal. Among the by-products is the palm oil boiler stone produced from the combustion of fiber and husk in the boiler under very high temperatures and produces enzyme steam for oil extraction. By recycling the waste, it not only saves the landfill but also maintains the green environment (Ahmad et al., 2014).

2.3.1 Type of Waste

The agroindustry has been the backbone of Malaysia for a few decades. Products from this industry generate a huge amount of waste. Palm oil factories generate various types of waste, which include Palm Oil Boiler Stone (POBS), oil palm shell (OPS), Oil Palm empty fruit bunches (OPEFB) and others. Palm Oil Boiler Stone (POBS) produced from the combustion of fiber, husk in the boiler under high temperatures, and produce enzyme steam for oil extraction. The use of POBS in concrete can overcome the problem of waste disposal and can save the use of landfill. Oil palm shell (OPS) is an agricultural solid waste that generates from the palm oil industry. Oil Palm Shell (OPS) is an agricultural solid waste lightweight aggregate for making lightweight concrete (Shafigh et al., 2013). The use of OPS as an aggregate in concrete reduces the needs for finite resources such as stone and gravel.

Last but not least, the waste material that produced by Palm Oil Industry is oil palm empty fruit bunch (OPEFB) is used as the burning fuel in boilers to supply electricity for the plantation mills. Due to its disposal, OPEFB also causes the environmental problem. Incorporation of these waste products would also help to sustain those natural resources that are rapidly depleting and support the global push towards “green” production (Kanadasan et al., 2015). Figure 2.2 shows the oil palm bio products in Malaysia that produced millions tons per year (Hosseini and Wahid, 2014).

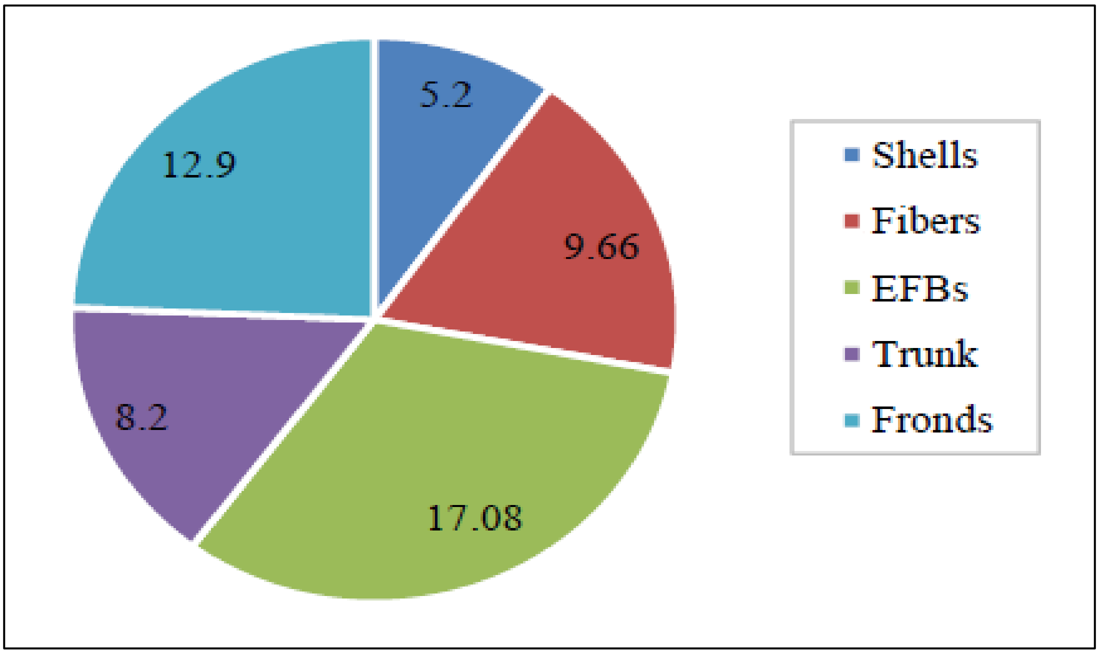

Figure 2.2 Oil palm bio products in Malaysia (millions tons per year)

Source: Hosseini and Wahid (2014).

Figure 2.3 Palm oil boiler stone (POBS)

Source: Abutaha et al., (2016)

Figure 2.4 Oil palm shell (OPS)

Source: Aslam et al., (2016)

Figure 2.5 Oil palm empty fruit bunch (OPEFB)

Source: Or, Putra and Selamat (2017)

2.3.2 Palm Oil Boiler Stone (POBS) as Waste

The agricultural industry increasing rapidly over the year. Palm Oil Boiler Stone was produced from the combustion of fiber and husk in the boiler under high temperature and produces enzyme steam for oil extraction. These wastes are disposed to dumping sites, causing environmental pollution and problems (Abutaha et al., 2016).One of the by-product obtained from palm oil industry is palm oil boiler stone (POBS) that is potential as recycle materials for sustaining the green environment. POBS were incorporated as a replacement material for aggregates and their engineering characteristics were ascertain.

2.3.3 Utilization of POBS in Concrete

The use of waste materials such as palm oil clinker from the palm oil industry provides substantial benefits to the construction industry. The use of these wastes into industrial buildings can promote sustainability, overcome the problem of garbage disposal and can prevent environmental pollution. In this study, palm oil boiler stone was used as a coarse aggregate of lightweight concrete. Besides that, POBS also can be the aggregate replacement in lightweight concrete production and can be used as a replacement for sand. The basic strategies to decrease solid waste problems is to reuse the materials from waste because it can ensure the preservation of our natural resources by mitigating the use of rock outcrops that are usually quarried and crushed to be used as aggregate for construction work. Lastly, the inclusion of these wastes can benefit a certain industry with the cost and the energy consumption of the products can be reduced.

2.4 Lightweight Aggregate Concrete (LWAC)

2.4.1 Production

Lightweight concrete is a popular choice in the construction. The use of lightweight concrete (LWC) has many advantages over normal concrete, such as a reduction in the size of the structural elements, increase in building height and a greater span-depth ratio for beams in pre-stressed concrete construction (Huda et al., 2016). Many materials can be use as lightweight aggregate concrete consist of oil palm shell, coconut shell, and others. Usually, the material that will be use as lightweight aggregate concrete is waste material from palm oil industry. This is because there are millions of tons of waste material that is produce from palm oil industry that cause the environmental problem. By using this waste material as lightweight aggregate, environmental pollution can be reduce and will be more sustainable in the construction industry. The lightweight concrete has its obvious advantages of high strength water ratio, good tensile strength, low coefficient of thermal expansion, and superior heat and sound insulation characteristic due to air voids in lightweight aggregates (Zulkarnain and Ramli, 2008).

2.4.2 Characteristic

In general, a correlation between the compressive strength and permeability of concrete depends on the denser of the concrete matrix. The denser the concrete, the harder the bond between concrete matrix, therefore the compressive strength increased (Ahmad et al., 2014). Water-cement ratios and compressive strength of concrete are related to each other. According to this relation, the strength of the concrete is inversely proportional to the water-cement ratio (Nadesan and Dinakar, 2017). In addition, lightweight aggregate concrete may present the low modulus of elasticity that may cause excessive deflection in flexural strength. However, it may be beneficial for reducing the internal stress concentrations in concretes and consequently reducing the micro-cracks.

Lightweight concrete has no special resistance as it is generally more porous than the more conventional concrete, it is if anything, more vulnerable (Zulkarnain and Ramli, 2008). The use of lightweight aggregate concrete has superior advantages as using natural materials, lightness and easy workability. Laboratory tests had been shown that for the majority of aggregate types both in the pre-soaked and air-dry condition non-air-entrained lightweight aggregate concrete is potentially more durable under freeze/thaw condition that equivalent strength non-air-entrained normal weight concrete, particularly when natural fines are used (Zulkarnain and Ramli, 2008).

2.4.3 Advantage and Application

Lightweight concrete has more advantage which are reduction in manpower, fast for simple construction and reduction in weight that can result in reducing structural frame, footing or pile. There are several options of lightweight concrete that are structural full-lightweight, semi-lightweight, non-structural lightweight concrete fill, non-structural polystyrene lightweight fill. The structural full-lightweight is made with lightweight porous ceramic material produced by expanding and vitrifying select shale in a rotary kiln. Semi-lightweight concrete produced by using aggregate made from slag. Cellular concrete/grout is used to produce a non-structural lightweight fill. This lightweight concrete is created by adding air bubbles and foaming to the concrete, resulting in a lighter density product. Polystyrene-based concrete is essentially a concrete/grout that has styrofoam beads introduced into the mix to make the product lighter. It is mostly used as fill.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this methodology section, the material used in design the concrete that used fly ash as partial cement replacement. In the beginning, the preparation of water, sand, cement, fly ash, POBS and superplasticizer are present. Then, followed by detail elaboration on the material used to design the mixed concrete, which includes the process of mixing, casting and curing until it ready to be tested. It consists of water curing method to achieve the objective of the study that is to investigate the strength of concrete. Otherwise, this study also will be explained in detail about three type of test that has been conducted which are slump test, compressive strength test, and flexural strength test.

3.2 Material Used

The production of concrete specimen consists of water, sand, cement, fly ash, palm oil boiler stone, and superplasticizer.

3.2.1 Water

In this study, tap water has been used in mixing, curing and in another purpose. Enough water to be added is important to make the mix workable. Mixing water should not contain undesirable organic substance and inorganic constituent in excessive proportion. Figure 3.2 shows the water.

Figure 3.1 Water

3.2.2 Sand

River sand is the type of sand used throughout this testing. Sand is left in air-dries before kept in container protecting it from getting wet due to rain or moisture from the surrounding. Figure 3.2 shows the fine aggregate used in this testing.

Figure 3.2 Sand

3.2.3 Cement

An Ordinary Portland Cement (OPC) produced by YTL cement Sdn Bhd is in use throughout this research. This type of cement is identified as type 1 according to ASTM C 150-05 (2005) which is suitable for general concrete work. To protect the cement from damage, cement bags are stored away from damp floors and stacked close together in a well-aired, clean and dry place. Figure 3.3 shows the cement that has been choosing for this testing.

Figure 3.3 Ordinary portland cement

3.2.4 Fly Ash

Fly ash is used as the partial cement replacement. Fly ash has been taken from Tanjung Bin Power Plant, Johor. Fly ash is a byproduct from burning pulverized coal in electric power generating plants. Figure 3.4 shows the fly ash.

Figure 3.4 Fly ash

3.2.5 Palm Oil Boiler Stone (POBS)

Palm oil boiler stone has been used in this testing as the coarse aggregate. Preparation for POBC has many steps. Firstly, wash the clinker and dry. Then, crush the clinker using the hammer to get a small size. Then, put the POBC in the crushing machine. After crush, the aggregate was sieve to obtain the required size of aggregate. Figure 3.5 shows the Palm Oil Boiler Stone (POBC).

Figure 3.5 Palm Oil Boiler Stone (POBC).

3.2.6 Superplasticizer

Superplasticizer is an agent to help the concrete mixing easy to mix and to increase the workability of the concrete mixing. Superplasticizer was an admixture based on modified polycarboxylic ether. It is free of chloride and low alkali. Figure 3.6 shows the Sika ViscoCrete 2088PC of superplasticizer that has been used in this testing.

Figure 3.6 Sika ViscoCrete 2088PC of superplasticizer

3.3 Design Mix

In this study, there are five differences percentage of fly ash as partial cement replacement for structural concrete. Five set of samples was cast, a control mix with no fly ash and four mixtures consist of 10%, 20%, 30% and 40% of fly ash as a partial replacement for cement. All the mixed was used POBC as lightweight aggregate concrete. The specimen was prepared for the slump test, compressive strength test, and flexural strength test. Water-cement ratio for this test is fixed with 0.40. The compressive strength and flexural strength were determined at 7, 14 and 28 days. The details of the concrete mixes with the proportions of ingredients are shown in Table 3.1 and Table 3.2.

Table 3.1 Concrete mix proportion for cube

%	CEMENT (kg)	SAND (kg)	POBS (kg)	FLY ASH (kg)	w/c	SP (%)
0	4.536	7.088	5.339	0	0.40	1
10	4.082	7.088	5.339	0.454	0.40	1
20	3.629	7.088	5.339	0.907	0.40	1
30	3.175	7.088	5.339	1.361	0.40	1
40	2.722	7.088	5.339	1.814	0.40	1

Table 3.2 Concrete mix proportion for beam

%	CEMENT (kg)	SAND (kg)	POBS (kg)	FLY ASH (kg)	w/c	SP (%)
0	23.760	37.125	27.968	0	0.40	1
10	21.492	37.125	27.968	2.268	0.40	1
20	19.008	37.125	27.968	4.752	0.40	1
30	16.632	37.125	27.968	7.128	0.40	1
40	14.256	37.125	27.968	9.504	0.40	1

3.4 Specimen Preparation

The material of structural concrete was weight and mix with the mixer. In the concrete making process, water, sand, cement, fly ash, POBC and superplasticizer are mixed until all the materials are well mixed and workable. After all the materials are well mixed, cast into the mold for three layers to ensure the concrete well cast. Then, the specimen is vibrate using the vibrating table so that the mixture will compact perfectly. After vibrating process was finished, the specimen is leveled and finished using hand trowel. Three specimens from each category were prepared for obtaining the average value. Remove the specimen from the mold after 24 hours and ready for curing process that is a cure for water. Lastly, test the concrete specimens for 7, 14 and 28 days to evaluate the compressive strength and flexural strength.

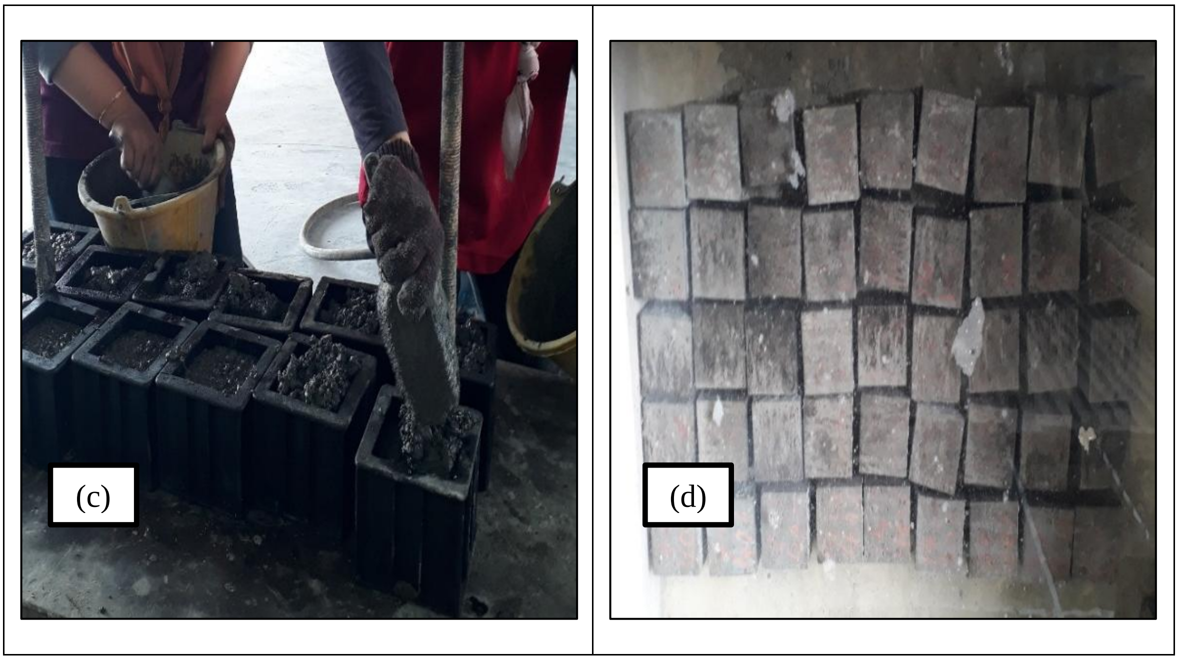

Figure 3.7 Preparation of concrete samples

3.5 Slump Test

In this study, the test conducted is slump test that is important to show the mix is sufficiently workable to enable good compaction and carried out for detecting changes in workability. Slump test for all mixes of this study is conducted in accordance with BS 1881: Part 102: 1993. In addition, there are three forms of the slump, which are the true slump, shear slump, and collapse slump.

At the beginning of the test, ensure that the internal surface of the mold is clean and damp but free from superfluous moisture before commencing the test. Place the mold on a smooth, horizontal, rigid and non-absorbent surface free from vibration and shock. Hold the mold firmly against the surface below with the funnel, if used, in position at the top whilst it is filled in three layers, each approximately one-third of the height of the mold when tamped. Tamp each layer with 25 strokes of the tamping rod, the strokes being distributed uniformly over the cross-section of the layer. Tamp each layer to its full depth, ensuring that the tamping rod does not forcibly strike the surface below when tamping the first layer and just passes through the second and top layers into the layers immediately below.

Heap the concrete above the mold before the top layer is tamped. If necessary, add further concrete to maintain an excess above the top of the mold throughout the tamping operation. After the top layer already tamps, remove the funnel, if fitted, and strike off the concrete level with the top of the mold with a sawing and rolling motion of the tamping rod. With the mold still held down, clean from the surface below any concrete, which may have fallen onto it or leaked from the lower edge of the mold. Remove the mold from the concrete by raising it vertically, slowly and carefully, in 5s to 10s, in such a manner as to impart minimum lateral or torsional movement to the concrete. The entire operation from the start of filling to the removal of the mold shall be carried out without interruption and shall be complete within 150s. Immediately after the mold is removed, measure the slump to the nearest 5 mm by using the rule to determine the difference between the height of the mold and of the highest point of the specimen that being tested. Figure 3.8 shows the slump test apparatus.

Figure 3.8 The slump test apparatus

3.6 Compressive Strength Test

Compressive strength test determines the behaviour of materials under crushing loads. It is the method for determining the compressive strength of concrete cubes. The compressive strength has been follow the procedure conducted specified BS 1881-116:1983. The cube is test for 7, 14 and 28 days of water cured. Firstly, remove the cubes from curing or density water tank and test while they are still wet. Next, placed the cube in the testing machine. Ensure that all testing-machine bearing surfaces are wipe clean and that any loose grit or extraneous material is remove from the surface of the cube, which will be in contact with the platens. Use no packing between the cube and platens, and the spacing blocks if used. Carefully centre the cube on the lower platen and ensure that the load will be apply to two opposite cast faces of the cube. If auxiliary platens are being used, align the top auxiliary platen with the cube. Without shock, apply and increase the load continuously at a nominal rate within the range 0.2N/(mm2s) to 0.4N/(mm2s) until no greater load can be sustained. On manually controlled machines as failure is approached the loading rate will decrease at this stage operate the controls to maintain as far as possible the specified loading rate. Lastly, record any unusual features in the type of failure and record the data. Figure 3.9 shows the machine to test compression strength.

Figure 3.9 Comprressive strength testing machine

3.7 Flexural Strength Test

The procedure of flexural strength test was conduct according to BS 1881: Part 118: 1983. The arrangement of loading for flexural strength test is two-point loading. The beam is tested for 7, 14 and 28 days of water cured. The specimens stored in water shall be tested immediately upon removal from the water whilst they are still wet. Specimens for testing at 24hours shall be tested in the moist condition. Specimens previously used for non-destructive tests shall not remain out of water for more than 15 min and shall be returned to water storage at least 15 minutes before testing for flexural strength. If out of the water more than 15 minutes, the specimen shall be tested after a minimum of 12 hours immersion in water. Wipe clean the bearing surfaces of the supporting and loading rollers, wipe surface water, and grit off the specimen.

Place the test specimen in the machine, correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For molded specimens, the mold-filling direction shall be normal to the direction of loading. Place sawn specimens in the machine so that the original finished surface is in tension. The original surface may not, therefore, be oriented to its position in the structure. Do not use packing between the specimen and the rollers. Do not begin to apply the load until all loading and supporting rollers are in even contact with the test specimen. Apply the load steadily and without shock at such a rate as to increase the stress at a rate of 0.06±0.04 N/(mm2.s). Choose the lower loading rates for low strength concretes and the higher loading rates for high strength concrete. Once adjusted, maintain the rate of loading without change until failure occurs. Record the maximum load read on the scale as the breaking load. Figure 3.10 shows the arrangement of loading of the test piece (two-point loading) and Figure 3.11 shows the flexural machine.

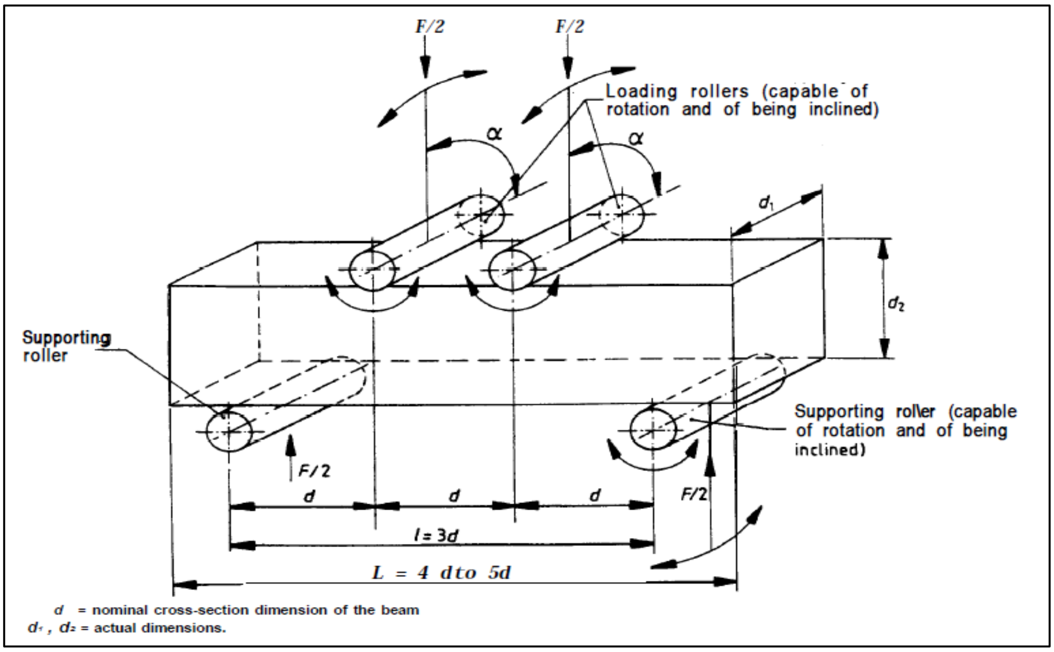

Figure 3.10 Arrangement of loading of test piece (two-point loading)

The calculation is according to BS 1881: Part 118: 1983. The f flexural strength F_{cf} (in N/mm^2) is given by the equation:

$$F_{cf} = \frac{F \; x \; l}{d1^1 \; x \; d2^2}$$

where:

F is the breaking loan (in N)

d_1 and d_2 are the lateral dimensons of the cross-section (in mm)

l is the distance between the supporting rollers (in mm)

Express the flexural strength to the nearest 0.1 N/mm^2.

Figure 3.11 Flexural strength testing machine

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, all the data collected from the laboratory for this research have been analysed and discusses. The effect of different fly ash as partial cement replacement on workability, compressive and flexural strength properties towards water cured is observed and discuss in this chapter. Method and test carried out as described in chapter 3 of this thesis.

4.2 Effect of Fly Ash Content on Concrete Workability

Figure 4.1 shows slump result of lightweight concrete containing the different percentage of fly ash as partial cement replacement. From the result that has been observed, concrete that contained 40% of fly ash shows the highest workability with the result of 195mm. The control specimen that shows the lowest workability with the result of 65mm. The workability increased as the fly ash content in concrete specimen increases. From the result that has been observed, the slump of concrete containing 0% of fly ash shows the true slump pattern. It is different to another slump result that contains fly ash, which shows the shear slump for 10%, 20% and 30% of fly ash respectively and collapses slump for 40% of fly ash respectively.

From the test, the concrete workability increased as the fly ash content increased. This is because the particles of fly ash are hard and round shape, hence, concrete's workability increases without adding extra water (Kocak and Nas, 2014). The improvement in the fluidity of fresh mixtures with the inclusion of fly ash is one advantage of improving workability. The improvement in the fluidity of fresh mixtures with the inclusion of fly ash could be attributed to the fine particle size and smooth glassy texture as well as the spherical shape of fly ash could act as the plasticizer (Rashad, 2015). It is possible to use fly ash to produce high-performance concrete according to high workability is required. The variation of slump pattern is shown in Figure 4.2.

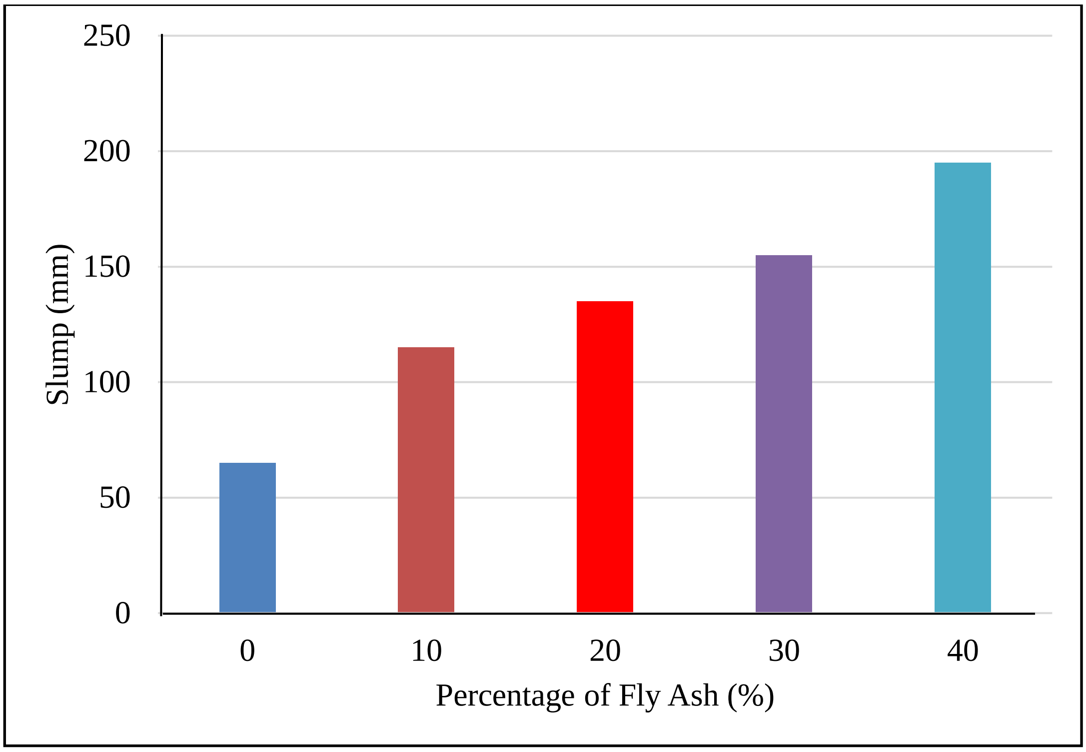

Figure 4.1 Effect of fly ash as partial cement replacement on slump value

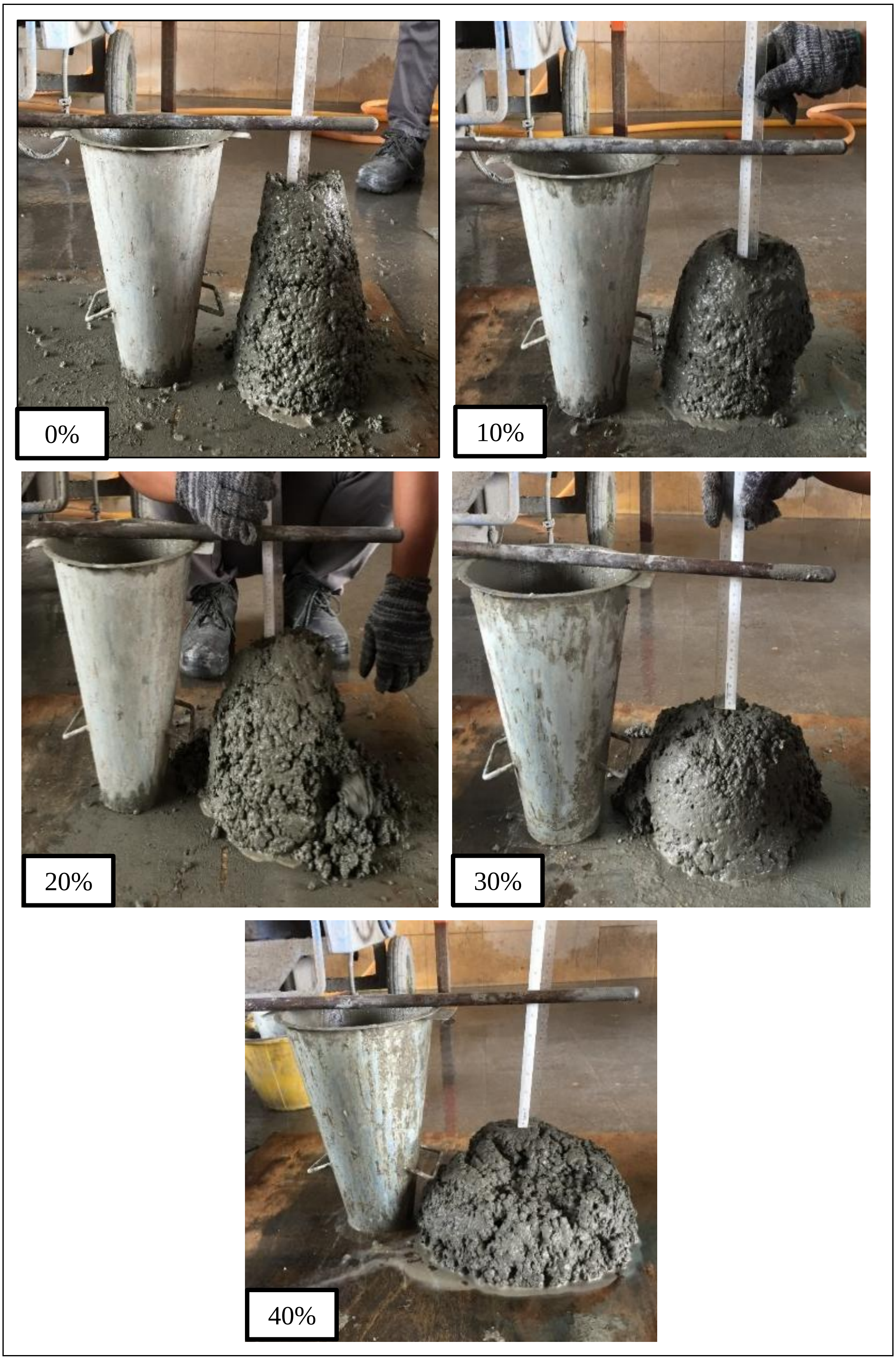

Figure 4.2 Slump of concrete containing of fly ash as partial cement replacement

4.3 Effect of Fly Ash Content on Compressive Strength of Concrete

Figure 4.3 shows the compressive strength of concrete containing fly ash as partial cement replacement at 7, 14 and 28 days. All the specimens containing the different percentage of fly ash shows the strength of the curing day. It can be seen that the use of different percentage of fly ash as partial cement replacement causes variation in the compressive strength performance of concrete. The figure shows that in all cases was relatively highest than the control during the interval 7 to 28 days and probably due to the presence of fly ash in concrete. The compressive strength that contains 10% of fly ash as partial cement replacement is showed a sharp improvement than other specimens that containing fly ash. The compressive strength that 0% of fly ash as partial cement replacement that acts as the control of concrete specimens is the lowest than other specimens.

According to the result that has been analysing, the difference of concrete specimens that contain 10% of fly ash is 10.88% compared to the control specimens. The minimum compressive strength of concrete that contains fly ash is 40% with 47.56 MPa compared to other fly ash content with 58.29 MPa, 57.34 MPa and 50.54 MPa for 10%, 20% and 30% of fly ash content respectively. On the other hand, all the fly ash content in the concrete specimen is higher than control specimen result. Golewski (2017) and Mohamed (2011) stated that the result with 10% of fly ash is better in relation to concrete with additives that greater increase of compressive strength. This happens because of the pozzolanic materials content in the concrete mixture has the ability to convert calcium hydroxide to calcium silicate hydrate (C-S-H) as strength product. This concept gives an opportunity for concrete technology, to reduce cement and automatically reduce energy and resource that to produce cement. The physical appearance of concrete made of fly ash as partial cement replacement can be seen in Figures 4.9.

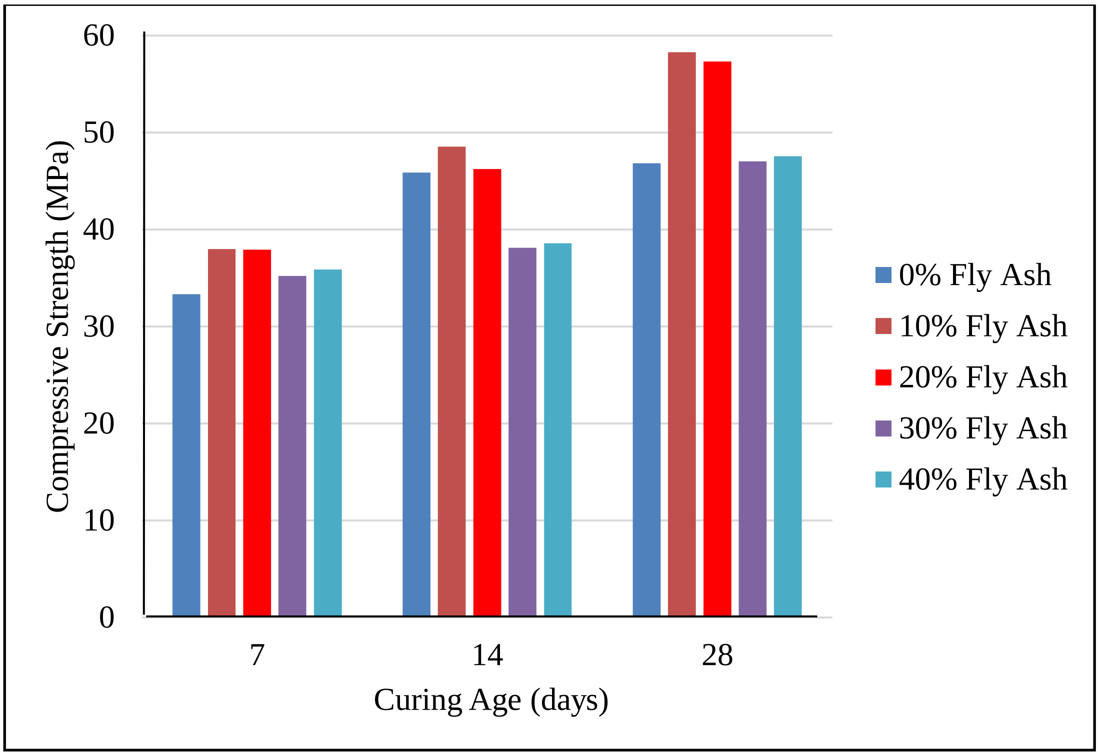

Figure 4.3 Effect of fly ash as partial cement replacement on compressive strength

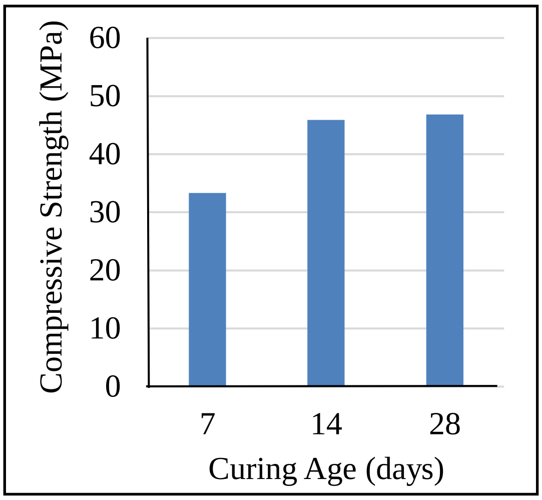

Figure 4.4 Compressive strength of concrete with 0% fly ash

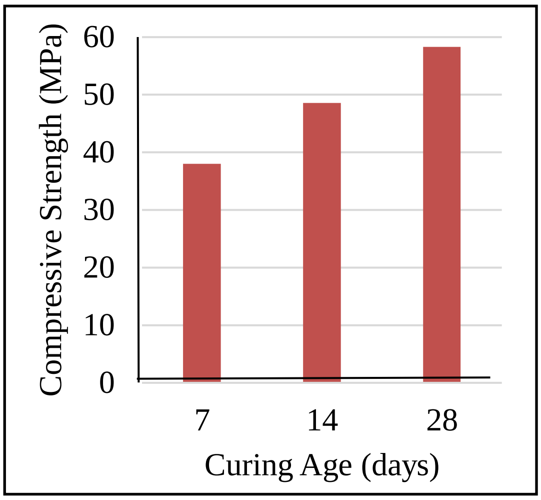

Figure 4.5 Compressive strength of concrete with 10% fly ash

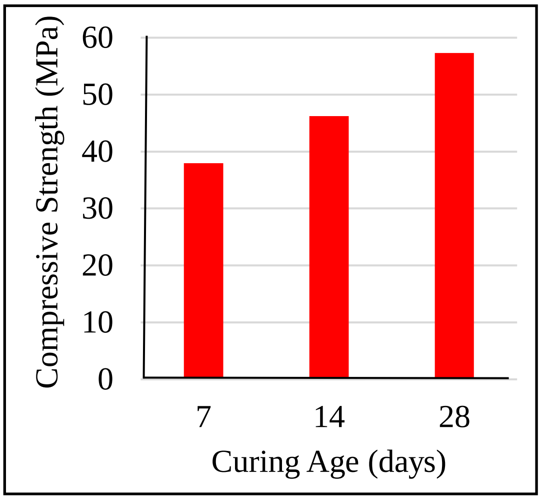

Figure 4.6 Compressive strength of concrete with 20% fly ash

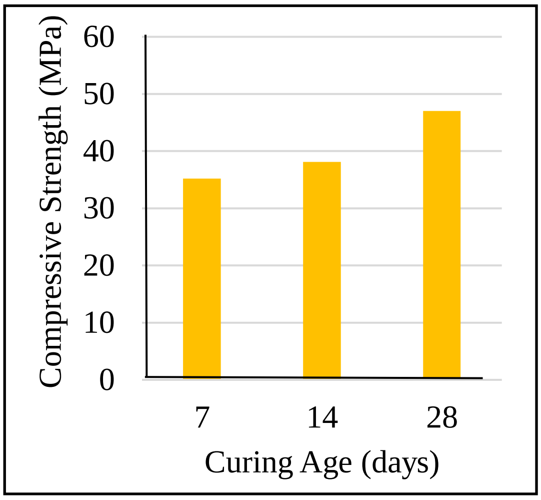

Figure 4.7 Compressive strength of concrete with 30% fly ash

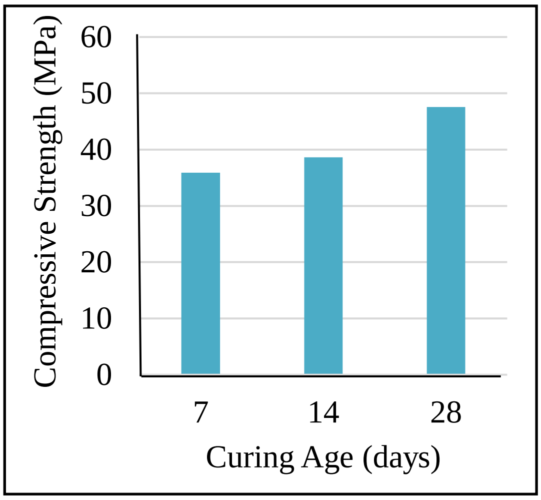

Figure 4.8 Compressive strength of concrete with 40% fly ash

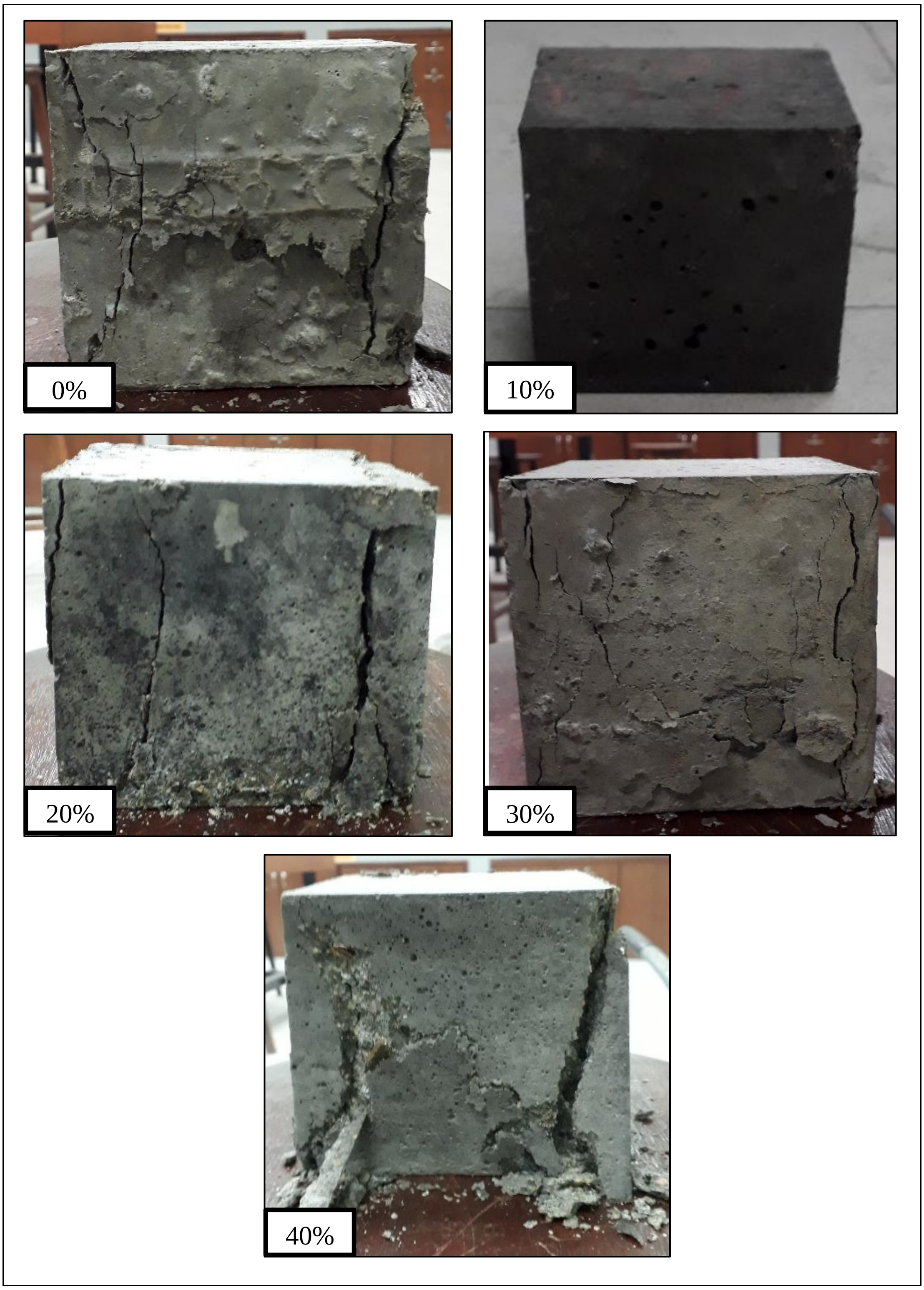

Figure 4.9 Effect of fly ash content towards compressive strength

4.4 Effect of Fly Ash Content on Flexural Strength of Concrete

Figure 4.10 shows the flexural strength of concrete containing fly ash as partial cement replacement at 7, 14 and 28 days. From the result, all the specimens containing the different percentage of fly ash shows the increment on strength as the curing day than control specimen. It can be seen that the use of different percentage of fly ash causes the variation in the flexural strength performance of concrete. The specimen with 10% of fly ash shows the highest effect of flexural strength than others. Barbuta, et al. (2017) reported that the maximum value obtained for 10% fly ash and was bigger than another concrete specimen result.

From the observation, the flexural strength was increase as compressive strength increase. This is due to pozzolanic reaction that has ability to produce the product with more strength. Kabir, et al., (2017) reported that as seen from the compressive and flexural strength result, the higher the compressive strength, the higher the flexural strength. The relation between compressive strength and flexural strength is reported with the square root of the compressive strength with the corresponding flexural strength. According to Nath and Sarker (2017), the flexural strength mostly followed similar development trend as that of compressive strength.

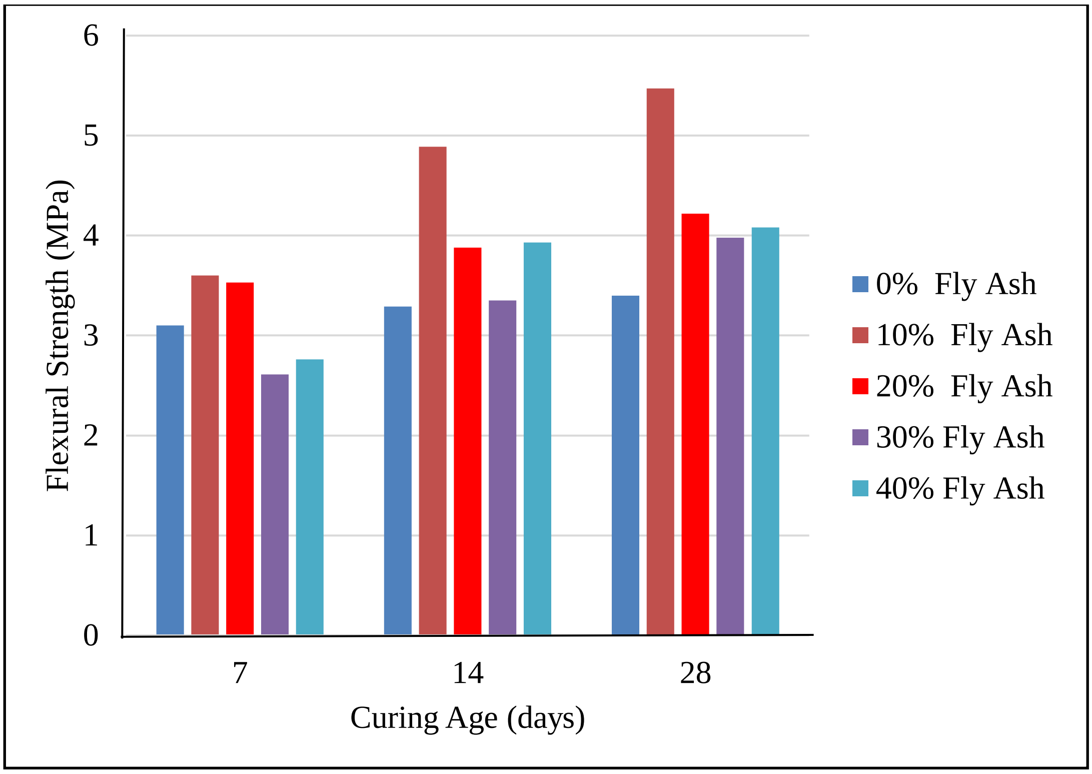

Figure 4.10 Effect of fly ash as partial cement replacement on flexural strength

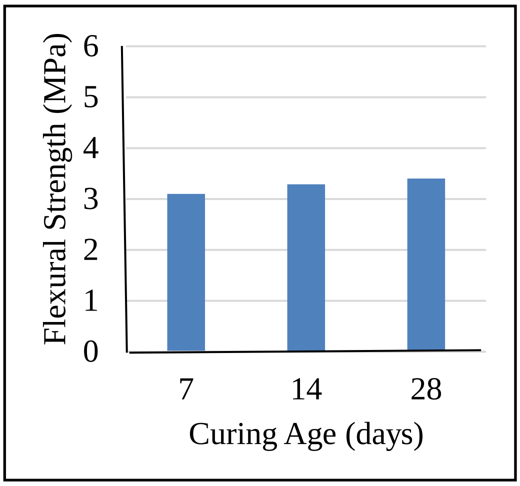

Figure 4.11 Flexural strength of concrete with 0% of fly ash

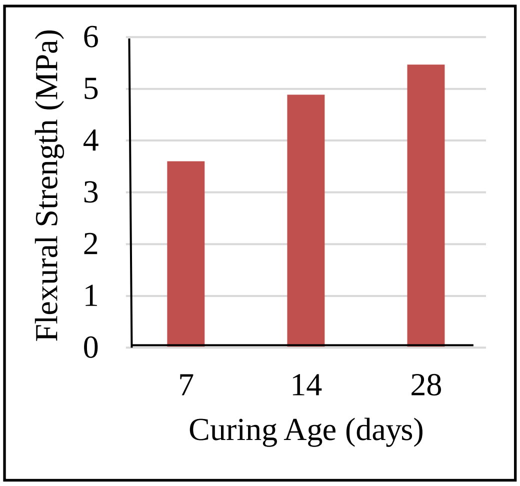

Figure 4.12 Flexural strength of concrete with 10% of fly ash

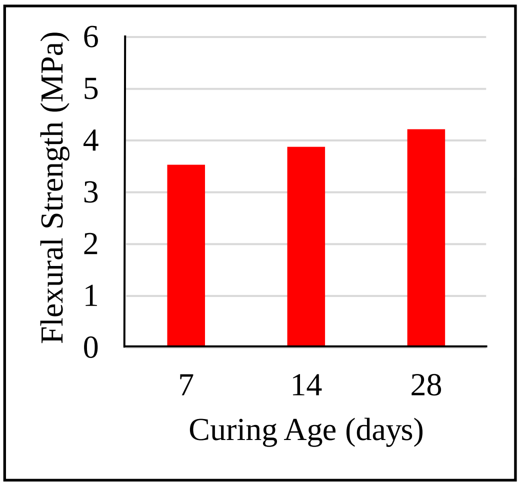

Figure 4.13 Flexural strength of concrete with 20% of fly ash

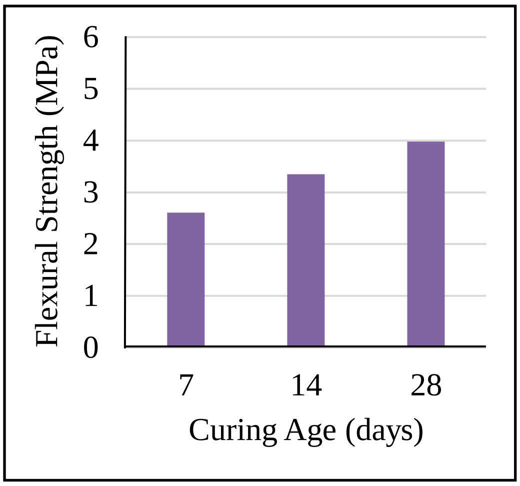

Figure 4.14 Flexural strength of concrete with 30% of fly ash

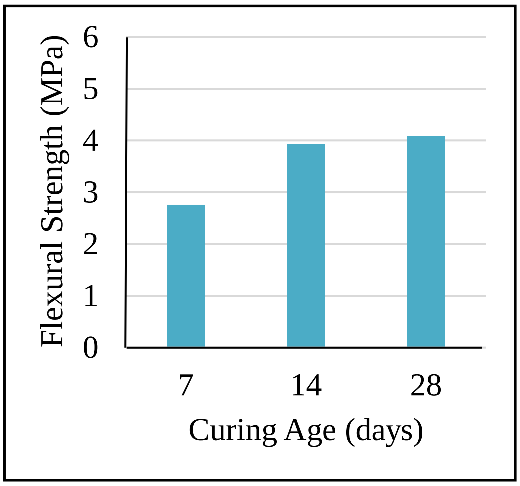

Figure 4.15 Flexural strength of concrete with 40% of fly ash

CHAPTER 5

CONCLUSION

5.1 Introduction

The conclusion of the research that needs to achieve the objectives has been a highlight of this chapter. All the analysis of the research is summarized and all the important information of the research has been a note in this section. In addition, some recommendations were suggested for further study.

5.2 Brief Conclusion

There are three objectives for the research that effect on water curing of fly ash as partial cement replacement on lightweight concrete. The workability, compressive strength and flexural strength of the concrete specimen that containing fly ash as partial cement replacement are present in subsection 5.2.1 until 5.2.3.

5.2.1 Effect of Fly Ash Content as Partial Cement Replacement on Workability of Concrete

Workability of the concrete increases as more of fly ash as partial cement replacement is used. The workability test is conducted to enable good compaction. The highest workability happens in concrete that contained 40% of fly ash with 195mm. The lowest workability occurs in concrete that contained 0% of fly ash that acts as control specimen with 65mm.

5.2.2 Effect of Fly Ash Content as Partial Cement Replacement on Compressive Strength of Concrete

Lightweight concrete that containing 10% of fly ash showed better strength than another concrete specimen. It increases about 11% from control specimen and can be classified the as good quality of concrete. The increases are because it has more ability to convert calcium hydroxide in fly ash to calcium silicate hydrate as strength product.

5.2.3 Effect of Fly Ash Content as Partial Cement Replacement on Flexural Strength of Concrete

From the observation, the concrete specimen of 10% that containing fly ash has higher flexural strength result in compressive strength. The increases of the concrete are about 23% from control specimen. The increases in flexural strength are because the material that is contained in fly ash have higher ability to produce the product with more strength.

5.3 Recommendations

The following are the recommendation made for future study:

a) The mechanical properties lightweight concrete containing high volume fly ash.

b) The fire resistance of lightweight aggregate concrete containing fly ash is also one of the topic that should be investigated.

REFERENCES

Abbasa, S., Saleema, M. A., Kazmib, S. M., & Munirb, M. J. (2017). Production of sustainable clay bricks using waste fly ash. *Mechanical* .

Abutaha, F., Razak, H. A., & Kanadasan, J. (2016). Effect of palm oil clinker (POC) aggregates on fresh and hardened properties of concrete. *Construction and Building Materials, 112*, 416–423.

Adanan, M. A. (2014). *Flexural Behaviors of Semi-Precast Lightweight Foam Concrete Beam.*

Ahmad, A., AzizulBuang, & A.H.Bhat. (2016). Renewableandsustainablebioenergyproductionfrommicroalgal.

Ahmad, H., Lee, Y. L., & Md.Noor, N. (2008, March). Water Permeability of Malaysia Palm Oil Clinker Concrete.

Ahmad, M. H., Loon, L. Y., Noor, N. M., & Adnan, S. H. (2014). Shrinkage of Malaysia Palm Oil Clinker Concrete.

Ahmaruzzaman, M. (2010). A review on the utilization of fly ash. *Progress in Energy and Combustion Science, 36*, 327-363.

Algoufi, Y., & Hameed, B. (2014). Synthesis of glycerol carbonate by transesterification of glycerol with dimethyl carbonate over K-zeolite derived from coal fly ash. *Fuel Processing Technology, 126* , 5–11.

Aslam, M., Shafigh, P., & Jumaat, M. Z. (2016). Drying shrinkage behaviour of structural lightweight aggregate concrete containing blended oil palm bio-products. *Journal of Cleaner Production, 127* , 183-194.

Aslam, M., Shafigh, P., Jumaat, M. Z., & Lachemi, M. (2016). Benefits of using blended waste coarse lightweight aggregates in structural lightweight aggregate concrete.

Barbuta, M., Bucur, R., Serbanoiu, A. A., Scutarasu, S., & Burlacu, A. (2017). Combined Effect of Fly Ash and Fibers on Properties of Cement Concrete. *Procedia Engineering, 181* , 280 – 284.

Bashar, S. M. (2014, January). Flexural Strength of Palm Oil Clinker Concrete Beams. 325-331.

Bayuaji, R., Kurniawan, R. W., Yasin, A. K., Fatoni, H. A., & Lutfi, F. M. (2016). The effect of fly ash and coconut fibre ash as cement replacement materials on cement paste strength. *Materials Science and Engineering, 128* .

Chin, K., & Zhang, M. (2007). Workability of air-entrained lightweight concrete from rheology perspective.

Chindaprasirt, P. (2005, April). Effect of Fly Ash Fineness on Compressive Strength and Pore Siza of Blended Cement Paste. 425-428.

Chowdhury, S. (2015). The Incorporation of Wood Waste Ash as Partial Cement Replacement Material for Making Structural Grade Concrete : An Overview. 429-437.

Golewski, G. L. (2017). Improvement of fracture toughness of green concrete as a result of addition of coal fly ash. Characterization of fly ash microstructure.

Hosseini, S., & Wahid, M. (2014). Utilization of palm solid residue as a source of.

Huang T, Y., Chiueh, P., & Lo, S. (2017). Life-cycle environmental and cost impacts of reusing fly ash. *Resources, Conservation and Recycling, 123* , 255–260.

Huda, M. N., Jumat, M. Z., Islam, A., & Soeb, M. R. (2016). Influence of palm oil factory wastes as coarse aggregate species for green lightweight concrete.

Hui, K., Lee, S., & Ash, A. (2009). A Novel and Green Approach to Produce Nano- Porous Materials Zeolite A and MCM-41 from Coal Fly Ash and their Applications in Environmental Protection. 165-175.

Ikkurthi, S. K., Kanneganti, B. C., & Hygrive, M. K. (2017). Comparative study on compressive strength of fly ash concrete. *8*.

Islam, M. M. (2010, September). Strength Behaviour of Mortar Using Fly Ash as Partial Replacement of Cement.

Kabir, S. A., Alengaram, U. J., Jumaat, M. Z., Yusoff, S., Sharmin, A., & Bashar, I. I. (2017). Performance evaluation and some durability characteristics of environmental friendly palm oil clinker based geopolymer concrete.

Kanadasan, J. (2014, April). Mix Design for Self-Compacting Palm Oil Clinker Concrete based on Particle Packing. 9-19.

Kanadasan, J., & Razak, H. A. (2015). Utilization of Palm Oil Clinker as Cement Replacement Material.

Kanadasan, J., Fauzi, A. F., Razak, H. A., Selliah, P., Subramaniam, V., & Yusoff, S. (2015). Feasibility Studies of Palm Oil Mill Waste Aggregates for the Construction Industry. *8*, 6508-6530.

Kaushal, K. (2017). Characteristics of Fly Ash in Relation of Soil. 527-532.

Kocak, Y., & Nas, S. (2014). The effect of using fly ash on the strength and hydration characteristics of blended cements. *Construction and Building Materials*, 25-32.

Kondraivendhan, B., & Bhattacharjee, B. (2015). Flow behavior and strength for fly ash blended cement paste and mortar. *International Journal of Sustainable Built Environment, 4,* 270–277.

Mahmud, P. S., Jumaat, M. Z., Ahmmad, R., Shafigh, P., Mahmud, H. B., Jumaat, M. Z., & Ahmmad, R. (2014). Structural lightweight aggregate concrete using two types of waste from the palm oil industry as aggregate. *ournal of Cleaner Production, 80* , 187-196.

Mazarei, V., Trejo, D., Ideker, J. H., & Isgor, O. B. (2017). Synergistic effects of ASR and fly ash on the corrosion characteristics of.

Md. Moinul Islam, M. S. (2010). Strength Behaviour of Mortar Using Fly Ash as Partial Replacement of Cement.

Mo, K. H., Ling, T.-C., Alengaram, U. J., Yap, S. P., & Yuen, C. W. (2017). Overview of supplementary cementitious materials usage in lightweight. *Construction and Building Materials, 139* , 403–418.

Moffatt, E. G., Thoma, M. D., & Fahim, A. (2017). Performance of high-volume fly ash concrete in marine environment. *Cement and Concrete Research*. Retrieved from www.elsevier.com/locate/cemconres

Mohamed, H. A. (2011). Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions. *Ain Shams Engineering Journal, 2*, 79–86.

Mohammed, B. S. (2011, August). Analytical and Experimental Studies on Composite Slabs Utilising Palm Oil Clinker Concrete. 3550-3560.

Nadesan, M. S., & Dinakar, P. (2017). Mix design and properties of fly ash waste lightweight aggregates. *Case Studies in Construction Materials, 7*, 336–347.

Nair, H. (2016). Use of Lightweight Concrete for Reducing Cracks in Bridge Decks.

Nath, P., & Sarker, P. K. (2017). Flexural strength and elastic modulus of ambient-cured blended low-calcium fly ash geopolymer concrete.

Nematollahi, B., & Sanjayan, J. (2014). Effect of different superplasticizers and activator combinations on workability and strength of fly ash based geopolymer. *Materials and Design, 57* , 667–672.

Nugteren, H. (2007). Coal fly ash: From waste to industrial product. 49-55.

Or, K. H., Putra, A., & Selamat, M. Z. (2017). Oil palm empty fruit bunch fibres as sustainable acoustic absorber. *Applied Acoustics, 119* , 9–16.

Posi, P., Thongjapo, P., Thamultree, N., Boontee, P., Kasemsiri, P., & Chindaprasirt, P. (2016). Pressed lightweight fly ash-OPC geopolymer concrete containing recycled lightweight concrete aggregate. *Construction and Building Materials , 127*, 450–456.

Rafieizonooz, M., Mirza, J., Salim, M. R., Hussin, M. W., & Khankhaje, E. (2016). Investigation of coal bottom ash and fly ash in concrete as replacement.

Ranjbar, N., Mehrali, M., Behnia, A., Alengaram, U. J., & Jumaat, M. Z. (2014). Compressive strength and microstructural analysis of fly ash/palm oil. *Materials and Design, 59* , 532–539.

Rashad, A. M. (2015). A brief on high-volume Class F fly ash as cement replacement – A guide for Civil Engineer. *International Journal of Sustainable Built Environment*, 278–306.

Region, T. G. (2010). Testing Concrete.

Saha, A. K. (2017). Effect of class F fly ash on the durability properties of concrete. *Sustainable Environment Research*. doi:10.1016/j.serj.2017.09.001

Shafigh, P., Alegaram, U. J., Bin, H. B., & Jumaat, M. Z. (2013). Engineering Properties of Oil Palm Shell Lightweight Concrete Containing Fly Ash. *Materia ls and Design, 49*, 613–621.

Toniolo, N., & Boccaccini, A. R. (2017). Fly ash-based geopolymers containing added silicate waste. A review.

Wahab, R. A., Jamaludin, S. B., Noor, M. M., & Nizar, K. (2013). Effects of Fly Ash Addition on Compressive Strength and Flexural Strength of Foamed Cement CompoSites.

Yew, M. K., Mahmuda, H. B., Ang, B. C., & Yew, M. C. (2014). Effects of heat treatment on oil palm shell coarse aggregates for high strength lightweight concrete. *Materials and Design, 54* , 702–707.

Zamri, N. A., Muthusamy, K., & Kusbiantoro, A. (2016). Mix Design: Effect of Mixing Constituents towards Palm Oil Clinker Lightweight Aggregate Concrete.

Zulkarnain, F., & Ramli, M. (2008). Durability Performance of Lightweight Aggregate Concrete for Housing Construction.