EFFECT OF FLY ASH AS PARTIAL CEMENT REPLACEMENT ON PROPERTIES OF LIGHTWEIGHT CONCRETE SUBJECTED TO AIR CURING

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ABSTRAK

Abu terbang dan batu dandang minyak sawit merupakan bahan terbuang yang boleh menyebabkan pencemaran alam sekitar. Oleh itu, kajian ini adalah untuk menyiasat kesan abu terbang sebagai gantian simen separa pada kebolehkerjaan, kekuatan mampatan dan kekuatan lentur konkrit ringan yang diawet pada udara. Lima jenis campuran akan digunakan dalam kajian ini. Konkrit yang mengandungi 100% simen akan bertindak sebagai spesimen kawalan. Manakala, bancuhan konkrit selebihnya akan menggunakan abu terbang dengan peratusan yang berlainan dari 10%, 20%, 30% dan 40%. Semua specimen diawet pada udara. Kekuatan mampatan dan kekuatan lentur dijalankan pada 7, 14 dan 28 hari. Keputusan menunjukkan bahawa kebolehkerjaan meningkat dengan pertambahan abu terbang dalam kandungan konkrit segar. Manakala untuk kekuatan mampatan dan kekuatan lentur, ia menunjukkan bahawa kekuatan konkrit abu terbang adalah lebih tinggi daripada konkrit tanpa abu terbang. Pada 28 hari, campuran 10% abu terbang merekodkan nilai tertinggi pada kekuatan berbanding dengan peratusan abu terbang konkrit yang lain. Keputusan menunjukkan bahawa kita boleh menggantikan sebahagian simen dengan bahan buangan, supaya kita boleh mengurangkan pengeluaran karbon dioksida ke atmosfera dan juga menjimatkan bahan semula jadi.

ABSTRACT

Fly ash and palm oil boiler stone are waste product that causes environmental pollution. Thus, this research study is to investigate the effect of fly ash as partial cement replacement on workability, compressive strength and flexural strength of lightweight concrete subjected to air curing. Five mixtures were used in this research. The mix containing 100% cement would act as a control specimen. The rest of the mixes contained various percentage of fly ash which are 10%, 20%, 30% and 40%. The samples were subjected to air curing. Compressive strength and flexural strength conducted at 7, 14 and 28 days. The results revealed that the workability increases with the increase in the use of fly ash content. For both compressive strength and flexural strength, it shows that fly ash concrete is much higher than the concrete without fly ash. The mix containing 10% of fly ash recorded the highest strength value compared to other percentage of fly ash concretes at 28 days. The results showed that we can partially replace the cement with the waste material, therefore we can reduce the emission of carbon dioxide into the atmosphere and save natural material.

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LIST OF SYMBOLS

%	Percent
°C	Degree Celcius
Mpa	Megapascal
kg/m^3	Kilogram per cubic meter
Mm	Micrometer
Mm	Milimeter
m^2/kg	Meter square per kilogram
N	Newton

LIST OF ABBREVIATIONS

POBS	Palm Oil Boiler Stone
LWAC	Lightweight Aggregate Concrete
ASTM	American Standard Testing
CEA	Central Electricity Authority
FESEM	Field Emission Scanning Electron Microscope
CO_2	Carbon dioxide
SO_2	Sulfur dioxide
SCM	Supplementary Cementitious Material
LW	Lightweight Concrete
OPC	Ordinary Portland Cement
YTL	Yeoh Teong Lay

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In recent years, with the development of economy and growth of urban population, buildings have been more and more intensive and led to high demand for cement use. Cement is actually an environmentally hazardous material that produces a lot of carbon dioxide emissions that can contribute to global warming. In addition, high usage of natural resources would result in a high amount of industrial wastes. Therefore, to prevent the issue on environmental concerns, artificial aggregates such as fly ash and palm oil boiler stone can be used as substitutes to produce an environmentally friendly lightweight concrete. Utilization of industrial wastes as a construction material is a healthy sustainable practice to dispose the waste and conserve the available resources for future generations (Nadesan, 2017).

At the same time, huge quantities of fly ash and palm oil boiler stone were found in the world but the only certain amount of it is being used while the rest was disposed of in landfills. Fly ash and palm oil boiler stone are a waste product that can cause environmental pollution quality and human health. Fly ash is derived from coal-burning power plants while palm oil boiler stone is from burning of solid wastes in the boiler combustion process. According to the annual survey results published by American Coal Ash Association, about one ton of carbon dioxide can be reduced per each ton of coal fly ash used in place of common Portland cement (Argiz, 2017). By using fly ash and palm oil boiler stone in concrete production, this will reduce the usage of natural resources.

1.2 PROBLEM STATEMENT

In the future raw material and alternative fuels that involved in the production of cement would become extinct. Hence, cement's price and market demand would increase due to lack of resources. Therefore, resulting carbon dioxide emission making it be not sustainable in construction activities (Tam, 2009). Other than that, fly ash having a high content of toxic that can cause human health. The fly ash and POBS are waste product disposed to dumping places that cause environmental pollution and problems. Thus, these wastes must be eliminated or reduced to protect the environment.

1.3 OBJECTIVES

This study was conducted to achieve the following objectives:

i. To determine the workability of the lightweight aggregate concrete containing fly ash as partial cement replacement.

ii. To determine the compressive strength of the lightweight aggregate concrete containing fly ash as partial cement replacement.

iii. To determine the flexural strength of the lightweight aggregate concrete containing fly ash as partial cement replacement.

1.4 SCOPE OF RESEARCH

The study aims to investigate the properties of LWAC in term of workability, compressive strength and flexural strength when fly ash as partial cement replacement. Various percentage of fly ash range from 0%, 10%, 20%, 30% and 40% have been used as a partial cement replacement in concrete. There are two types of specimens which are a cube and beam. The sample size for the cube is about 100 x 100 x 100 mm for compressive strength. The beam is about 100 x 100 x 500 mm for flexural strength. All specimens were subjected to air curing. The curing was conducted at 7, 14 and 28 days. All the testing was conducted at Concrete Laboratory.

1.5 SIGNIFICANCE OF RESEARCH

The use of fly ash and waste product in the production of concrete can reduce the utilization of raw material and avert it from extinction. Benefits of using fly ash and palm oil boiler stone are our environment become cleaner and environmentally friendly. Besides that, the cost to make a concrete will decrease by using these waste. Other than that, it can reduce the fly ash and POBS wastes ending at the landfill.

1.6 LAYOUT OF THESIS

Chapter one is introduced to investigate the 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, properties, application, and pollution of fly ash and palm oil boiler stone. This includes the review of previous research on lightweight aggregate concrete.

Chapter three discusses the methodologies used in this study. The preparation of mixing ingredients and apparatus used in conducting the experiment is reported in this section. The testing procedures also discussed in this chapter three. Chapter four discusses laboratory results of POC lightweight aggregate concrete incorporated with fly ash. Data that has been analysed and made in form of graph for workability, compression strength and flexural strength test result is presented in this chapter.

Chapter five concludes the whole study. The conclusions are drawn from respective objectives listed based on the results obtained from the testing. The recommendations for future study also in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter review previous research on the use fly ash as a partial cement replacement, as well as the use of POBS as fully coarse aggregate replacement of lightweight concrete. The purpose of this review is to link the utilization of fly ash in the production of concrete with the previous researcher. The chapter also tracks the development of fly ash that discussed the properties, utilization, pollution, and availability of fly ash. The study also reviews studies about POBS and lightweight concrete.

2.2 FLY ASH

India is the country that produced a lot of fly ash in the world that generated by its existing coal-fired power stations. Figure 2.1 shows the Vindhyachal Thermal Power Station, in the Singrauli district of Madhya Pradesh which is currently the biggest thermal power plant in India. Fly ash generally is a by-product of the combustion of pulverized coal in thermal power plants as shown in Figure 2.2. The unburned residue that is carried away from the burning zone in the boiler by the flue gases and then collected by either mechanical or electrostatic separators as shown in Figure 2.3. Fly ash can be divided into two classes according to ASTM Specification for Fly Ash based on Table 2.2.

Figure 2.1 Vindhyachal Thermal Power Station, Madhya Pradesh

Source : Gupta, (2013)

Figure 2.2 Fly ash

Source : Thomas, (2007)

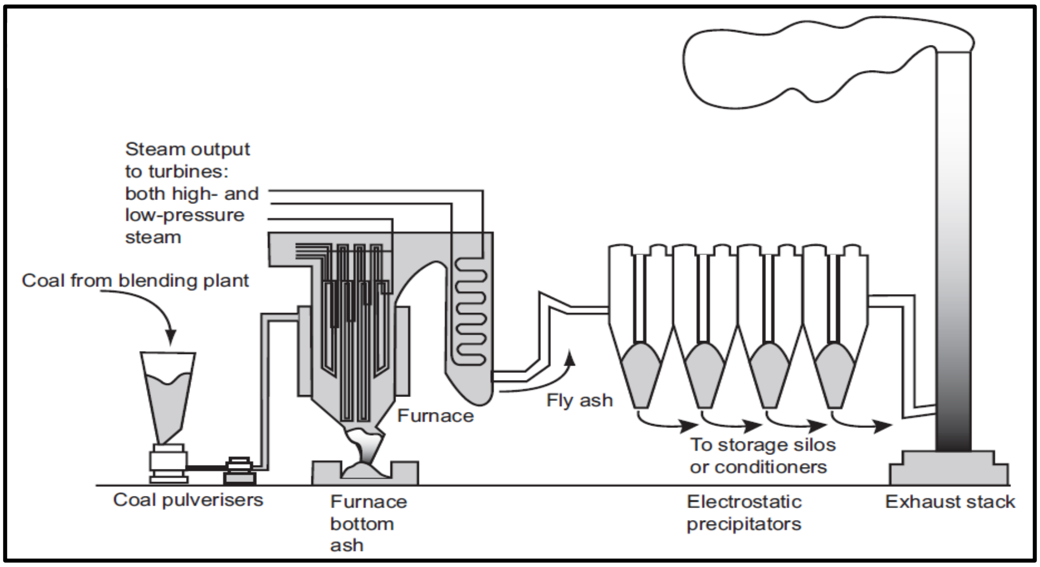


Figure 2.3 Schematic layout of a coal-fired electrical generating station in the production of fly ash

Source : Thomas, (2007)

Table 2.1 ASTM Specification for fly ash

Class	Description in ASTM C 618	Chemical Requirements
F	Fly ash normally produced from burning anthracite or bituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash has pozzolanic properties.	$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$
C	Fly ash normally produced from lignite or sub-bituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties. Note: Some Class C fly ashes may contain lime contents higher than 10%.	$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 50\%$

Source : Thomas, (2017)

2.2.1 Availability of Fly Ash in the World

Coal-fired thermal power plants have created tremendous volumes of coal bottom ash and coal fly ash (20-80% respectively) for years. According to CEA report, about 166 million tons of fly ash is generated from 132 thermal plants annually in India (CEA, 2010), while Malaysia produces about 8.5 million tons of coal ash as waste which comprises of bottom ash and fly ash. Figure 2.4 shows the fly ash production (million tonnes/year) in different countries. Fly ash are by-products of pulverized coal combustion. Using them together, increase the use of disposal wastes which can reduce the environmental impact (Rafieizonooz, 2016).

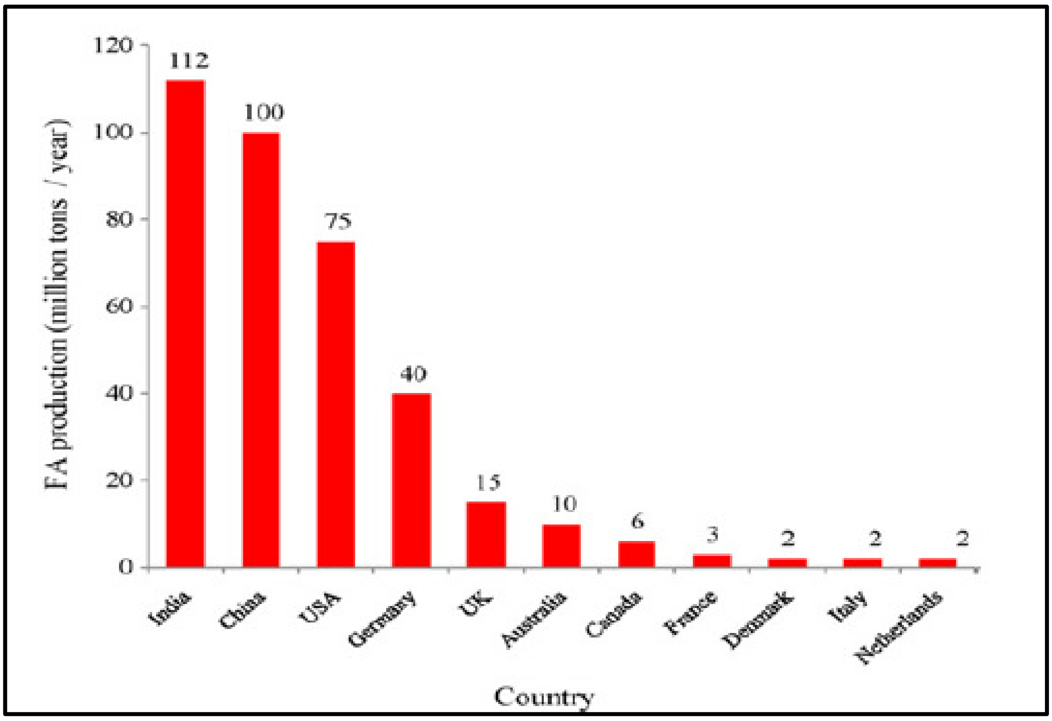


Figure 2.4 Fly ash production (million tonnes/year) in different countries

Source : Dwivedi and Kumar (2014)

2.2.2 Properties of Fly Ash

Usually, the fly ash particle is solid spheres and some are hollow cenospheres but also present plerospheres which sphere containing smaller spheres. The particles size in fly ash varies from <1 μm up to more than 1001 μm with the typical particle size measuring under 20 μm. (Rashad, 2015). The Field Emission Scanning Electron Microscope (FESEM) image shows in Figure 2.5, that coal fly ash has spherical and regular shape and smaller particles. The physical properties and chemical composition of fly ash are given in Table 2.2 and Table 2.3.

Table 2.2 Physical properties of fly ash

Properties	**Fly ash**
Specific gravity	2.4
Fineness (% retain in 45 μm)	7%
Specific surface area (m^2/kg)	308
Water demanded (%)	84
Loss on ignition (%)	6.2

Source : Wei, et al. (2017)

Table 2.3 Chemical composition of fly ash

Oxide	Fly ash (%)
Sodium oxide (Na_2O)	0.51
Manganese oxide (MgO)	0.75
Aluminium oxide (Al_2O_3)	32.8
Silicone dioxide (SiO_2)	54.5
Potassium oxide (K_2O)	1.4
Calcium oxide (CaO)	2.7
Ferric oxide (Fe_2O_3)	4.1
Manganese dioxide (MnO)	0.02
Titanium dioxide (TiO_2)	1.3
Phosphorus pentoxide (P_2O_5)	0.15
Sulfur trioxide (SO_3)	0.4

Source : Wei, et al. (2017)

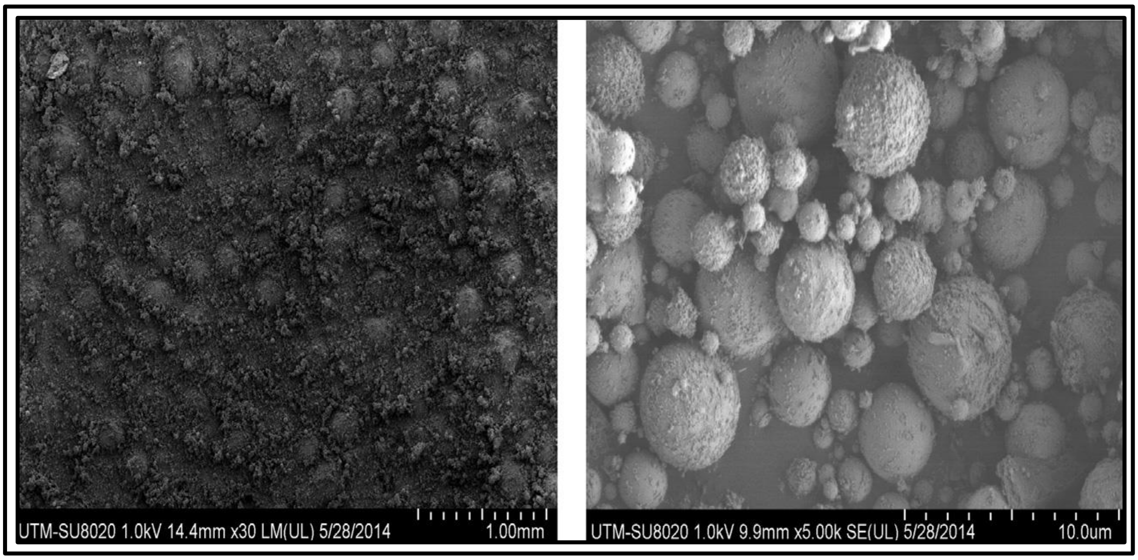


Figure 2.5 FESEM image of coal fly ash

Source : Rafieizonooz, et al. (2016)

2.2.3 Fly Ash and Pollution

Fly ash often contains pollutants such as heavy metals and organic compounds. The composition of fly ash is very variable, depending on their origins, then also the pollutants can be very different. For example, municipal solid waste incineration fly ash are the most problematic ash in terms of contaminant content (Bontempi, 2013). Only a small part of this ash is used (20%-30%) the rest is land filled-and surface-impounded, with potential risks of air pollution and contamination of water due to leaching (Fernandez, 2005). Due to the rapid economic development and the growth in the world production consumption of energy over the world, fly ash has increased a lot. Hence, fly ash must be properly disposed but at the same time, it can be treated as valuable resources. Instead of dumping it as a waste material, fly ash can be used in concrete to reduce the environmental problems of power plants.

2.2.4 Utilization of Fly Ash in Concrete

The previous researcher has been carried out to use the fly ash in different areas, as it is not considered as dangerous waste. Utilization of industrial wastes as the construction material is a healthy sustainable practice to dispose the waste and conserve the available resources for future generations (Nadesan, 2017). Figure 2.6 shows the utilization of total produced fly ash in different countries in the world. The production of cement consumes a lot of energy and increase carbon dioxide emission to the atmosphere (Shehab, 2016). Thus, mixing it into concrete not only saves a large amount of cement and fine aggregate and reduces water consumption, but also improve the workability, anti-permeability, and modification of concrete and reduce the creep, hydration heat and thermal expansion of concrete (Wei, 2017). In India, about 56% of fly ash is utilized effectively through various methods as shown in Figure 2.7.

Other than that, fly ash is used as a supplementary cementitious material (SCM) in the production of Portland cement concrete. The potential for using fly ash as a supplementary cementing material (SCM) in concrete has been known almost since the start of the last century (Anon, 1914). A supplementary cementitious material, when used in conjunction with Portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both (Thomas, 2007). Therefore, by using fly ash as replacement of cement can increase the use of disposal wastes which can reduce the environmental impact and also can improve long-term strength and workability.

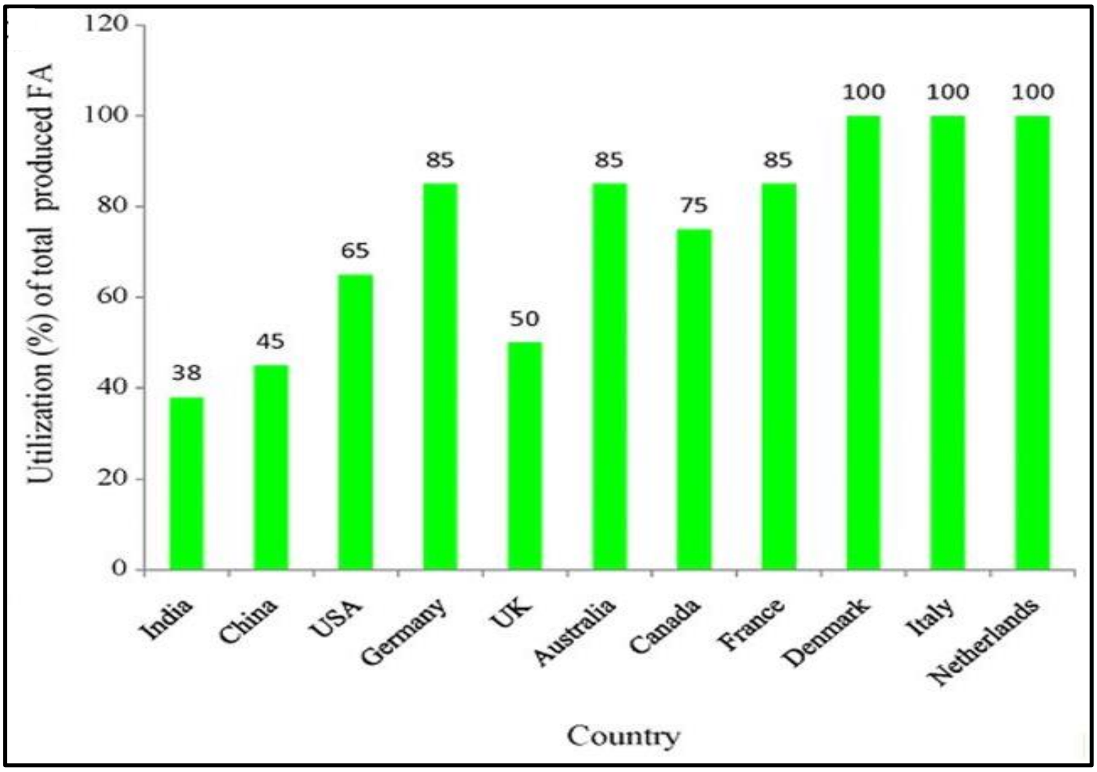


Figure 2.6 Utilization (%) of total produced fly ash in different countries

Source : Dwivedi and Kumar (2014)

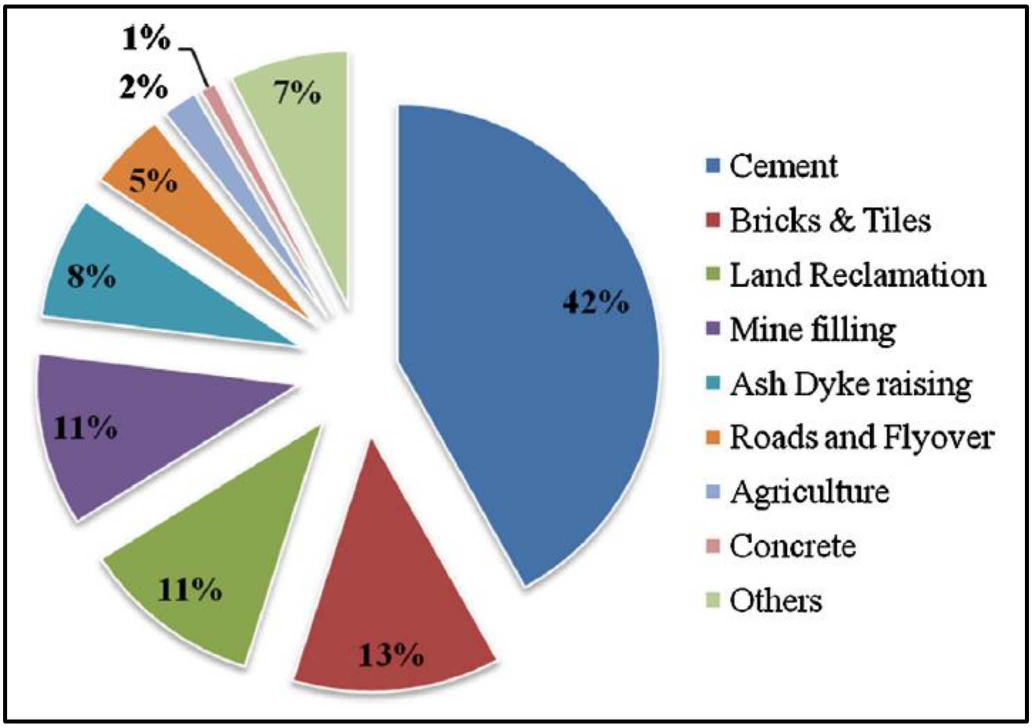


Figure 2.7 Different modes of utilization of fly ash in India

Source : Nadesan, et al. (2017)

2.3 PALM OIL BOILER STONE (POBS) FROM PALM OIL INDUSTRY

The oil palm industry is important in many countries such as Nigeria, Indonesia, and Malaysia. Malaysia is the second largest palm oil producing countries in the world and hence the production of palm oil results in many waste products such as oil palm shell, empty fruit bunches, palm oil fibres and palm oil fuel ash. POBS is a waste material available produced mainly in palm oil industries in South East Asia. The major environmental impact categories for the production process of waste materials from the oil palm industry are mentioned in Table 2.4. In order to run the generator to produce electricity in palm oil industries, palm oil fibre and oil palm shell are burnt at 850 C (Ahmmad, 2016).

Table 2.4 Environmental impact categories for the production process of waste materials from oil palm industry

No.	Impact category	Characterization factors
1.	Land use and degradation	Land pollution, desertification, overgrazing, habitat destruction
2.	Resources use and depletion	Over use of natural resources, deforestation, illegal logging
3.	Chemical emissions	Waste disposal incidence, herbicides drifts, landfills, incineration
4.	Air quality change	Smog, air pollution, volatile organic compound
5.	Water quality change	Waste water pollution, eco-toxicity, marine pollution, urban runoffs

Source : Aslam, et al. (2016)

2.3.1 Palm Oil Boiler Stone and Pollution

The palm oil industry is a major contributor to the pollution occurring in the country, with an estimated 2.6 million tons of solid waste produced annually. The high amount of waste generated is mostly composed of palm oil boiler stone (Abutaha, 2016). Oil palm industry operates in countries located in tropical regimes like Malaysia. This industry produces a wide variety of waste in large quantities. One of the wastes is POBS, Malaysia generates about 4.0 million tonnes oil palm shell (OPS) and a huge amount of POBS as waste materials (Teo, 2006). It is treated as a solid waste with no economic value and has the disposal problem.

2.3.2 Palm Oil Boiler Stone in Concrete

POBS is in clinker form and should be crushed before being used as aggregate in concrete. POBS is easy to crush and has even been used in powder form for making a composite artificial aggregate (Chan, 2008). The nature of POBS which is light and applicable has been used in lightweight aggregate concrete. POBS aggregate can be replaced partially or fully as an aggregate in lightweight aggregate concrete. In addition, by using POBS as part in the production of POBS concrete, this will reduce the usage of natural resources by making use of waste and make the concrete be more “green” (Herry, 2016). Other than that, the use of POBS as an alternative to the conventional coarse aggregate could reduce the cost of construction as well as an overwhelming burden to environmental ill impact (Kabir, 2017).

POBS is available in boulders of sizes ranging from 100 to 300 mm (Shafiqh, 2014) and it is like a porous stone, grey in color, flaky and irregular in shape (Mohammed, 2011). Figure 2.8 shows large clinker of POBS obtained from the palm oil mill. An ordinary POBS may be in size between 20 cm (width) by 30 cm (length) (Kanadasan, 2017). Particles of POBS that less than 5 mm are considered as fine aggregate while particles in the range of 5–14 mm are considered as coarse aggregate (Mohammed, 2014).Figure 2.9 and Figure 2.10 shows the POBS after crushed. POBS aggregate improves the properties of lightweight aggregate concrete compared to the oil palm shell lightweight concrete. The physical properties and chemical composition of POBS waste material are given in Table 2.5 and Table 2.6.

Figure 2.8 Large clinker of POBS

Source : Kanadasan, et al. (2017)

Figure 2.9 Palm oil boiler stone (5-9 mm)

Figure 2.10 Palm oil boiler stone (9-14 mm)

Source : Alamgir Kabir, et al. (2017)

Table 2.5 Physical properties of POBS

Properties	**Palm oil boiler stone**
Specific gravity	1.80
Fineness modulus	6.32
Compacted bulk density (kg/ m^3)	782
Water absorption at 24h (%)	3.56

Source : Jumaat et al. (2015)

Table 2.6 Chemical composition of POBS

Oxide	(%)
Silicone dioxide (SiO_2)	59.63
Potassium oxide (K_2O)	11.66
Calcium oxide (CaO)	8.16
Diphosphorus trioxide (P_2O_3)	5.37
Manganese oxide (MgO)	5.01
Ferric oxide (Fe_2O_3)	4.62
Aluminium oxide (Al_2O_3)	3.7
Sulfur dioxide (SO_2)	0.73
Sodium oxide (Na_2O)	0.32
Titanium dioxide (TiO_2)	0.22
Others	0.53

Source : Jumaat et al. (2015)

2.4 LIGHTWEIGHT CONCRETE (LWC)

The use of LWC has been a feature in the construction industry. The compositions of lightweight aggregates are determined from the experimental analysis. Structural LWC has a density (unit weight) usually below 2000kg/m^3 compared to normal weight concrete with density in the range of 2240 to 2400 kg/m^3 (Kim, 2017). For structural applications, the concrete strength should be in the range of 17-53.6Mpa (Jumaat, 2015). The characteristic of the lightweight aggregate must fulfill the requirement stated in British Standard (BS).

2.4.1 Production

The popular way of achieving lightweight concrete production is by using a lightweight aggregate (Aslam, 2016). There are two types of aggregate concrete can be used as a coarse aggregate which is natural aggregate and artificial aggregate concrete. The main natural lightweight aggregate are pumice, diatomite, volcanic cinders, scoria and tuff (Neville, 2008). While artificial aggregate can be classified into two group which are industrial by-products and modified naturally arising materials. Lightweight aggregate concrete made of artificial aggregate such as shale, slate, expanded clay and is a type of environmentally-friendly material for the construction industry. There is no standard strength to water-cement ratio relation available for the mix design of lightweight aggregate concrete. By using lightweight aggregate it may exhibit higher workability than normal density aggregate concrete (Nadesan, 2017).

2.4.2 Application

Lightweight concretes are commonly desired for different structural applications including slabs and joints in high rise buildings, offshore and marine structure, and bridge decks in highway bridge structures (Malier, 1992). Besides, lightweight concrete has been widely used in buildings as masonry blocks, wall panels, roof decks and precast concrete units (Payam, 2014). Other than that, a small footbridge about 2 min span and a low-cost house with a floor area of about 59 m^2 were built by Universiti Malaysia Sabah by using OPS concrete (Teo, 2006) as shown in Figure 2.11 and 2.12.

Figure 2.11 Foot-bridge structures made from OPS concrete.

Source : Teo et al. (2006)

Figure 2.12 Low-cost house structures made from OPS concrete.

Source : Teo et al. (2006)

2.4.3 Advantages

Lightweight concrete reduces a dead load of construction by making savings in the cross-section of steel reinforced column, beams and plates and foundations (Yasar, 2013). Also, there are fewer micro cracks in lightweight aggregate concrete due to the significantly lower stiffness of lightweight aggregate than normal weight aggregates (Shafiqh, 2014). It has been proven that it can reduce the cost and provide both structural stability and economic viability (Aslam, 2016). In addition, (Al-Khaiat, 1998) reported that structural LWC has obvious advantages such as high strength, better tensile strain capacity, lower coefficient of thermal expansion and superior heat and sound insulation due to air voids in the lightweight aggregate.

Moreover, other advantages are lesser transport, reinforcement, foundation cost, cost-effective scaffolding, formwork, improved constructability, no surface bleed water, sound absorption, superior anti-condensation properties, improved hydration due to internal curing, lower tendency to buckle due to variant temperature gradients, reduced seismic forces, and better heat insulation, fire and frost resistance (Aslama, 2017).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

At the beginning of this chapter, the materials used, and procedure of the test is discussed in detail. In the first part of this chapter shows the details about the preparation of required materials to be used in order to produce specimens needed for experimental works. Next, the detail of this chapter focuses on the preparation of specimens and the standards required to conduct the experiment so that the goals of the study is achieved.

3.2 MATERIALS FOR CONCRETE PREPARATION

3.2.1 Ordinary Portland cement

YTL brand of ordinary Portland cement (OPC) was used as the binder in this study as shown in Figure 3.1. Ordinary Portland cement is the main component in producing concrete. It is a mixture that contains calcium, silicon, aluminium, iron, and also a small number of other components. This type of cement will go through hydration in order to create a new solid formation with the presence of water. The cement used is kept in the suitable airtight container.

Figure 3.1	Ordinary Portland cement.

3.2.2 Sand

In this study, the type of sand used is river sand as a fine aggregate. River sand is used because of its fine quality compared to other sand types. It is air-dried before kept in the container to protect it from getting wet due to moisture or rain from surroundings. Figure 3.2 shows the river sand used in this experiment.

Figure 3.2	River sand

3.2.3 Palm Oil Boiler Stone (POBS)

Palm oil boiler stone (POBS) also known as clinker is obtained from the combustion of palm oil fiber and palm oil shell. POBS was collected from palm oil mill which is located in Felda Lepar Hilir, Gambang. The clinker was collected in form of big rocks and it used as lightweight aggregate concrete. Figure 3.3 shows the raw palm oil boiler stone before it cleaned. As the clinker was collected using shovel then were packed in the gunny and bought to the laboratory. Figure 3.4 illustrates the process of collecting clinker at Felda Lepar Hilir.

After reached the laboratory, the POBS were cleaned before placed inside the oven dry at 120 °C for about 24 hours to remove moisture in it. POBS then will be crushed it into the small particle by using Jaw Crusher machine to get a fine size. Then it is sieved to obtain the required size. POBS used in this experiment that retained on 5mm, while retained at 10mm will be crushed again while retained at pan will be throw away.

Figure 3.3 Raw palm oil burned stone (POBS)

Figure 3.4 Process of collecting Palm oil boiler stone at the palm oil mill.

Figure 3.5 Processing of palm oil boiler stone to be lightweight aggregate.

3.2.4 Fly Ash

Fly ash shown in Figure 3.4 is used as a partial cement replacement in this research. The fly is obtained from Tanjung Bin Power Station located at Pontian Johor, Malaysia. Fly ash generally is a by-product of the combustion of pulverized coal in thermal power plants.

Figure 3.6 Fly ash

3.2.5 Water

In concrete production, water is the most important thing and played the big parts throughout the processes. Besides that, water is also important for mixing concrete, compacting the fresh concrete and concrete curing process. The presence of water in concrete mixing is to promote hydration. Hydration is a complex process which is the reaction between water and cement in the mixture. Water reducing admixture was used to achieve the targeted workability of concrete mix with reduced water content. In this study, tap water is used for concrete mixing and to avoid any side effect to the concrete that may affect the properties, durability, and also the strength of the concrete itself.

3.2.6 Superplasticizer

Superplasticizer has been used in this study. During the process of concrete mixing, superplasticizer was added. The function of adding it is to shorten the placement time, increase the water reduction, superior cohesion without segregation, increase early strength, and lower the shrinkage and creep. The type of superplasticizer used in this study is Sika ViscoCrete-2199 shown in Figure 3.7. It is a type of liquid admixture of superplasticizer which is ready to use.

Figure 3.7 Superplasticizer used in concrete mixing

3.3 CONCRETE MIX PROPORTION

In order to produce a lightweight concrete containing fly ash as a partial cement replacement, the mix proportion needed is shown in Table 3.1 and 3.2 below. The concrete of Grade 40 was used in this testing.

Table 3.1 Concrete mix proportion for concrete cube (100x100x100)

Materials (kg)	**Designation**				
	C0	**C10**	**C20**	**C30**	**C40**
Cement	4.530	4.082	3.629	3.175	2.722
POBS	5.340	5.340	5.340	5.340	5.340
Fly Ash	-	0.454	0.907	1.361	1.814
Sand	7.088	7.088	7.088	7.088	7.088
Water	1.94	1.94	1.94	1.94	1.94
Superplasticizer	0.055	0.055	0.055	0.055	0.055

Table 3.2 Concrete mix proportion for concrete beam (100x100x500)

Materials (kg)	**Designation**				
	B0	**B10**	**B20**	**B30**	**B40**
Cement	23.76	21.492	19.008	16.632	14.256
POBS	27.968	27.968	27.968	27.968	27.968
Fly Ash	0.00	2.268	4.752	7.128	9.504
Sand	37.125	37.125	37.125	37.125	37.125
Water	1.94	1.94	1.94	1.94	1.94
Superplasticizer	0.138	0.138	0.138	0.138	0.138

3.4 CONCRETE PREPARATION

At the beginning of concrete preparation procedure, materials such as POBS, fly ash, sand, cement, water, and superplasticizer was weighted. In the process of making concrete, POBS is mixed with water and sand prior to addition of fly ash and cement. The concrete was mixed for 5 minutes using a pan concrete mixer. After finished mixing the concrete, a slump test was carried out first.

Besides that, to prevent the concrete mix from sticking onto the surface of the mold, the surface of the mold was coated by a layer of oil before the fresh concrete was placed into the cube mold and beam mold. Cubes and beams mold are filled with three layers, each layer need to be blow 25 times using the tamping rod. Lastly, it will have vibrated using the vibrating table to remove entrapped air. Figure 3.8 shows the preparation of specimen is done.

The fresh concrete in the mold was left to dry for about 24 hours. After 24 hours, all the specimens were demoulded and then were cured until their compressive strengths and flexural strengths were determined at the age of 7,14, and 28 days. The curing techniques that were applied is air curing (AC) which involved no form of active curing by just exposing the specimens to ambient air in the Laboratory.

Figure 3.8 Preparation of specimen

3.5 TESTING PROCEDURE

3.5.1 Workability

Using industrial by-products in concrete as a total or partial substitute could affect the fresh concrete properties of the mix. Slump test was conducted in this study to measure the workability and consistency of fresh concrete before it sets. The slump test for all type of mixes is conducted in accordance with BS 188: Part 102: 1983.

At the beginning of the test, the inner surface of the mold and its base were moistened and cleaned thoroughly to reduce the influence on slump by surface friction. The mold for slump test is a frustum of a 300 mm high cone. It was placed in smooth horizontal, rigid and non-absorbent surface like the rigid plate. The mould was filled with concrete in three layers, each layer filled in about one-quarter of the height of mould and tamped down 25 times using the tamping rod with standard 16 mm diameter steel rod., rounded at the end.

Next, the top of concrete is stuck off by using the trowel and any leaked out is cleaned away. Immediately removed the mould from the concrete by lifting it slowly in the vertical direction. The slump must be measured immediately by determining the difference between the height of mould and that of the highest point of slump concrete. Figure 3.9 shows the process of the slump test is done.

Figure 3.9 Process of slump test

3.5.2 Compressive Strength

A compressive strength test is to determines the behavior of materials under crushing loads. The compressive strength test was conducted to determine the effect of fly ash as partial cement replacement towards the compressive strength of lightweight aggregate concrete. An interesting compressive load was applied to the sample until a fail result recorded while obtaining the maximum compressive load. The compressive strength has been following the procedure conducted specified BS 1881-116:1983. The cubes are tested at age 7, 14 and 28 days. It started with hardened concrete is measured by its weight and diameter of each sample. It needs to be measured in several locations, both horizontally and vertically. The concrete was placed between the compression plates with the appropriate cushioning material. The load is then slowly applied without a shock. The highest load reached is observed and record. After the load begins to decrease, the load was removed then the unusual features of the concrete are recorded. The same procedure applied for other samples. Figure 3.10 shows the compressive strength test. Lastly, the maximum sustained load of the sample were then recorded and the compressive strength of the concrete is calculated.

Compressive strength of the concrete (Eq. 3.1) :

$$fc = F / Ac \qquad (3.1)$$

where,

fc is the compressive strength in MPa (N/mm^2);

F is the maximum load at failure in N;

Ac is the cross-sectional area of the specimen on which the compressive force acts, calculated from the designated size of the specimen or from measurements on the specimen if tested according to Annex B, in mm^2.

Figure 3.10 Compressive strength test

3.5.3 Flexural Strength

The flexural test is to measure flexural strength and flexural modulus. The test required to bend a beam under third point loading conditions to obtain the force. The flexural strength has been following the procedure conducted specified BS 1881-118:1983. The beams are tested at age 7, 14 and 28 days. It started with all the dimension d_1 and d_2 of the specimen is measured. Firstly, the bearing surface of the supporting and loading rollers are wipe cleaned. The concrete was placed centre with the longitudinal axis of the specimen at right angles to the rollers correctly. The load is then slowly applied without a shock after all loading and supporting rollers are in contact with the test specimen. The test is observed until the specimen fails to bear the load. The maximum load on the scale as the breaking load is recorded. The same process for other specimens will be repeated. Figure 3.11 shows the flexural strength test. Lastly, maximum load by the specimen were then recorded and the flexural strength of the concrete is calculated.

Flexural strength of the concrete (Eq. 3.2) :

$$f_{cf} = \frac{F\ x\ l}{d1\ x\ d2} \qquad (3.2)$$

where,

f_{cf} is the flexural strength in MPa (N/mm²);

F is the breaking load in N;

d_1 and d_2 are the lateral dimensions of the cross-section in mm;

l is the distance between the supporting rollers in mm.

Figure 3.11 Flexural strength test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter, all data that has been collected from tests during laboratory testing is presented. The influence of various percentage of fly ash on workability, compressive strength and flexural strength properties of concrete containing fly ash as cement replacement is observed and then summarized into figures in this chapter.

4.2 IMPACT OF FLY ASH AS PARTIAL CEMENT REPLACEMENT ON WORKABILITY OF CONCRETE

Figure 4.1 shows slump result of fresh concrete containing a various percentage of fly ash. It has been observed that the slump pattern of the specimen is influenced by the amount of fly ash for the same water-cement ratio. Slump values of control mix 0%, 10%, 20%, 30% and 40% were 65 mm, 75 mm, 88 mm, 100 mm, and 105 mm, respectively. Concrete with 0% of fly ash has the lowest workability with 65 mm compared with other mixes. This clearly shows that when 0% of fly ash in concrete will lead to stiffer slump compared to other concrete mixers. On the contrary, 40% of fly ash concrete shows the higher workability with results of 105 mm. Types of slump for 0%, 10% and 20% are true slump, while 30% and 40% are shear slump

As the fly ash increase, the workability increase. The fly ash replacement level from 0 to 40% results in an increase in the slump value in the range of 0 - 40mm. This is due to the spherical fly ash particles. There are similar findings has been reported by

(Duran, 2011). Variation of slump pattern is illustrated in Figure 4.2 until 4.6 respectively.

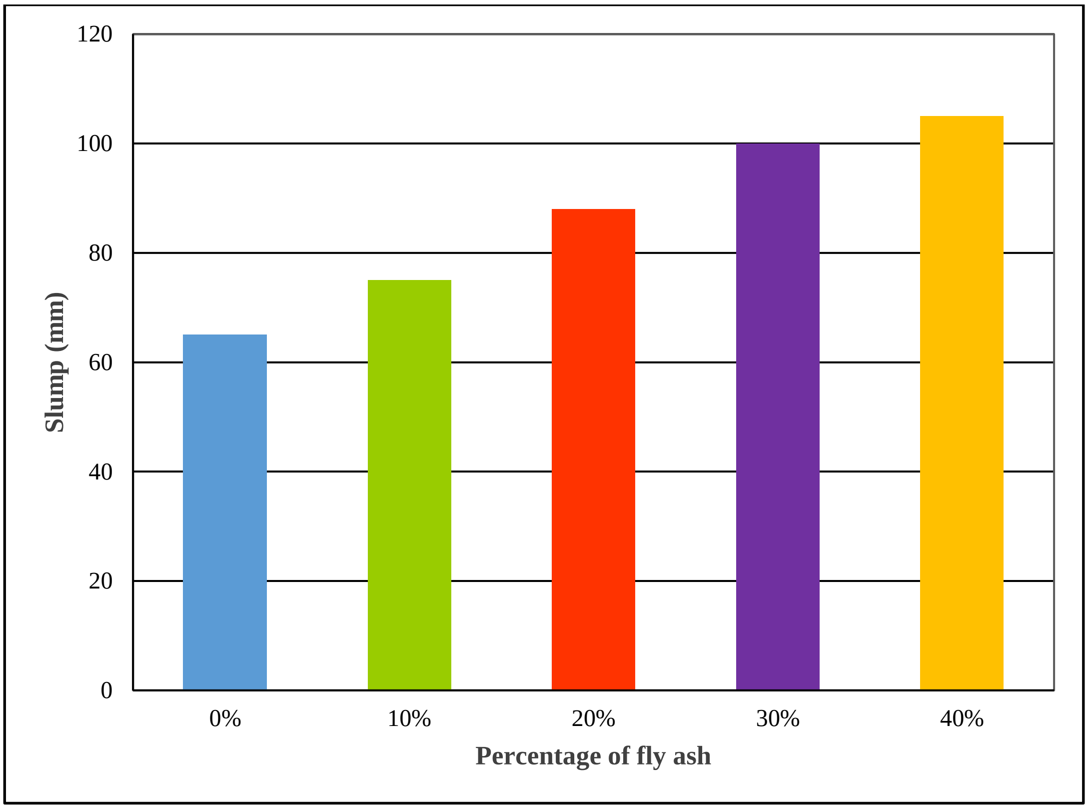


Figure 4.1 Effect of various percentage of fly ash on slump value

Figure 4.2 Slump of concrete 0%

Figure 4.3 Slump of concrete 10%

Figure 4.4 Slump of concrete 20%

Figure 4.5 Slump of concrete 30%

Figure 4.6 Slump of concrete 40%

4.3 IMPACT OF FLY ASH AS PARTIAL CEMENT REPLACEMENT ON COMPRESSIVE STRENGTH OF CONCRETE

The compressive strength of each percentage is shown in Figure 4.8. It can be seen that the use of fly ash with different amount of fly ash causes variation in the compressive strength performance of concrete in Figure 4.9 until 4.13. Compressive strength test results are illustrated in Figure 4.7. It is evident that compressive strength of concrete containing fly ash up to 20% showed some increment with 6.29% and 3.05% in compressive strength for 10% and 20%. With increasing curing age, the compressive strength of 10% exhibit highest value than other concrete mixtures. On the other hand, the concrete mixture of 40% gained the lowest value with 22.92 MPa at 28 days.

There is the decrease in compressive strength with an increase in the percentage of fly ash in the concrete has been proved according to (Jing Yu, 2018). It can be easily deduced that significant compression strength of the experimental mixtures at 28 days maturity was attributable to the pozzolanic activity of fly ash based on (Rafieizonooz, 2016).

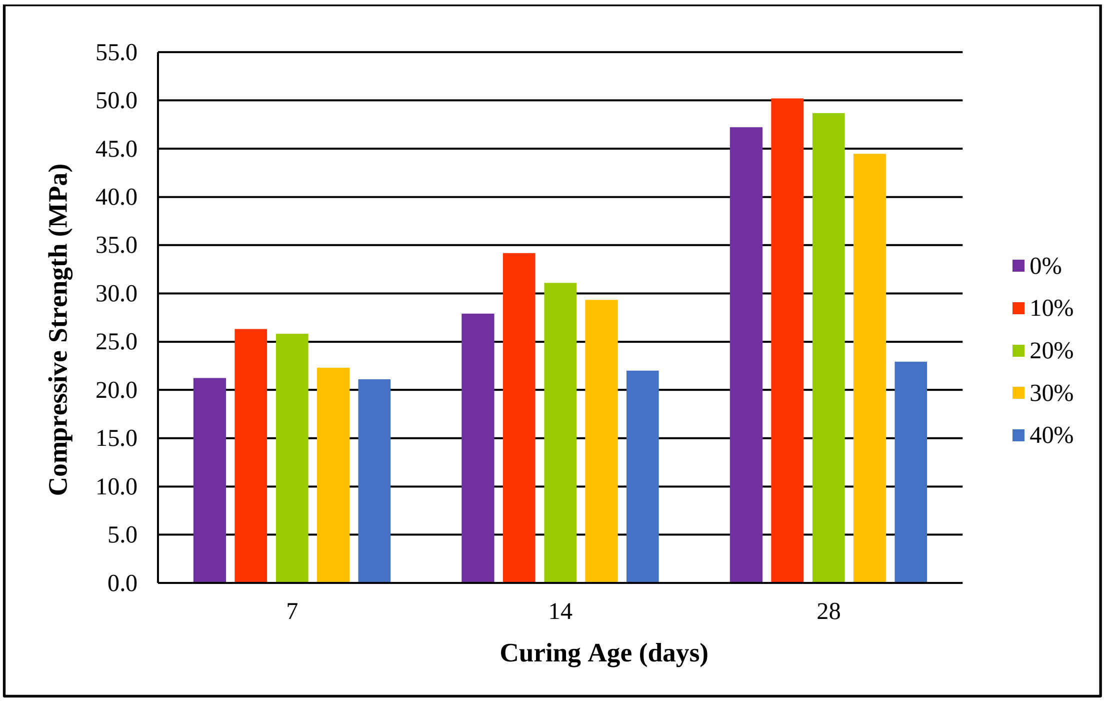
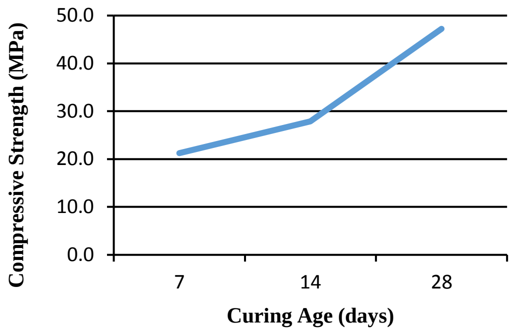
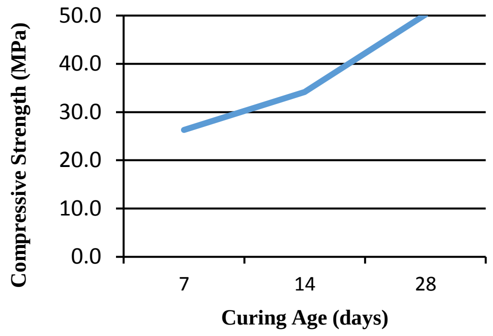


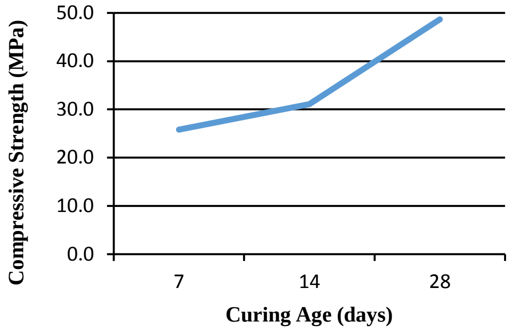
Figure 4.7 Effect of fly ash on compressive strength of concrete at the age of 7, 14, 28 days



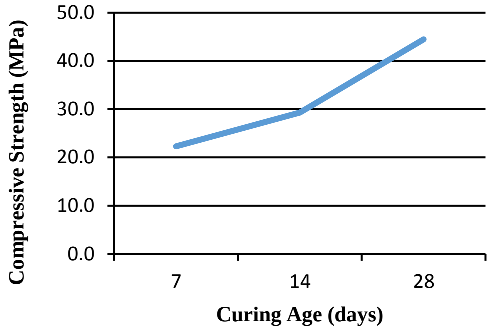
Compressive strength 0%



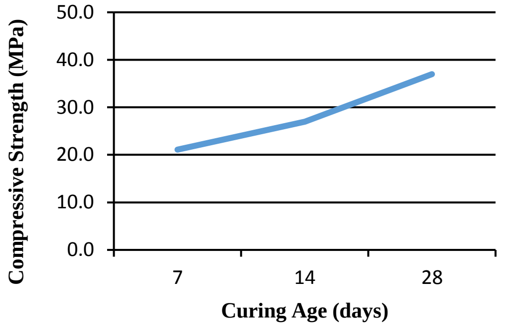
Compressive strength 10%



Compressive strength 20%



Compressive strength 30%



Compressive strength 40%

Figure 4.8 Compressive strength of concrete 0%, 10%, 20%, 30% and 40%

Figure 4.9 Compressive strength failure of 0% of fly ash

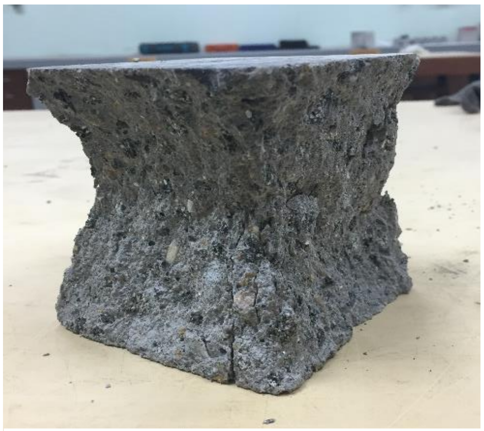


Figure 4.10 Compressive strength failure of 10% of fly ash

Figure 4.11 Compressive strength failure of 30% of fly ash

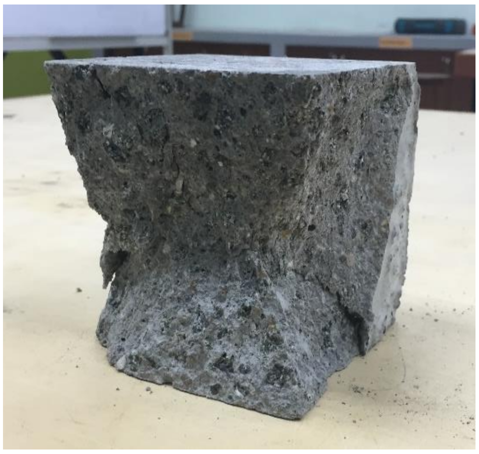


Figure 4.12 Compressive strength failure of 40% of fly ash

Figure 4.13 Compressive strength failure of 40% of fly ash

4.4 IMPACT OF FLY ASH AS PARTIAL CEMENT REPLACEMENT ON FLEXURAL STRENGTH OF CONCRETE

The results of compressive strength with different percentage of fly ash are shown in Table 4.1. The graph for flexural strength is shown in Figure 4.14 that the growing trend of flexural strength was similar to that of compressive strength. At curing period 28 days, the flexural strength of concrete containing fly ash up to 20% showed there are increasing in flexural strength. The same trend was observed at the age 28 days with 10%, 20%, 30%, and 40% of concrete mixtures achieved 119.40%, 107.02%, 94.98% and 89.97% of control concrete respectively. It is found that concrete produced using 10% of fly ash exhibit highest value of flexural strength than control mixture. While the concrete mixture of 40% gained the lowest value with 2.69 MPa at 28 days.

From the results, flexural strength test data showed that fly ash concrete mixtures increase with age reported by (Rafieizonooz, 2016). The delay in hydration and slow pozzolanic activity of fly ash during early curing period may be the possible explanation for the decrease in flexural strength of fly ash concrete at earlier ages. Besides all the other factors considered in achieving the potential strength of concrete, this may be mainly related to the fineness fly ash based on (Feng, 2017).

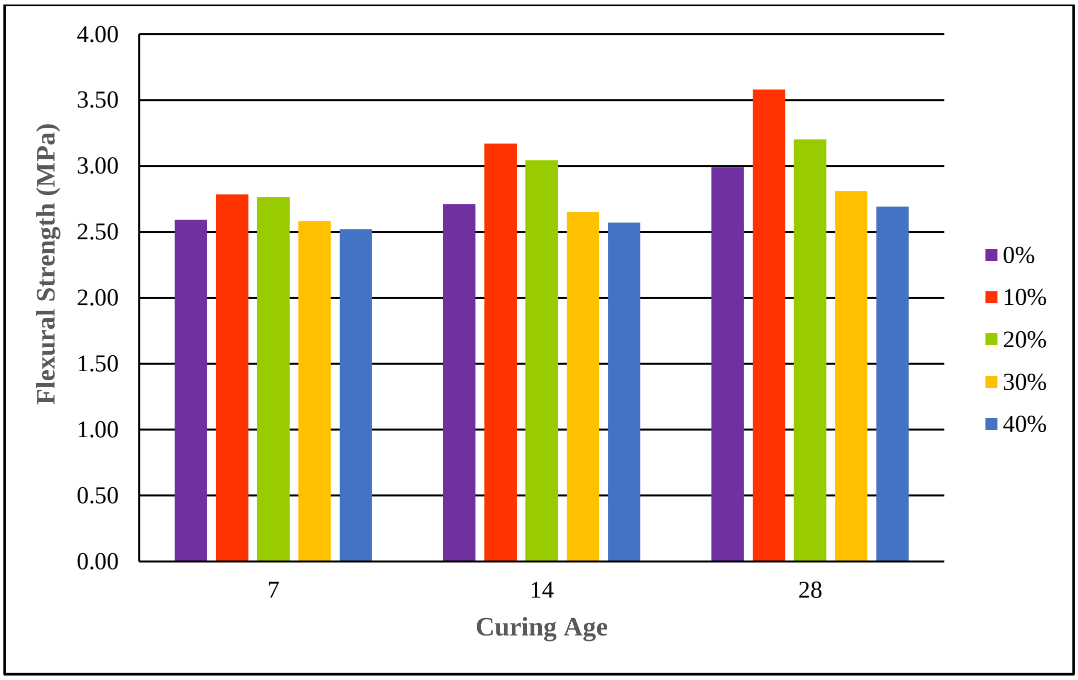


Figure 4.14 Effect of fly ash on flexural strength of concrete at the age of 7, 14, 28 days

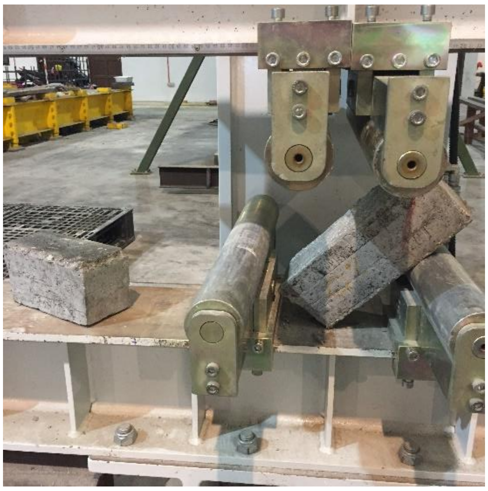


Figure 4.15 Flexural strength failure of 0% of fly ash

Figure 4.16 Flexural strength failure of 40% of fly ash

CHAPTER 5

CONCLUSION AND RECOMMENDATION FOR FUTURE STUDY

5.1 INTRODUCTION

For this chapter, the conclusion has been done to take out the objectives and outcomes of this study. Some recommendations were also included to further the study of properties of fly ash as a partial cement replacement in concrete.

5.2 BRIEF CONCLUSION

The objective of the study of properties of concrete containing fly ash as partial cement replacement can be concluded as follows:

5.2.1 The impact of the workability of the lightweight aggregate concrete containing fly ash as partial cement replacement

It was observed that the workability of concrete reduces when the volume of fly ash added is small. The mix consisting high volume of fly ash as partial replacement of cement exhibit higher workability which can be observed in the higher value of slump in the range of 0-40mm.

5.2.2 The impact of the compressive strength of the lightweight aggregate concrete containing fly ash as partial cement replacement

The addition fly ash could avoid the decrease of strength that can improve the strength due to the significant increase in pozzolanic activity. The compressive strength of fly ash concrete increases positively up to a replacement of 20% of fly ash. Therefore, the study revealed that utilization of fly ash results in concrete with higher compressive strength.

5.2.3 The impact of the flexural strength of the lightweight aggregate concrete containing fly ash as partial cement replacement

Fly ash concrete with 10% and 20% exhibit slightly high value of strength compared to control concrete. This is because of the smaller particle size fills the voids between the POBS and sand particles creating a denser and stronger concrete. But too much of fly ash also will lead to strength drop.

5.3 RECOMMENDATIONS

Among the recommendation for this study is as follows:

a. Investigation on durability aspect of lightweight concrete with fly ash when placed in aggressive environment should be studied

b. Investigate long term mechanical properties of lightweight concrete with fly ash should be studied.

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