COMPRESSIVE STRENGTH AND SPLITTING TENSILE STRENGTH OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING COAL BOTTOM ASH

NUR LIYANA HANIS BINTI HAMDAN

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name	: NUR LIYANA HANIS BINTI HAMDAN
Date of Birth	: 21 DECEMBER 1996
Title	: COMPRESSIVE STRENGTH AND SPLITTING TENSILE STRENGTH OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING COAL BOTTOM ASH
Academic Session	: 2018/2019

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_______________________	_______________________
(Student's Signature)	(Supervisor's Signature)
961221035534	ASSOC. PROF DR KHAIRUNISA BINTI MUTHUSAMY
_______________________	_______________________
New IC/Passport Number Date: MAY 2019	Name of Supervisor Date: MAY 2019

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : NUR LIYANA HANIS BINTI HAMDAN

ID Number : AA15095

Date : MAY 2019

COMPRESSIVE STRENGTH AND SPLITTING TENSILE STRENGTH OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING COAL BOTTOM ASH

NUR LIYANA HANIS BINTI HAMDAN

Thesis submitted in partial fulfillment of the requirements
for the award of the
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

Alhamdulillah, first and foremost, I would like to express my deepest sense of gratitude to Allah SWT for giving me strength to complete my Final Year Project of Bachelor Eng. (Hons.) Civil Engineering successfully. I would like to thank my research supervisor, Assoc. Prof. Dr Khairunisa Binti Muthusamy for her assistance, guidance and support throughout the process in completing this project. Without her dedicated involvement, this paper would have never been accomplished. I would like to thank you very much for your encouragement and constructive advices throughout this project.

In completing my project, it required more than academic support. I am really grateful that I have so many people that been there for me to assist and listen to throughout the study. My sincere thanks go to all my lab mates and staffs of Civil Engineering and Earth Resources Department who helped me in so many ways and make my work in lab easier and unforgettable. Special thanks should be given to my fellow friends for their comments and suggestions which crucial for the successful of this research.

Most importantly, this project cannot be completed in time without moral support and understanding from my beloved family. I am really blessed with their sacrifice, patience and unstoppable support in order I can complete this project within time. I could not find appropriate words to describe my appreciation towards their support and faith in me to achieve my goals. I acknowledge my sincere gratitude to my parents for their love and sacrifice through my life.

ABSTRAK

Abu dasar arang batu (CBA) ialah sisa daripada loji tenaga haba arang batu. Sementara itu, tempurung kelapa sawit (OPS) adalah bahan buangan daripada industri kelapa sawit. Kebiasaanya, kedua-dua bahan ini tidak mempunyai sebarang kegunaan terhadap industri-industri tersebut dan akan ditempatkan di tempat pelupusan sampah. Peningkatan jumlah OPS dan CBA membawa kepada kajian ini untuk menggunakan bahan buangan tersebut di dalam pembuatan konkrit. Penggantian pasir sungai dengan bahan buangan industri daripada arang batu di dalam konkrit aggregat ringan dengan OPS dapat dibuktikan bermanfaat secara teknikal dan ekonomi terhadap industri pembinaan. Menurut kajian ini, beberapa ujian makmal telah dijalankan untuk mengetahui kesan abu dasar arang batu sebagai bahan penggantian pasir sungai terhadap sifat-sifat mekanikal dalam konkrit aggregat ringan. Pasir sungai telah digantikan dengan abu dasar arang batu mengikut berat 0, 10, 20 dan 30% darjah penggantian. Kesemua spesimen diawet menggunakan kaedah pengawetan udara sehingga 60 hari. Ujian-ujian makmal yang terlibat dalam kajian ini adalah kekuatan mampatan dan kekuatan tarik terpecah. Keputusan ujian menunjukkan penggantian CBA sebanyak 10% merekodkan bacaan kekuatan tertinggi pada ujian kekuatan mampatan dan kekuatan tarik terpecah pada semua usia pengawetan. Sementara itu, penggantian separa CBA yang melebihi 10% mengurangkan kekuatan konkrit.

ABSTRACT

Coal bottom ash (CBA) is a residue of coal thermal power plant. Meanwhile, oil palm shell (OPS) is a by-product of oil palm industries. Usually, both of this materials have no use towards this industries and being abandon at landfill. The increment amount of OPS and CBA lead to this research to make use of this waste product in concrete making. The replacement of river sand with industrial by-products of coal in OPS lightweight aggregate concrete can prove both technically and economically beneficial to the construction industry. In this research, laboratory tests have been conducted to find out the effect of coal bottom ash as a substitute material of river sand towards mechanical properties in lightweight aggregate concrete. River sand was substituted with coal bottom ash by mass in concrete at 0, 10, 20, and 30% replacement level. All of these specimen are subjected to air curing up to 60 days. The tests involved in this research are compressive strength test and splitting tensile strength test. The test results show that at 10% of CBA replacement give the highest reading of compressive and splitting tensile strength at all curing age. Meanwhile, partial replacement of CBA greater than 10% decrease the concrete strength.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

P	Maximum load failure
A	Cross-sectional area of cube
L	Length of specimen
D	Diameter of specimen

LIST OF ABBREVIATIONS

OPS	Oil palm shell
CBA	Coal bottom ash
LWAC	Lightweight aggregate concrete
ASTM	America Society Testing and Materials
BS	British Standard

CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete was a mixture of cement, aggregates, sand and water that widely used in construction. This mixture would go through a chemical reaction called hydration process producing Calcium Silicate Hydrate gel (CSH) and Calcium Hydroxide ($Ca(OH)_2$) which make them hardened and gained its strength to form a strong solid. Components of concrete that consist of cement and aggregates were produced from limestone rocks where it required process of blasting in order to obtain the raw material. As this raw materials were non-reproducible, producing concrete materials not just costly but also would reduce the natural resources of limestone rocks. In this case, several studies had been done in order to replace and minimize the usage of cement and aggregates material in producing concrete to ensure this natural resources could be preserved. Waste material that has likely the same properties had been proposed as another option in replacing cement and aggregate in concrete.

Globally, 998 million tonnes of agricultural waste was produced per year and in Malaysia, 1.2 million tonnes of agricultural waste was disposed of into landfills annually (Agamuthu et al., 2009). The waste that being ended up at landfill had no used and created another problems to environment and human being. Approximately 30,000 tonnes of municipal solid wastes were generated daily, covering 83% of the country's waste generation, including agro wastes. About 95% of the total wastes were sent to landfills for disposal (Fauziah and Agamuthu, 2011). Malaysia was one of the biggest producer and exporter of oil palm industries in the world. This activity had brought up a large number of oil palm waste as it got no use towards this industry. The large amounts of untreated waste from agriculture and industrial sectors contaminate land, water and air by means of leaching, dusting, and volatilization. In this case, a study over oil palm shell had been proposed to use it as a replacement for concrete materials.

Coal bottom ash (CBA) was one of the biggest sources of industrial wastes that had been produced from thermal power plants (Nikbin et al., 2016). On burning of coal in coal fired boilers, it left behind the various types of ash, some of which were removed from the bottom due to coarser in nature of the furnace (generally known as CBA) and the remaining had been collected in other forms like fly ash and scrubber ash (Kim and Lee, 2015). This waste product usually being dumped into waste area, resulting air pollution and hazardous to human and surrounding. In order to prevent this problem, a study had been proposed to make this material could be used and beneficial to others.

1.2 Problem Statement

Oil palm shell and coal bottom ash were by-product of oil palm and coal industries. In 2007, there was approximately 3 million tonnes of waste product derived throughout the electricity generated process in Malaysia (Lau, 2004). Other than that, this waste materials from coal industries were harmful to environment as it could cause air pollution. Using these material as concrete properties replacement could minimize the effect to the environment. In addition, sand and granite aggregate that commonly used in concrete was produced by sand mining and granite quarrying activities. This action could cause depletion to natural resources as it were non-reproducible resources. Meanwhile, using CBA as sand partial replacement would lessen the dependency towards sand and preserved natural resources. In order to reduce the production and consumption amount of granite aggregate, using OPS as granite aggregate replacement could be a wiser choice. It not only cut down the dependency towards natural resources, but also reduce the amount of wastage that abandon in landfill area.

1.3 Objectives of Research

The objectives of the study as followed:

i. To determine the effect of coal bottom ash (CBA) as a partial sand replacement on dry density and compressive strength of OPS lightweight aggregate concrete.

ii. To determine the effect of coal bottom ash (CBA) as a partial sand replacement on splitting tensile strength of OPS lightweight aggregate concrete.

1.4 Scopes of Research

The main focus of this research were on investigating the mechanical properties of OPS lightweight aggregate concrete containing coal bottom ash (CBA) as partial sand replacement in concrete. The mechanical properties that had been investigated were dry density, compressive strength and splitting tensile strength. In this research, four mixes had been used. A plain OPS concrete containing 100% sand had been used as a control mix. Another mixes were OPS with percent of CBA of 10, 20 and 30 were used as partial sand replacement. All of the samples had undergo air curing and tested for 7, 28 and 60 days.

1.5 Significance of Research

The usage of oil palm shell and coal bottom ash as aggregate and partial sand replacement respectively would reduce large amount of waste that disposed at landfill. In addition, this action also would help to reduce environmental problems related to depletion of natural resources involving granite aggregates and sand. Moreover, this research would help to preserve and minimize the high dependency of construction materials towards natural resources.

1.6 Layout of Thesis

Chapter 1 provided a brief introduction about the main topic of oil palm shell (OPS) lightweight aggregate concrete used and CBA as the partial sand replacement in concrete. This chapter also provided information about the problem statement and objectives of this research. Scopes and significance of research were also included in this chapter.

Chapter 2 presents the literature review and a brief about the issues investigated in this research. It focused on the physical properties and general information about the material that had been done by previous researchers. This chapter also included conclusion of the literature reviews. Chapter 3 presents methodology, materials and experimental work during the research was done. The specific methods for each work and progress during the research were elaborated clearly here. This chapter also included the existing standard available that been referred in conducting the research.

Chapter 4 discussed on the data findings and processing from experiment that had been conducted during research. All results from the test had been presented in form of graphs, charts and figures. Lastly, in chapter 5, it presented the overall finding throughout the research. Discussion on this topic had been done on accomplishment of the research align with its objectives. Recommendations for future study to improve the research also be provided.

CHAPTER 2

LITERATURE REVIEWS

2.1 Construction Industry and Environment Issues

Wooden, concrete and steel were among the type of construction materials that commonly been used in Malaysia and all over the world. Nowadays, concrete were widely used in construction. Concrete materials that consist of cement, aggregates and sand were produced by non-renewable raw materials. In 2010, nations mined about 11 billion tonnes of sand just for construction (Torres et al., 2017). In addition, the high production and usage of concrete in construction lead to some environmental issues. Extraction rates were highest in the Asia-Pacific region, followed by Europe and North America. Massive production of this material resulting to depletion of natural resources of raw material as it was a non-reproducible materials. For example, in Vietnam domestic demand for sand exceeded the country's total reserves. If this mismatch continued, the country might run out of construction sand by 2020.

In addition, the method used in producing this materials involving large emission of carbon dioxide (CO_2). If the consumption of the construction materials remain the same all around the world then by the year of 2050 the production of the cement in the world could reach 3.5 billion metric tonnes. The annual production and consumption of the construction materials were increasing simultaneously, in this case the production of cement itself could reach over 5 billion metric tonnes with approximately about 4 billion tonnes of CO_2 emission (Lomite and Kare, 2009). Increasing number of CO_2 would lead to many environmental issues such as greenhouse effect and climate change.

According to Department of Environment and Energy of Australia, greenhouse effect could be classified as a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it were reflected back to space and the rest were absorbed and reradiated by greenhouse gases. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs). The absorbed energy warmed the atmosphere and the surface of the Earth. This process maintained the Earth's temperature at around 33 degrees Celsius and allowed life on Earth to exist. However, increasing of greenhouse gases such as CO_2 due to construction industry would abruptly increase the Earth's temperature. This situation would resulting to high sea water level as it fasten the ice melting at the pole. It also related to natural disaster that happened such as tsunami and flood. As the temperature went up, it also would cause climate change where the environmental condition at certain place would be disturbed.

2.1.1 Sand Mining

Sand or fine aggregate was one of the main components in producing plain concrete. It occupied the volume and space within the concrete making them high in density. The amount of fine aggregates in concrete also would influenced the properties of concrete. High amount of sand resulted concrete to have higher workability. Sand was usually produced by sand mining activity. Sand mining was a process removal of sand from their natural configuration (Ashraf et al., 2011). It was an activity referring to the process of removing sand from the rivers, streams and lakes. Sand was mined from beaches and inland dunes and dug up from ocean and river banks. It was used for all kinds of projects like land reclamations, construction of artificial islands and coastline stabilization (McLellan et al., 2009). These projects had economic and social benefits, but would also cause environmental problems. The mining industry undeniably interferes with the natural environment.

According to data from Department of Minerals and Geoscience Malaysia in 2018, the production of sand and gravel in Malaysia were highly increased in the year of 2015 and 2016. This was due to high consumption of sand for industrial purposed. Sand produced by industry would be used for construction work. As the country was at rapid growth of development, more buildings were constructed. It was predicted that the production of sand and gravel were going to rise as in future there would be lots of development and need more construction works. Realizing this matter, a proper proposed action should be implemented to lessen the dependency towards sand.

In addition, sand mining activities brought many side effects to environment. According to Ashraf (2011), the physical impacts of sand mining include reduction of water quality and affect the ecosystem in the stream and rivers. Sand mining also resulted to destabilization of the stream bed and banks. Other than that, it also disrupted sediment supply and channel form. This could result in a deepening of the channel as well as sedimentation of habitats downstream. Moreover, sand mining activities also could disturb the infrastructure structure such as component of bridges and pipelines. This was due to unstable of foundation condition as the condition of sand had been disturbed. The sand will lose its strength and cause failure to foundation.

It was proven that there were many side effects of sand mining activity, some researches had been done to lessen the usage of sand in construction. Siddique et al. (2013), had done researches on using bottom ash (CBA) as sand partial replacement. They found out that the properties of concrete containing CBA had compressive strength value of each cube was within 10% variation from average compressive strength of the test. This shows that CBA could be used as sand replacement but resulting concrete to have a bit lower strength compared to concrete using sand as fine aggregates.

Figure 2.1 below shows the chart production of sand and gravel in Malaysia from year of 2010 to 2016. From that chart, it clearly shown that production of sand and gravel had rapidly increased for starting the year of 2014 to 2016. Country with high development would require more number of new buildings. This would increase the construction rate in that country. In this case, high amount of sand and gravel that being used as construction materials were needed. Figure 2.2 shows the river sand particles in high resolution image.

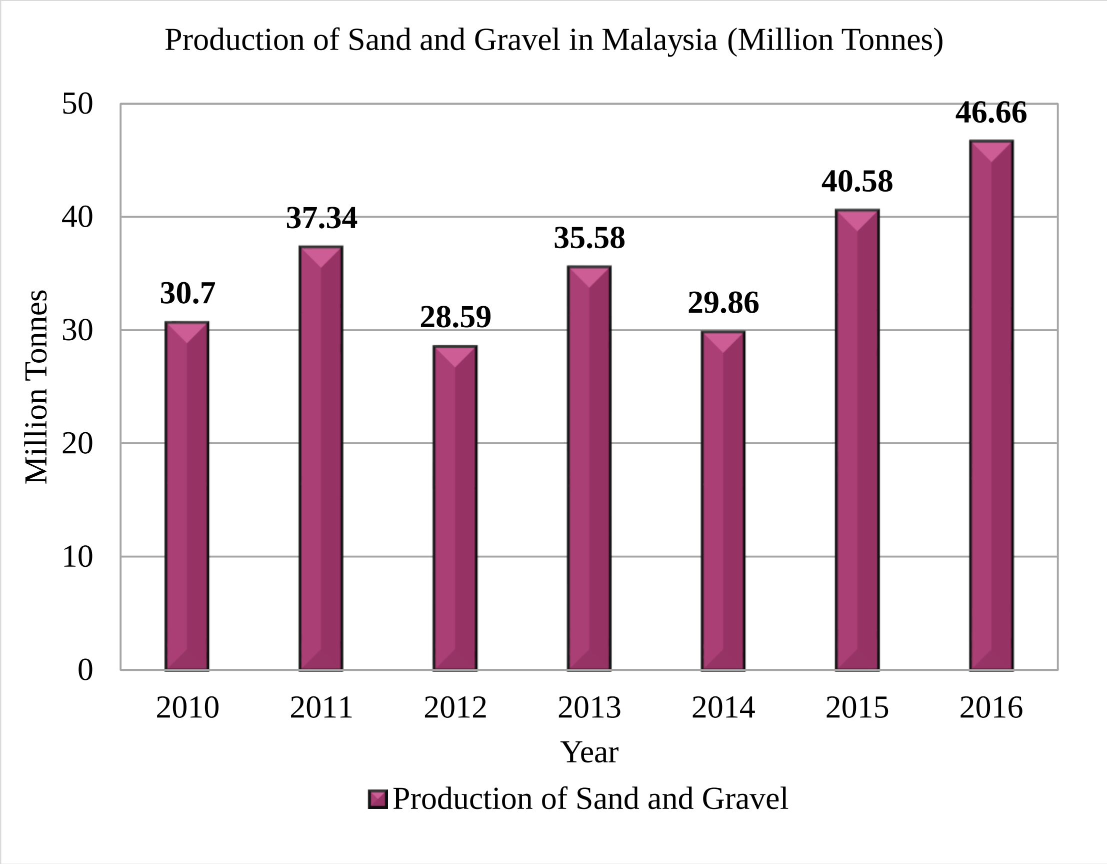

Figure 2.1 Production of Sand and Gravel in Malaysia (Million Tonnes)

Source: Department of Minerals and Geoscience Malaysia (2018).

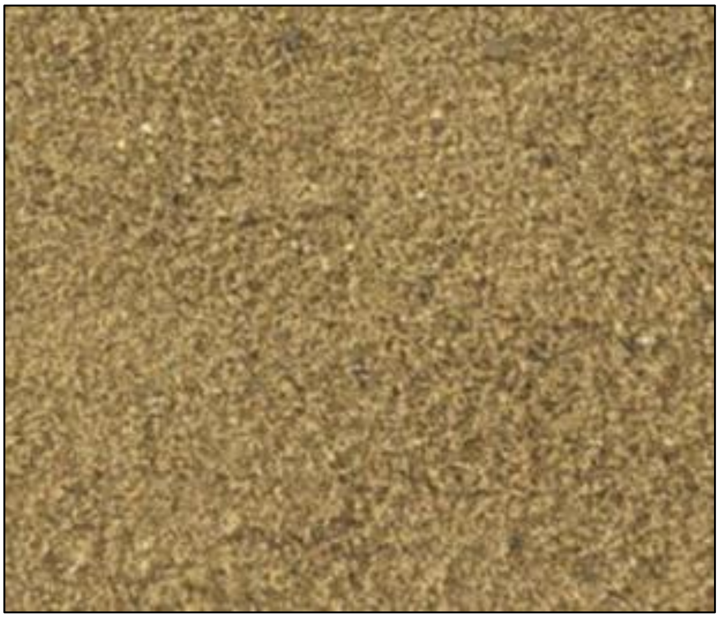

Figure 2.2 High resolution image of river sand

Source: Agrawal et al. (2019).

2.1.2 Aggregate Quarrying

Aggregates were produced from quarrying activity that involving process of blasting, drilling and screening. They were being separated according to its size. Aggregates were widely used in construction and become the main material in producing concrete. Quarrying is the oldest and most activity that been done in order to produce aggregate from its natural resources. However, quarrying activities brought many bad effect especially to environment. According to Chenot (2018), in contrast to underground mines, the impact of which may be more localized, the exploitation of opencast quarries had a direct impact on the environment, and in particular on the vegetation and the soil, since it lead inevitably to a profound alteration of the composition or structure of the soil, or even its complete disappearance. It showed that quarrying activities lead to disruption towards environment.

There were more than 2.7 billion tons of aggregates produced each year in 25,000 quarries spread throughout Europe (Chenot, 2018). Quarrying activities also lead to air and noise pollution. According to a journal wrote by Liberman (2018), said that the remaining quarry fines which was particles smaller than sand were stockpiled creating environmental risks such as dust emission and runoff into natural fluvial systems. The dust would flew away to nearby area and cause air pollution. Moreover, as quarrying process involved blasting activity to break the granite rocks into pieces, it would cause noise pollution.

According to the Figure 2.3 below, it could be concluded that the consumption of granite were increased as the year increased. Granite aggregate was one of the main ingredients in preparing concrete. High consumption of granite would reduce its natural resources. Realizing the effect of quarrying activities towards environment, several types of material had been proposed to reduce the dependency towards natural aggregate. Material that contain alike properties as aggregate had been studied and tested to replace the function of aggregates in concrete. Figure 2.3 shows the granite consumption in United State and Figure 2.4 below shows aggregate quarrying activity.

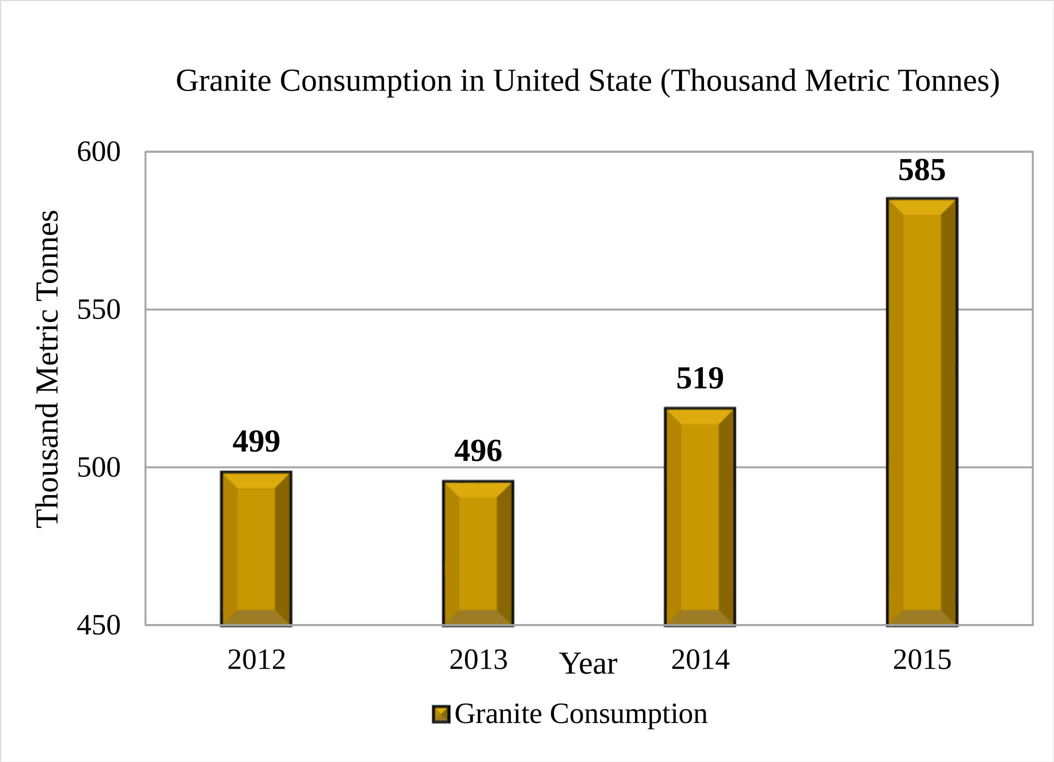

Figure 2.3 Granite Consumption in United State (Thousand Metric Tonnes)

Source: US Geological Survey (2017).

Figure 2.4 Aggregate quarrying

Source: Sebarang Bina Quarry (2018).

2.2 Lightweight Aggregate Concrete

Lightweight concrete was a concrete that had lower density compared to normal concrete. The concrete element in lightweight concrete was replaced by other material that have lower density but can perform alike properties. According to Neville (2003), the practical density range of lightweight concrete was between 300 to 1850 kg/m^3 while for normal concrete was within the range of 2200 to 2600 kg/m^3. In lightweight aggregate concrete, aggregate was replaced with material that had lower density, but have same or higher in strength. Lightweight aggregates could be manufactured from natural materials or from industrial by-product. In choosing the lightweight aggregate to be used in constructing a structure, it was a must to follow the ASTM C 330-09 and BS EN 13055-1:2002 to ensure that proposed aggregates not only suitable, but also safe to be in concrete used (Neville, 2011).

Manufactured aggregates could be produced by natural materials such as expanded clay, shale and slate. This materials were obtained by some process including heating them in rotary kiln. According to Neville (2011), as aggregates had been subjected to high temperature of 1000 to 1200 °C, it would be expanded due to generation of gases which become entrapped in a viscous pyroplastic mass. This process allow the aggregates to have higher voids in it, thus resulted aggregates to have lower specific gravity. Expansion of aggregates could be achieved by using sinter strand. During this method, it would collect moistened materials altogether and be burned gradually. Gases that entrapped in the materials would reduce the specific gravity. The bulk density of manufactured aggregates that made by sinter strands was in the range of 650 to 900 kg/m^3 while for made by rotary kiln was 300 to 650 kg/m^3.

Other than that, lightweight aggregates also could be obtained by industrial by-products such as oil palm shell, oil palm clinker, coal bottom ash and etc. Those materials usually being abundant at landfill as it had no use towards the industry. Tropical regions and countries with palm oil industries produced many types of waste that could be used as lightweight aggregates or replacements to cement, which in turn can aid in the development of sustainable structural lightweight concrete (Shafigh et al., 2018). Several steps should be taken to ensure that the waste materials that being used as aggregate replacement can perform better and did not affect the properties of concrete. Figure 2.5

and Figure 2.6 show the manufactured aggregates and Pores structure of lightweight aggregate concrete.

Figure 2.5 Manufactured aggregates
Source: Ayati (2018).

Figure 2.6 Pores structure of lightweight aggregate concrete
Source: Ayati (2018).

2.2.1 Benefits

Lightweight aggregate concrete tend to have many benefits compared to normal concrete. The low density property of this lightweight aggregate were really suitable for constructing large-span bridge, high-rise building and offshore oil platforms (Wu, 2019). According to Clarke (2005), the inclusion of lightweight aggregate in structural concrete provide a weight reduction of 25% to 35%. A reduction of 25% in weight of reinforced concrete would result in a 50% reduction in load when it was under submerged condition such as for offshore structures (Nadesan, 2018). Using lightweight aggregate concrete lowered the self-weight and total weight of the structure. Structures with lower weight would reduce the load transferred to the foundation. In this case, building structure such as foundation, column and beam could be designed in a smaller size.

In addition, as the aggregate replacement was used from wastage material, where the overall cost to process it was much lower compared to the process in obtaining coarse aggregate from raw materials. In Malaysia, we also imported raw material in producing coarse aggregate. By using lightweight aggregate concrete, it can reduce the dependency towards raw material and imported materials from other country. This action would save our natural resources as it cannot be reproducible. Other than that, according to Traore (2018), as concrete structures could be designed in a smaller size, a substantial amount of cost can be reduced if the weight of the concrete structure is decreased.

2.2.2 Properties

According to Shafigh et al. (2018), the workability of concrete using lightweight aggregate with the same amount of water and superplasticizer used was lower than normal concrete with granite aggregates. Lightweight aggregate had more porous surface textures compared to granite. In this case, lightweight aggregates would absorb more water during mixing process. According to Neville (2011), there was no exact value of water needed in mixing lightweight aggregate concrete, but it depend on porosity of the aggregates. Aggregates with higher porosity would need higher amount of water as it would absorb more water during mixing process. The best way to control the rate of absorption was by immersing aggregates in water for 30 minutes before being used.

Next, lightweight aggregates concrete was low in strength compared to normal concrete. This was because granite aggregates were stronger than lightweight aggregates.

However, in order to achieve the same strength of concrete, lightweight aggregate concrete should be added with pozzolan materials with adequate amount of cement in mixing process. Cement would produce calcium hydroxide ($Ca(OH)_2$) and calcium silicate hydrate (CSH) gel in reaction with water called hydration process. Calcium hydroxide then would react with pozzolan materials in lightweight aggregate to form secondary CSH gel that responsible towards concrete strength. This action would produce concrete with higher strength.

Other than that, according to Neville (2011), lightweight aggregates concrete had higher heat insulation resistance compared to normal concrete. Lightweight aggregate used had high porosity compared to granite aggregate. This properties making them to have lower thermal conductivity. Rate of heat transferred to another aggregate was lower by using lightweight aggregates compared to granite making them a better fire resistance concrete. Table 2.1 shows the physical properties of normal concrete compared to lightweight aggregate concrete.

Table 2.1 Physical properties of normal concrete compared to LWAC

Properties	**Normal Concrete**	**Lightweight Aggregate Concrete**
Density (kg/m^3)	2200-2600	- Manufactured from natural materials - Industrial by-product
Aggregate	Granite aggregate	Higher
Specific Gravity	Lower	Lower
Heat Insulation Resistance	Higher	Higher
Thermal Conductivity	Lower	
Durability	Not much different	

Source: Neville (2011).

2.2.3 Application

Lightweight aggregate concrete had widely used in building construction in oversea. As lightweight aggregate concrete were lower in density compared to normal concrete, it was a type of concrete that suitable for high-rise building. This would make the building structure to be designed in smaller size compared using normal concrete. Figure 2.7 and 2.8 below show the building that used lightweight aggregate concrete.

Figure 2.7 Sacred Heart Hospital in Pensacola, Florida
Source: Expanded Shale, Clay and Slate Institute (2018).

In construction of Sacred Heart Hospital in Pensacola project, it involving expansion of five new floors of patient care units with 112 private rooms. This vertical addition was constructed on top of the hospital’s existing three-story raising the building to eight stories at a height of 220 feet. The $52 million expansion project began in April 2012 and was officially open for patient care on July 19, 2014, within time and budget.

The existing steel-framed building support an additional five floors was used structural lightweight concrete made with rotary kiln produced structural lightweight aggregate. It allowed the floor slabs to be thinner while providing better fire resistance. Lightweight aggregate concrete had lower thermal conductivity making heat transferred to another structure were lower compared to plain concrete. Moreover, the porous properties of lightweight aggregate would lessen the heat transferred. This properties increase the heat resistance of a building. Lightweight aggregate concrete was really suitable to be used in this hospital construction as there were lot of flammable properties in hospital.

Figure 2.8 Salesforce Tower in San Francisco, California.
Source: Expanded Shale, Clay and Slate Institute (2018).

Salesforce Tower has 61-storey was completed in 2018. In this construction, expanded shale lightweight concrete had been used to construct its floor. The overall cost for this project was $1.1 billion. The high rise building was suitable to be constructed using lightweight aggregate concrete. Lightweight aggregate concrete would reduce the self-weight of structure making them lighter than using the normal concrete. This situation reduced the overall weight of the building. In addition, the total load transferred from the building could be reduced as it has lower self-weight. In this case, the building structure could be design in smaller size. Using lightweight aggregate concrete resulted to less construction materials used and cut down the overall cost of project.

2.3 Coal Bottom Ash

Coal bottom ash was a by-product of combustion in furnace of coal fired thermal power plants. It was made up from agglomerated ash particles that were too large to be carried in the flue gases and fell through open grates to an ash hopper at the bottom of the furnace (Siddique, 2013). For coal industry, it produced fly ash and bottom ash as by-product. Bottom ash formed up to 25% of the total ash while fly ash formed the remaining of 75%. Fly ash were really light and could easily flied. It would be captured by electrostatic precipitators before it flied to the surrounding. Differ with fly ash, coal bottom ash were larger in size and remained at the bottom of furnace after combustion had carried out. Both fly ash and bottom ash were by-product that have no use for coal industry. They will end up abundant at landfill. Figure 2.9 and figure 2.10 below show the particles of fly ash and CBA under microscope.

According to a statistic that had been released by International Energy Agency in 2016, as shown in Table 2.2, 7269 million metric tonnes of coal were produced in that year. The high number of production resulted to high waste from coal industry were produced. The by-product of coal finally being sent to landfill as it give no use to the industries. It would increase the landfill area and caused problems to surrounding. Table 2.2 shows the coal production in 2016.

Table 2.2 Coal production in 2016

Producer	**Metric tonne**	**% of world total**
China	3242	44.6
India	708	9.7
United State	672	9.2
Australia	503	6.9
Indonesia	460	6.3
Russia	365	5.0
South Africa	257	3.5
Germany	176	2.4
Poland	131	1.8
Kazakhstan	98	1.3
Rest of world	657	9.3
Total	**7269**	**100**

Source: International Energy Agency (2016).

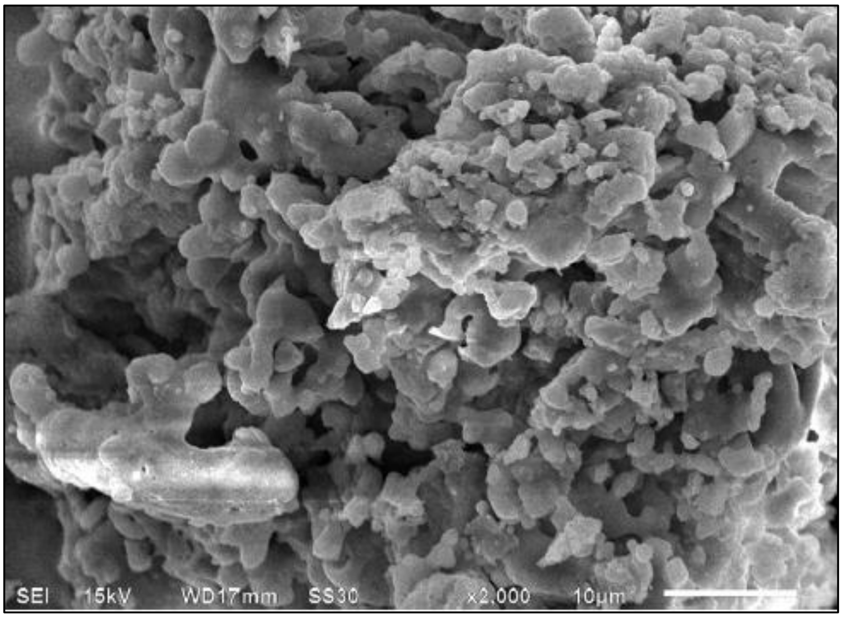

Figure 2.9 Scanning electron micrograph of coal bottom ash particle

Source: Siddique (2015).

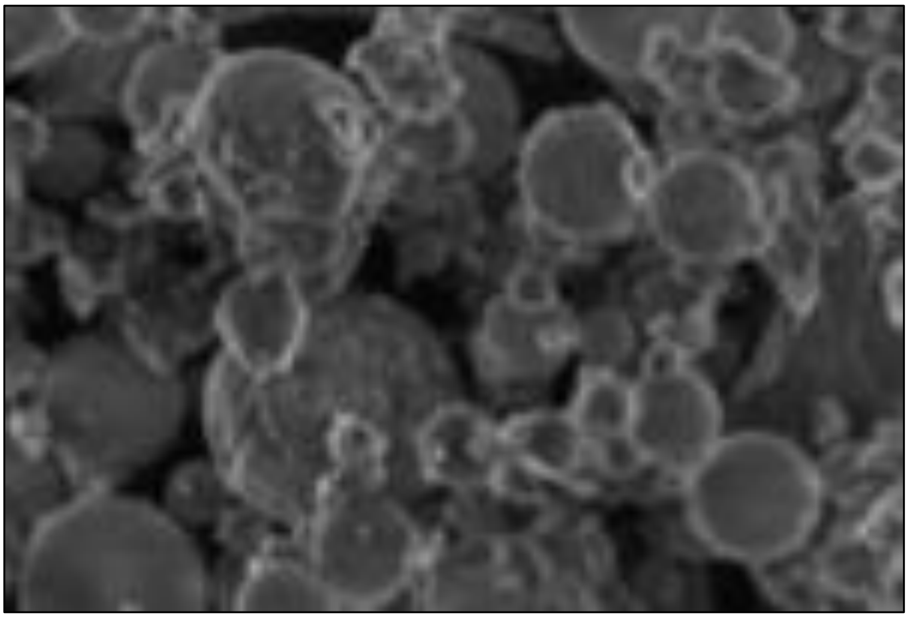

Figure 2.10 Scanning electron micrograph of fly ash particle
Source: Xing (2019).

2.3.1 Physical Properties

According to Pasetto (2014), laboratory observation showed that coal bottom ash was a dark grey materials with most angular particles in shape. It had a porous material with rough surface texture. The size of CBA varies between fine gravel to fine sand. CBA also had a lower unit weight and specific gravity compared to normal sand that commonly being used in concrete mixing. According to Siddique et al. (2013), they said that low content of ion iron in CBA were the reason of their lower specific gravity. The size of CBA used as sand partial replacement would affect the concrete in term of its mechanical and durability properties. Concrete that used smaller size of CBA would have better mechanical properties and ability towards any attack. This was because, smaller size CBA were filled into concrete volume making it denser and packed.

The physical properties of CBA usually were varies according to the type of thermal plants. This was because different thermal plants would produce different types and properties of coal bottom ash. Table 2.3 below shows the physical properties of CBA studied by different researcher.

Table 2.3 Physical properties of CBA

Physical properties	Sharma et al. (2012)	Tuhran (2012)	Rafat (2013)	Mathiraja (2013)	Jaleel and Maya (2015)	Aswathy and Mathews (2015)	Dinesh et al. (2016)
Specific gravity	2.12	1.39	1.93	2.14 – 2.42	2.3	2.97	2.46
Water Absorption (%)	3.8	-	-	-	1.80	18	6.63
Fineness modulus	-	-	1.6	-	3.86	2.97	3.06
Bulk density (kg/m^3)	-	2590	-	1120	1520	-	-

Source: Navdeep (2018).

2.3.2 Chemical Properties

Coal bottom ash usually were composed by silica, alumina, iron, magnesium, calcium and etc. The chemical properties of CBA were differ with one another according to the type of thermal plants at where they were produced. This resulted to CBA had vary amount of chemical elements. The chemical properties from several authors were shown in the Table 2.4 below.

Table 2.4 Chemical properties of CBA

Chemical composition (%)	Martins et al. (2010)	Surendar and Shanthi (2011)	Rafat (2013)	Sanjith et al. (2015)	Rafieizonooz et al. (2016)	Jamaluddhin et al. (2016)
SiO_2	52.02	47-55	57.76	48.71	45.3	68.9
Al_2O_2	23.23	25-35	21.58	29.23	18.1	18.7
Fe_2O_3	9.11	3-4	8.56	4.29	19.84	6.5
K_2O	1.14	0.5-1	1.08	0.55	2.48	1.52
Na_2O	0.49	0.2-0.8	0.14	1.16	-	0.24
CaO	6	4-10	1.58	7.44	8.7	1.61
MgO	2.17	0.5-2	1.19	1.7	0.97	0.53
SO_3	0.65	0.1-0.5	-	3.96	0.35	-
TiO_3	1.23	0.5-2	-	1.88	3.27	1.33
Manganese oxide	-	1-2.5	-	-	0.25	-
Ignition loss	-	-	5.8	-	-	2.68

Source: Navdeep (2018).

2.3.3 Application of CBA in Concrete

The coal fired thermal power plants were the main source of production of coal ash (Siddique, 2014). This by-product material have no use to the industries. They usually being dump into landfill as the disposal of this materials require a certain cost. This situation increase the landfill area. Realizing this issue, studies had been done to make use of this wastage materials. According to Aydin (2016), bottom ash was an alternative construction material to cement and could be used as a replacement for sand in bituminous mixtures and as a fine aggregate replacement in the production of concrete. Its porous nature makes it suitable for hot-mix asphalt applications.

In addition, according to study, it proved that CBA contains pozzolan materials which could contribute to more production of CSH gel and enhance the concrete strength. Concrete that cast with mixing of pozzolan material tend to have higher strength and durability compared to being cast by using fully cement. When cement was mixed with water during hydration process, it would produce calcium hydroxide ($Ca(OH)_2$) and primary CSH gel. However, in presence of pozzolan materials in concrete, it would react with ($Ca(OH)_2$), to form secondary calcium silicate hydrate (CSH) gel in concrete. This process was known as pozzolanic reaction. CSH gel was responsible towards the strength of concrete. High amount of CSH gel in concrete would increase the strength of concrete. It would produce concrete with higher in durability and better in performance.

According to Ramme and Tharaniyil (2013), CBA could be used in many application regard to civil engineering works such as road and embankment construction, material replacement in concrete (fine aggregates) and manufacturing of construction materials such as bricks and ceramics product. Making use of CBA would reduce the total amount of them that abundant in landfill, hence it would significantly reduce the cost that use in order to dispose this waste materials. In addition, according to study, incorporation of CBA during construction of stone mastic asphalt pavements, the fatigue performance had been improved while the macro-crack initiation had been delayed (Pasetto and Baldo, 2014). This study proved that application of CBA with proper method in constructing materials would produce a better quality of concrete structure.

2.3.4 Production of CBA and Effect to Environment

Coal was the main source in producing electricity and heat by combustion process. According to Naganathan (2017), coal ash was residue from combustion of coal at the thermal power plants. Burnt coal produced smoke that being flown into the air which captured by electrostatic precipitator as fly ash. While, the burnt coal at bottom of burning chamber was cooled, produced coal bottom ash. CBA was collected at the bottom of the kiln after each burning cycle. As it had higher density compared to fly ash, bottom ash would remain at the bottom of tunnel and not being flown away by wind. In Malaysia, there were 6 thermal plants available with annual coal consumption of 24.7 million tonnes (Naganathan, 2017). As the demand of electricity and heat continuously increased by years, the number of coal consumption would remain increased. This situation would resulted more waste product by coal industries would be produced.

However, the method of open disposal of CBA from the various industrial sectors and thermal power plants lead to major environmental pollution as well as various health hazards (Navdeep, 2018). This was because CBA contained lot of heavy metals such as copper, zinc, arsenic, barium, nickel and mercury. In addition, the chemical properties of CBA containing transitions metal such as copper and zinc that can cause damaging of lung tissues. In a research conducted by Cenni (2001), stated that the presence of CBA particles caused swelling and altering of cardio- pulmonary organs such as pulmonary vasculitis and hypertension. All of these study showed that production of CBA were affected the human health. Realizing the effect of CBA towards human health, a proper method in handling this waste material should be implemented. In addition, making use of this CBA could lessen the amount of this waste material.

2.4 Oil Palm Shell

Palm oil industry was one of the largest plantation industries in Malaysia. The type of soil in Malaysia which mostly consist of peat soil were really suitable for this type of plantation. This palm industry not only produce many palm products such as palm oil, side products like soaps and candles but contribute to many by-product such as oil palm shell (OPS) and oil palm clinker (OPC). According to research done by Abdullah (2011), it was estimated that 1.10 tonnes of oil palm shell would be produced from one hectares of oil palm estate. They also stated that from the total of fresh fruit bunches, 5.5% of them were oil palm shell. In Malaysia, there were record stated that Malaysia had produced 17.7 million tonnes of oil palm on 2008. The production had increased years by years. Higher production number of oil palm also would linearly increase the amount of wastage. Oil palm shell usually would be disposed or being end up at the landfill. The large number of waste product from oil palm industry caused a major disposal problem. This oil palm shell had no use towards oil palm industries. It would dump at the landfill and be disposed. However, disposing this materials require a certain cost. This case make industries to just dump them in landfill without any proper management. Finally, this material would end up at landfill with no action and this situation increased the landfill area. Figure 2.11 shows raw OPS materials that obtained from landfill.

Figure 2.11 Raw OPS materials
Source: Nabinejad (2015).

2.4.1 Production of OPS and Effect to Environment

Oil palm was the highest yielding edible oil crop in the world and a total of 14.4 million hectares were currently cultivated in 43 countries where Indonesia, Malaysia and Nigeria being responsible for approximately 83% of the worldwide production (Nabinejad, 2015). Oil palm shell was a waste product obtained during the extraction of oil from oil palm tree. According to Malaysia Palm oil board (2019), the production from oil palm tree included crude palm oil, palm kernel, palm kernel cake and crude palm kernel oil. These products were beneficial to palm industries as it produced oil palm that being used for cooking while palm kernel and palm kernel cake were used in production of pellet for animals' food. However, there were also by-product from this industries such as oil palm shell, oil palm clinker and brunches. Usually, these by-products had no use toward industries and would end up be disposed. However, the presence of these oil palm wastes had created a major disposal problem.

The higher production of oil palm industries would linearly increase the production of oil palm shell. According to Khankhaje, 2016, there were 4 million tonnes of oil palm shell produced annually in Malaysia and by the year of 2020, country was expected to have five million hectares of oil palm trees. Higher amount of oil palm industries production lead to high amount of by-product production. Oil palm shell had no use towards oil palm industries and end up being dump at landfill. This would resulted the increasing of landfill area. In addition, this situation also would affect the environment. The rapid expansion of oil palm cultivation has raised concerns about the sustainability and environmental impact of oil palm plantations, in particular with regard to biodiversity, destruction of old growth rainforest and air pollution (Abdullah, 2011). Abundant of oil palm shell would resulted to a not nice smell especially when they were exposed towards wet condition. This situation lead to air pollution problem. Figure 2.12 shows abundant OPS at landfill area.

Figure 2.12 Abundant OPS at landfill area

2.4.2 Properties of OPS

Oil palm shell physically was a small hard particles that consists of different shapes and sizes which was suitable to use as coarse aggregates replacement. It usually had dark brown color and a really hard shell. OPS came from oil palm plant and had plant cell behaviour. With the exception of water, plant cell walls comprise mainly of sugar based polymers, such as cellulose and hemicellulose, which were combined with lignin and lesser amounts of extracts, protein, starch and inorganic phases (Nabinejad, 2015). This made oil palm shell were much lighter in weight and had a lower strength compared to granite aggregates. According to Gungat (2013), the oil palm shell had lower specific gravity with only 1.17 kg/m3. The lower specific gravity indicated that this materials were less in density and high in porosity.

Other than that, oil palm shell also had a higher water absorption rate compared to granite aggregate. This was because the physical structure of oil palm shell were less dense compared to granite aggregate. It also had high porosity compared to granite aggregate. This porous materials lead water to flow into the oil palm shell. According to Traore (2018), the performance of oil palm shell as aggregate could be improved by implementing some treatment that used for woods. In addition, Traore et al. in their research had found out that oil palm shell could perform better when subjected to high temperature. By using oil palm shell in concrete, it would lower the thermal conductivity as heat transferred in oil palm shell were lower compared to using granite aggregate. It happened due to its properties that high in porosity. As concrete that contain oil palm shell had a lower thermal conductivity, it would resulted concrete to have a better heat and fire resistance.

2.4.3 Application of OPS in Concrete

According to Shafigh (2013), oil palm shell (OPS) was an agricultural solid waste that could be used for making lightweight aggregate concrete. The use of this materials had been recognized in Malaysia for more than two decades. The use of OPS as an aggregate for making lightweight concrete was researched as early as 1984 by Abdullah (Shafigh, 2013). However, Zhang and Gjorv (1990) stated that not all types of lightweight aggregate were suitable for producing high strength lightweight concrete. It was because different oil palm estate would produce various quality of oil palm shell. Factor of nutrient content in soil where the oil palm tree were planted also influenced the quality of the oil palm shell product.

As oil palm shell had no use towards oil palm industries, it would end up at landfill or being disposed. Using this materials in concrete mixing would reduce the amount of OPS at landfill. Oil palm shell usually being used as coarse aggregate replacement in the concrete. The usage of OPS as aggregate in concrete can help resolve the concomitant environmental problems (Traore, 2018). In addition, the lighter properties of oil palm shell resulted concrete to have lower density. Usually, this type of concrete would be used at high-rise building in order to reduce its self-weight. Furthermore, using this type of concrete also would reduce the size of structural elements such as column and beam. As the structure used to transfer lower load from the building, it was adequate to be designed in smaller size.

Other than that, according research done by Shafigh (2013), in using OPS as coarse aggregate in concrete mixing, some treatment some be implemented. The OPS need to be soaked in water for a certain period to minimize water absorption during mixing process. As the properties of OPS were differ according to the estate where it came from, there was no exact value of duration for the OPS to be soaked. This method was done to ensure that no excessive water needed during mixing process. Hence, it also to make sure that the workability of concrete mixtures were not affected. Figure 2.13 below shows OPS concrete.

Figure 2.13 Concrete containing oil palm shell

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the methodology flows, materials used for concrete specimens, the mix proportion, preparation of specimens and laboratory tests that involved in the research. In methodology flows part, it discussed about the overall process that involved during this research. Next, it move to the materials that being used in preparing the specimens which included the usage of cement, river sand, oil palm shell (OPS), coal bottom ash (CBA) as sand partial replacement and water and superplasticizer. Then, it discussed on the mix proportion and preparation of the specimen. Lastly, it followed up with discussing the laboratory tests involved. Dry density test, compressive strength test and splitting tensile strength test were the laboratory tests that conducted in this research and being discussed in detailed.

3.2 Methodology Flow

Figure 3.1 shows the overall process of this research.

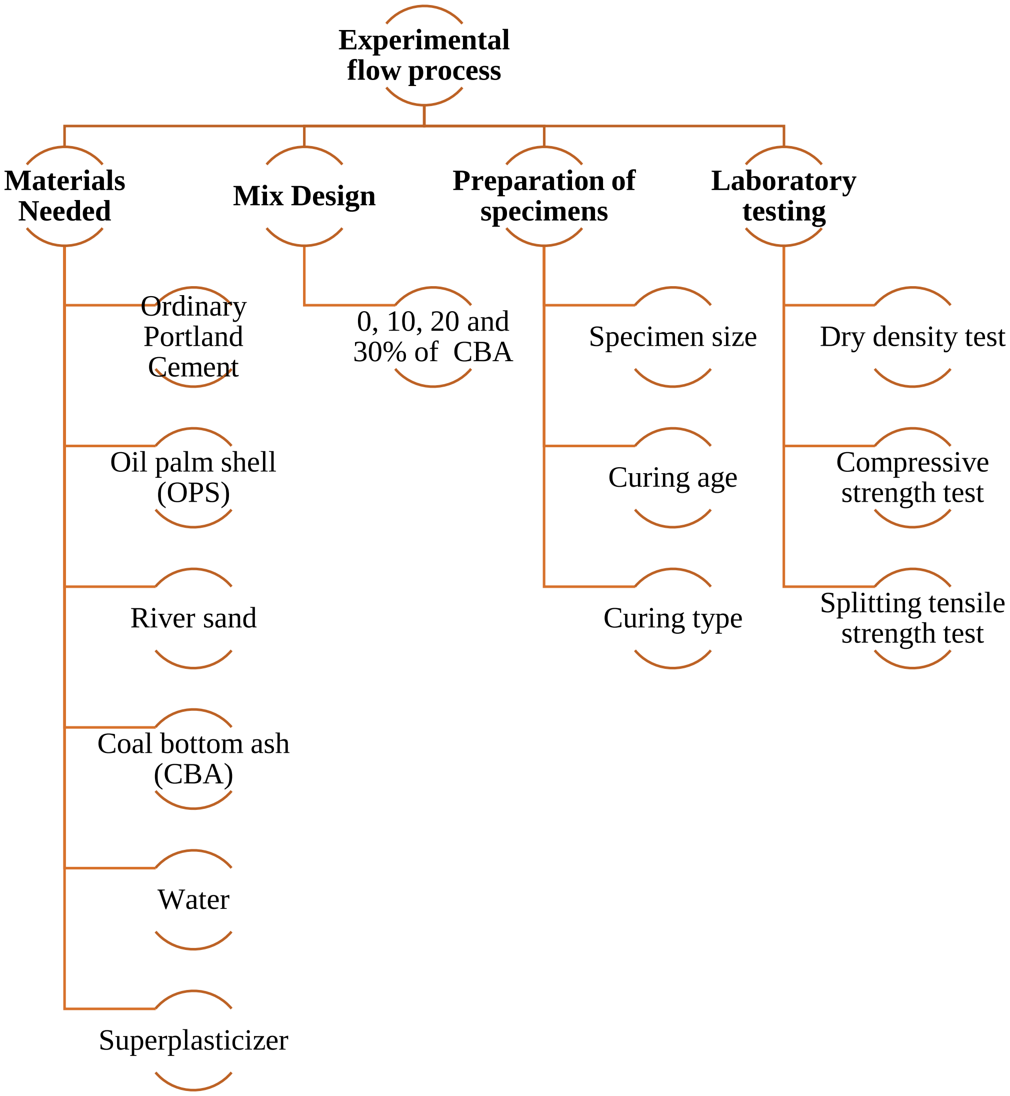

Figure 3.1 Methodology flow for work progress

3.3 Material Used for Concrete Specimen

3.3.1 Cement

In this research, the type of cement used was Ordinary Portland cement (OPC) Type 1. This cement was stored inside of FKASA laboratory to keep it from being exposed to rain and air. The main objective was to prevent it from start hardening and coagulate before being casted. For the remaining cement in opened bag, it being transferred into a sealed plastic bag to avoid from being exposed. In addition, we only took the exact amount of cement that required for each casting. This was to avoid wastage and to control the quality of cement. Next, we only took the cement once we wanted to start the casting process. This would minimize the time taken for cement exposed to the air. Hence, it was to ensure that the quality of concrete were in control. We also used the same type and brand of cement along this research to make sure the quality of cement were remain the same. Figure 3.2 below shows the type of cement used during this research.

Figure 3.2 Ordinary Portland cement

3.3.2 Oil Palm Shell (OPS)

During this research, we had used oil palm shell (OPS) as 100% coarse aggregate replacement. OPS that been used in this research was obtained from the nearest oil palm mill located at Felda Palm Industries Sdn. Bhd., Kilang Sawit Panching, Kuantan, Pahang. For the process of obtaining this OPS, we had contact the officer of oil palm plantation and set a date for taking the OPS. OPS were the by-product of palm industries that usually being abundant at landfill. The OPS were inserted into gunny sacks and weighed before being brought to the lab for the oil palm mill records. Figure 3.3 and 3.4 show the process of obtaining OPS from the oil palm mill.

In using this OPS, the obtained OPS would be cleaned by removing unnecessary materials such as small stone and dust. The OPS then been dried in oven dry for 24 hours. Next, it being soaked in water for another 24 hours. The main purposed of soaking the OPS in water was to minimize the absorption of water by OPS during mixing process. Before being used into mix proportion, the soaked OPS being left on a net for an hour. Figure 3.5 shows OPS was put on net to remove excessive water. The net was placed outside of the lab. The purpose of doing this process was to remove excessive water from it as it would affect the total of water during mixing process and workability of the concrete.

Several studies had been done to the obtained OPS in order to identify its properties. From laboratory tests, we found out that OPS used had specific gravity of 1.29 gm/mL and having water absorption of 36.25%. It showed that this material was lower in density and have higher porosity. Other than that, OPS that used in this research had 0.6 to 4.6 mm of shell thickness with maximum size particle of 10 mm. The bulk density of OPS was 858 kg/m^3. We had done particle size distribution test and found out that the OPS used had 5.696 of fineness modulus. Figure 3.6 and Table 3.1 show the particle size distribution results of OPS.

Figure 3.3 Process of collecting OPS in palm mill

Figure 3.4 Inserting obtained OPS into gunny sack

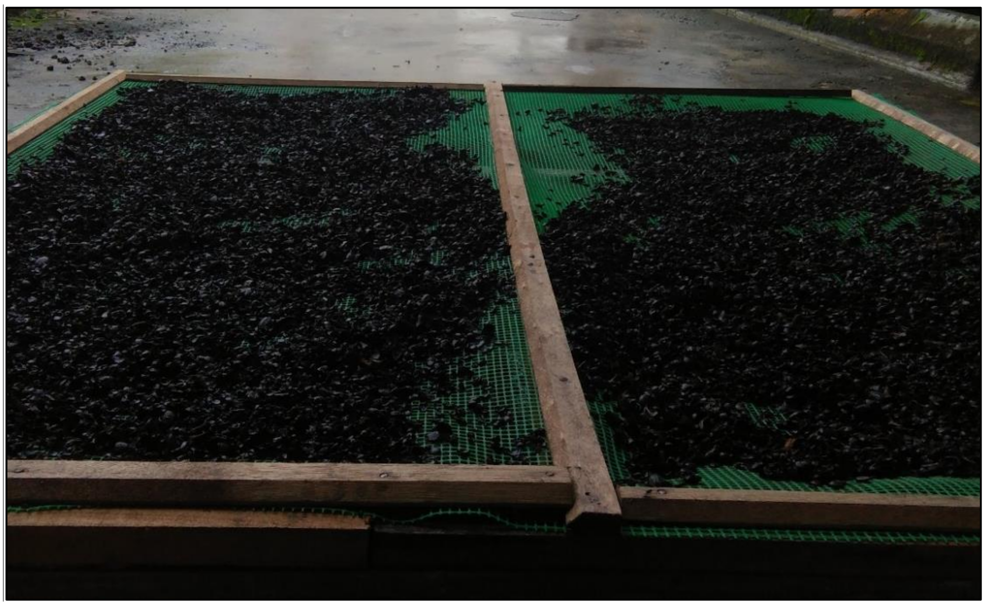

Figure 3.5 OPS was put on net to remove excessive water

Table 3.1 Sieve analysis of OPS

Sieve size	Weight sieve (g)	Weight sieve and sample (g)	Weight sample (g)	% Retained	Cumulative % Passing
5mm	956.7	1324.8	368.1	73.6	26.39
2mm	677.8	800.8	123	24.6	1.79
1.18mm	963	966.6	3.6	0.72	1.07
0.6mm	893.2	894.08	0.88	0.18	0.89
0.15mm	754.9	757.73	2.83	0.57	0.33
Pan	465.8	467.39	1.59	0.33	0
	Total		**500**		

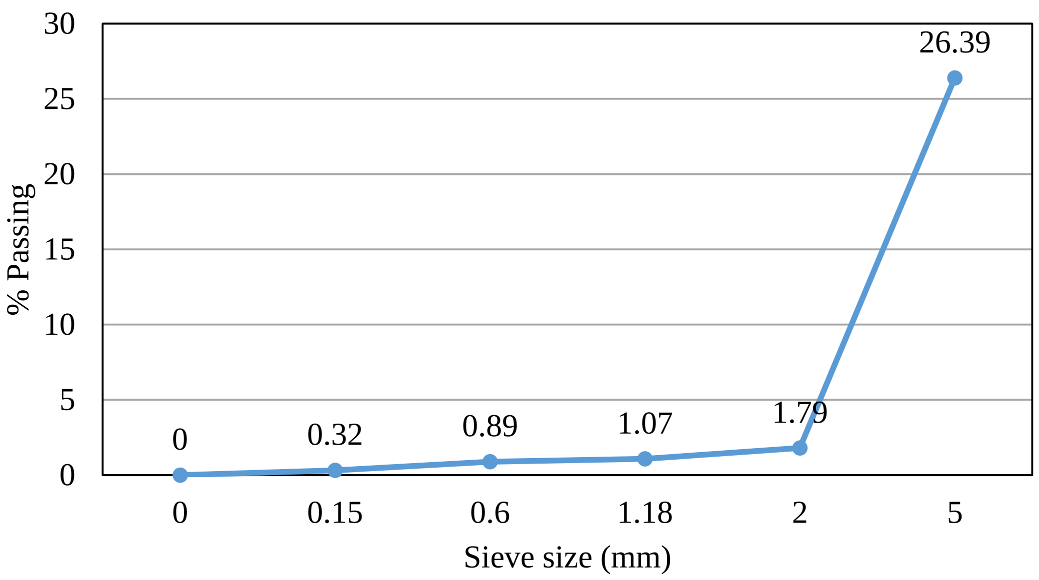

Figure 3.6 Particle size distribution of OPS

3.3.3 Fine Aggregate

River sand have been used in this research as fine aggregate. The main reason of using river sand was it free from excessive chloride that could affect the concrete specimens. Excessive chloride attacked the concrete structure when it reacted with calcium hydroxide in the presence of water. This reduced the performance and strength of concrete. Sand was a natural resources that cannot be renewable. In this research, CBA was proposed to be used as partial sand replacement to minimize the usage of sand in construction industries. The river sand that used in this research was stored at FKASA laboratory. Figure 3.7 below shows the river sand that placed at FKASA laboratory.

In using this river sand, we need to ensure that only sand in dry condition were used. This was to make sure that there was no excessive water presence in our raw materials. It also act as control to ensure that amount of water used were fixed. According to pycnometer test that had been done on sand as shown in Figure 3.8, we found out that the specific gravity of sand was 2.65 gm/mL. The sand used in this research had bulk density of 1458 kg/m^3. Other than that, sieve analysis had been done to observe the particle distribution of the river sand. From the obtained data, we found out that the sand used had fineness modulus of 3.157. The result of sieve analysis had been inserted in Table 3.2 and Figure 3.9.

Figure 3.7 River sand

Figure 3.8 Pycnometer test of sand

Table 3.2 Sieve analysis of river sand

Sieve size	**Weight sieve (g)**	**Weight sieve and sample (g)**	**Weight sample (g)**	**% Retained**	**Cumulative % Passing**
5mm	956.7	972.2	15.5	3.1	96.9
2mm	677.8	773.9	96.1	19.22	77.68
1.18mm	963	1077.7	114.7	22.94	54.74
0.6mm	893.2	1074.3	181.1	36.22	18.52
0.15mm	754.9	845.4	90.5	18.1	0.42
Pan	465.8	467.9	2.1	0.42	0
	Total		**500**		

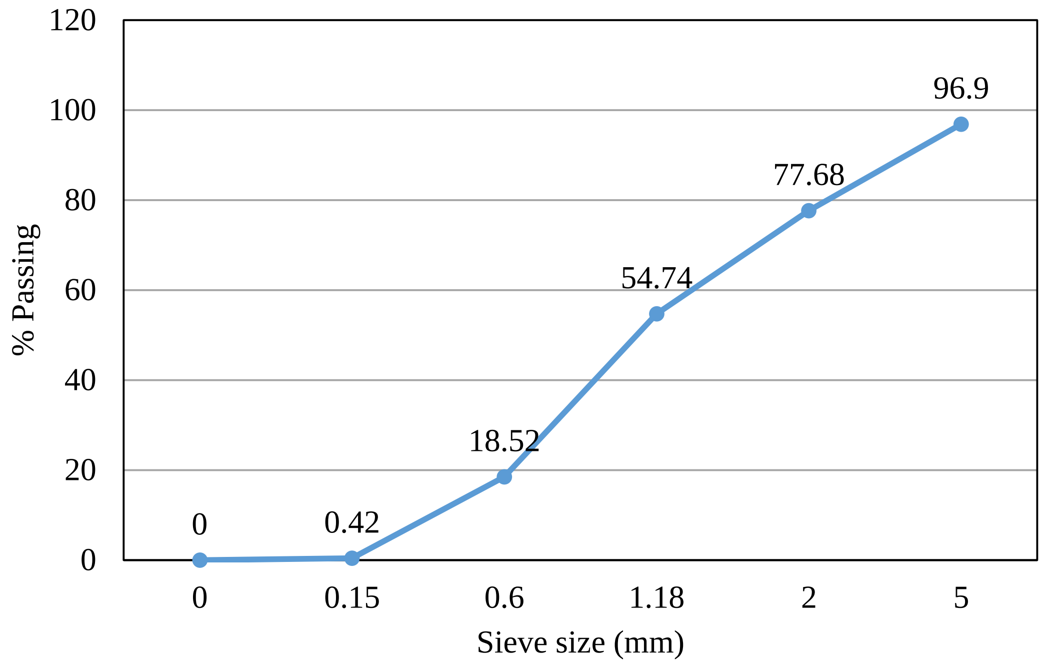

Figure 3.9 Particle size distribution of river sand

3.3.4 Coal Bottom Ash (CBA)

Coal bottom ash (CBA) was a by-product of coal thermal plants. In this research, coal bottom ash was used as partial sand replacement with percentage of 0, 10, 20, and 30% by the weight of sand. During this research, CBA used had been sieved first. Only CBA with passing of 2 mm were used. Figure 3.10 below shows the CBA with 2 mm passing that being used in mix proportion.

CBA that had being sieved were ready to be used. The excessive CBA that had being sieved were stored in a bucket with tight cover to avoid from being exposed to any moisture. The amount of CBA that needed for a casting were directly taken from the bucket, weighted and ready to use. According to pycnometer test, we found out that the CBA used has specific gravity of 2.21 gm/mL. This material had 1020 kg/m^3 in bulk density. Figure 3.11 shows the pycnometer test for CBA. From particle size distribution test, we found that the CBA used had fineness modulus of 2.834. Table 3.3 and Figure 3.12 show the results for particle size distribution of CBA.

Figure 3.10 Coal Bottom Ash (CBA)

Figure 3.11 Pycnometer test of CBA

Table 3.3 Sieve analysis of CBA

Sieve size	Weight sieve (g)	Weight sieve and sample (g)	Weight sample (g)	% Retained	Cumulative % Passing
5mm	956.7	972.2	0	0	100
2mm	677.8	773.9	0	0	100
1.18mm	963	1077.7	157.4	31.48	68.52
0.6mm	893.2	1074.3	168	33.6	34.92
0.15mm	754.9	845.4	138.3	27.66	7.26
Pan	465.8	467.9	36.3	7.26	0
	Total		**500**		

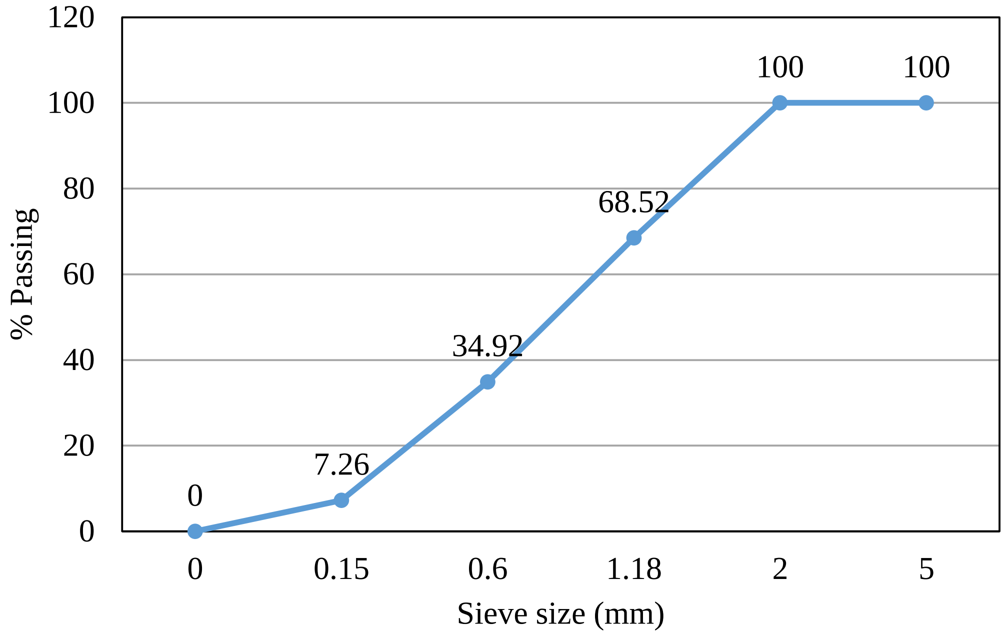

Figure 3.12 Particle size distribution of coal bottom ash

3.3.5 Water

Water was an important material in casting work. The chemical reaction such as hydration process only take place in the presence of water. During this research, tap water had been used in concrete batching. Tap water that obtained from FKASA laboratory was used in mixing process. It was clean, clear and free from any contamination that may affect the hydration process of concrete. A bad quality of water would affect durability of concrete specimens. During mixing process, water was put into a bucket, and being weighed according to water cement ratio of 0.37. Other than that, tap water also been used to clean the concrete mixer from any unpleasant materials such as dirt and dust. In addition, it was to ensure that less concrete were stuck at the mixer. Figure 3.13 shows tap water that used in this research.

Figure 3.13 Tap water

3.4 Mix Proportion

There were four type of specimen mixes involved in this research, plain OPS concrete and OPS concrete with substitution of river sand with designed percent of CBA, 10, 20 and 30% replacement. Plain OPS concrete Grade 20 was used as a control for this research. It was designed by using the mix proportion of cement, OPS, sand, water and superplasticizer. Meanwhile, for study specimens, the amount of river sand was replaced with 10, 20 and 30% of CBA by the weight of sand. The other ingredients used were constant which consist of cement, OPS, water and superplasticizer. The mix proportion of specimens were clearly shown in Table 3.4 below for $1m^3$ of concrete.

In mixing this ingredients, concrete mixer as shown in Figure 3.14 had been used. The concrete mixed for 5 minutes in the concrete mixer to ensure that all of the materials were mixed properly. Figure 3.15 below shows concrete after being mixing in mixer machine. After being mixed, the concrete were inserted in cube and cylindrical mould as shown in Figure 3.16 filling 1/3 of the total volume of the mould. Then, they were put on vibrating table for 2 minutes to remove air voids entrapped in the concrete. The procedure were repeated until the concrete were fully filled into the moulds. The concrete then leaved for 24 hours in the mould before being demoulded. We had place the concrete outside of FKASA laboratory to ensure that it were exposed to the atmosphere. Then, the concrete been demoulded in the next day and placed at racks inside the laboratory for air curing until it reach age of testing.

Table 3.4 Mix proportion of specimen for $1m^3$

Percentage of CBA replacement (%)	Constituents Weight (kg/m^3)					
	Cement	**River sand**	**Oil palm shell**	**Water**	**Super-plasticizer**	**Coal bottom ash**
0	500	700	300	185	5	0
10	500	630	300	185	5	70
20	500	560	300	185	5	140
30	500	490	300	185	5	210

Figure 3.14 Mixer machine used in concrete batching

Figure 3.15 Concrete after being mixing in mixer machine

Figure 3.16 Cube and cylindrical mould used in research

3.5 Preparation of specimen

In studying the mechanical properties of OPS concrete with CBA as sand partial replacement, the total of 72 specimens were produced. 36 of cube specimens with size of 100 x 100 x 100 mm^3 had been prepared for compressive strength test. The samples had been tested according to BS EN 12390-3:2009. Next, another 36 of cylinder specimens prepared for splitting tensile strength test. The size of the cylinder was 100 mm in diameter and 200 mm in height. The samples had been tested according to ASTM C496 (2017), splitting tensile strength test for lightweight concrete. All of the specimens consisted of four types of different percent of CBA which were 0, 10, 20 and 30% by the weight of sand. The specimen were subjected to air curing. The specimens then been tested for 7, 28 and 60 days. Table 3.5 below shows the type of testing with size of specimen used.

Table 3.5 Type of testing and size of specimen

Laboratory test	**Type**	**Size**
Compressive strength	Cube	100 x 100 x 100 mm^3
Splitting tensile strength	Cylinder	Ø 100mm x 200 mm

3.6 Laboratory Test

3.6.1 Dry Density Test

Dry density test was a test that been done when concrete were already hardened. The weight and volume of hardened concrete were measured and recorded. This test was done to compare the dry density of concrete using different percent of CBA with plain concrete. In this research, dry density test was measured according to a research done by Shafigh (2013). In this test, the weight of demoulded concrete that been subjected to air curing for 28 days were measured. High density of concrete showed that it had a denser volume. This situation resulted concrete to have higher strength and durability. By doing this test, we were able to find out the best mixing proportion that showed the highest density of concrete. Figure 3.17 show demoulded concrete before being tested and concrete was weighed in Figure 3.18.

Figure 3.17 Demoulded concrete

Figure 3.18 Weighing concrete specimen

3.6.2 Compressive Strength Test

Compressive strength test was a destructive test that been conducted in order to find out the compression strength of the concrete specimen. In this research, compressive strength test was conducted according to BS EN 12390-3:2009. The specimen were tested on 7, 28 and 60 days. The lightweight aggregate concrete had been subjected to air curing for 7, 28 and 60 days. The size of specimens used for this test was 100 x 100 x 100 mm^3

cube. This test was conducted using a compression machine that available in FKASA laboratory. A cube specimen was inserted into machine and placed at the centre to ensure that the load applied were equally distributed for the whole cube. Next, the right size of the mould with type of testing were selected at control panel of machine and ready to run. The load had applied to the specimen until it broke. For safety precaution, we need to ensure that the door of the machine was close tightly to avoid any concrete debris from splattered. The result of the maximum load had been subjected to the specimen were shown at the control panel were recorded. Equation 3.1 below was used to calculate the compressive strength for specimen. Figure 3.19 shows the specimen on compression machine.

$$\text{Compressive strength} = \frac{P}{A} \tag{3.1}$$

Where; P = Maximum load when concrete fail
A = Cross-sectional area of cube

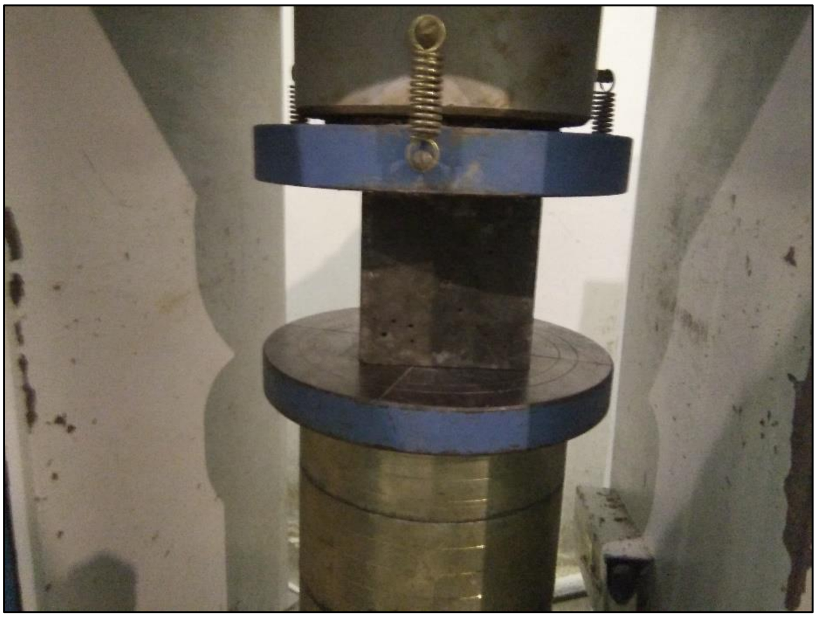

Figure 3.19 Compressive strength test in progress

3.6.3 Splitting Tensile Strength Test

Splitting tensile strength test was a destructive test that being conducted to determine the tensile strength of concrete in indirect way. In this research, splitting tensile strength test were conducted according to ASTM C496 (2017). In this test, the cylinder specimen with diameter of 100 mm and height of 200 mm was placed in Compression Testing Machine horizontally. The specimen was placed at centre of the plate in Compression machine to ensure that the load applied could be subjected equally. The test setting were set at the control panel by choosing the right size of specimen and type of testing for this cylinder. Mode testing of cylinder/tensile was chosen at the control panel. As precaution to avoid concrete debris from splattered over the machine, we had tightly close the machine's door. Next, a run button was pressed and the load were applied diametrically along the length of the cylinder until it fail. Cylinder that had been subjected to load showed a failure along the vertical of the cylinder. Generally, concrete cylinder would be splitted into two parts after load had been applied. From the maximum load that shown on the machine's screen after the test was done, the splitting tensile strength were calculated by using the equation 3.2 below. Figure 3.20 shows the cylinder specimen placed in the machine for splitting tensile strength test.

$$\text{Uniform lateral tensile strength} = \frac{2P}{\pi DL} \tag{3.2}$$

Where; P = Compressive load at failure
L = Length of cylinder
D = Diameter of cylinder

Figure 3.20 Splitting tensile strength test in progress

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presented the obtained results from all of the laboratory testing that had been conducted in order to achieve the objectives of this research. All the data and results from the test were recorded and analysed in form of charts, tables and graphs. Discussion between the relationships of parameters tested were included.

In the beginning of this chapter, the data for dry density test was presented. It included the discussion from the results that had been obtained. Then, discussion about compressive strength test and splitting tensile strength test were included. Charts were presented to portray the data obtained from the tests. Detailed explanation and founds from other researcher were included.

4.2 Dry Density

The results of this test were presented in Figure 4.1 below. At 0% CBA replacement, the dry density of concrete was 1767 kg/m^3 followed by 1693 kg/m^3 and 1654 kg/m^3 at 10% and 20% of CBA replacement. At 30% replacement showed the lowest dry density at 1635 kg/m^3. According to obtained result, the dry density of hardened concrete were decreased as the percent of CBA replacement were increased. Similar trend has observed by Kim and Lee (2011) who added CBA in high strength concrete. As the concrete had undergo air curing at the laboratory, the moisture within the concrete start to evaporated to surrounding. From pycnometer test, the specific gravity of sand is 2.65 gm/mL while CBA is 2.21 gm/mL. This showed that sand particles have higher density compared to CBA. It also indicated that CBA had more porous materials compared to sand material. Higher CBA replacement will lowered the overall weight of the concrete. Conclusively, according to Neville (2011), all of the specimens with 10, 20 and 30% of CBA replacement can be categorized as lightweight aggregate concrete because having density in the range of 300 to 1850 kg/m^3. Figure 4.1 shows the dry density results.

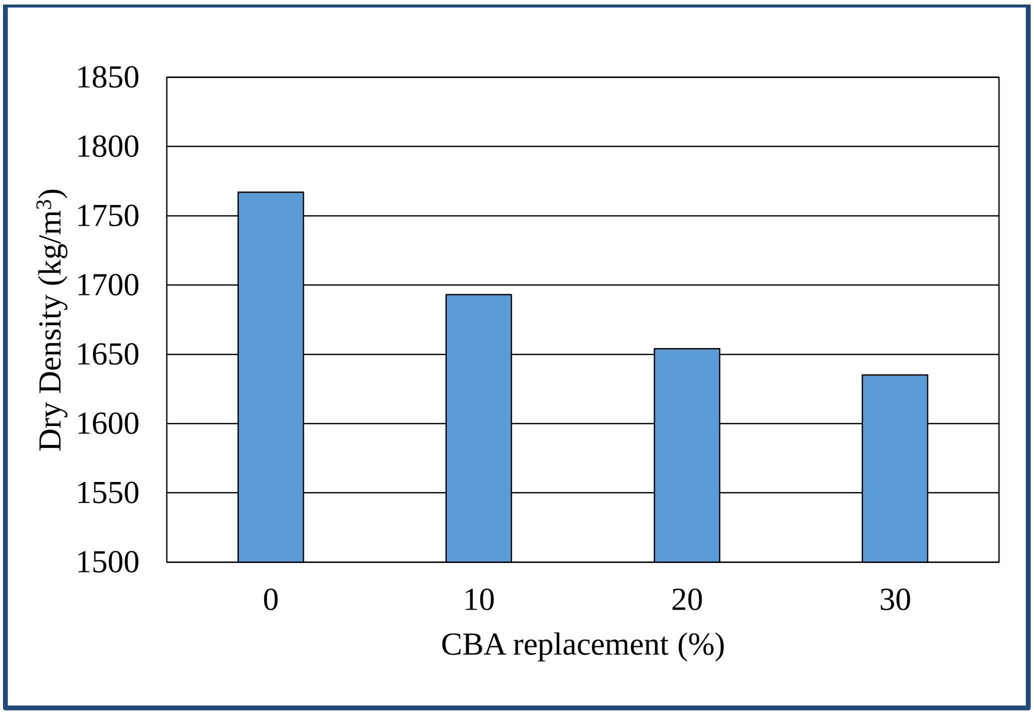

Figure 4.1 Dry density

4.3 Compressive Strength

Figure 4.2, 4.3, 4.4 and 4.5 below show the effect of compressive strength at different percent of CBA replacement on 7, 28 and 60 days age of curing respectively. From the figures below, it can be seen that different percent of CBA replacement affect the compressive strength of lightweight aggregate concrete. The compressive strength of concrete start to increase from 0% to 10% of CBA replacement and then dropped until 30% of CBA replacement. This trend were the same for all the age of curing. In Figure 4.5, it shows that the compressive strength gained as the age of curing were increased. At the curing age of 7 days, concrete mixtures containing 10%, 20% and 30% CBA as partial sand replacement gained 19.67 MPa, 18.83 MPa and 17.32 MPa respectively compared to 18.32 MPa for control specimen. After 28 days of curing, the concrete strength had increased to 20.2 MPa, 24.6 MPa, 21.1 MPa and 17.54 MPa for 0%, 10%, 20% and 30% respectively. Meanwhile, at the curing age of 60 days, the concrete gained 24.1 MPa, 25.84 MPa, 21.91 MPa and 20.77 MPa for 0%, 10%, 20% and 30% respectively.

From the obtained results, it recorded that the compressive strength were highest at 10% CBA replacement for 60 days of curing age. According to Siddique et al. (2013), they reported that the usage of 10% CBA replacement increased the concrete strength. This was because the concrete at that replacement level were denser compared to other percent of CBA replacement. CBA particles were smaller in size compared to sand particles. The optimum amount of CBA and sand filled the voids in concrete make them denser and stronger. Other than that, concrete at 10% CBA replacement had less voids and porosity compared to others. A denser concrete with low amount of voids would make them stronger. The small particles of CBA increase the inter particle friction (Siddique, 2013). It resulted concrete to have higher strength compared to other mixtures.

At 20% and 30% of CBA replacement the concrete recorded lower compression strength compared to 10% CBA replacement although been replaced by higher amount of CBA. This happen due to much replacement of sand with CBA. According to pycnometer test of CBA and sand, it recorded that sand had higher specific gravity with 2.65 gm/mL than CBA with 2.21 gm/mL. It showed that sand had higher density compared to CBA. Higher replacement of stronger materials with weaker materials would affect the overall strength of concrete. Other than that, from the pycnometer result showed that CBA particles were more porous compared to sand particles. According to

Siddique (2013), CBA absorbed more water during mixing process and leaves more pores in concrete. This finally resulted concrete to have more voids and high in porosity. It lowered the concrete strength.

Meanwhile, at 0% of CBA replacement, the compressive strength of concrete were a bit lower compared to 10% mixes. It happened due to absence of CBA particles to fill between the concrete particles. In this mixture, only sand particles were used. It resulted concrete to have more voids compared to concrete with presence of CBA. The absence of CBA particles affect the concrete strength. Figure 4.6 shows the failure pattern of cube specimen for different CBA replacement after compressive strength test was conducted.

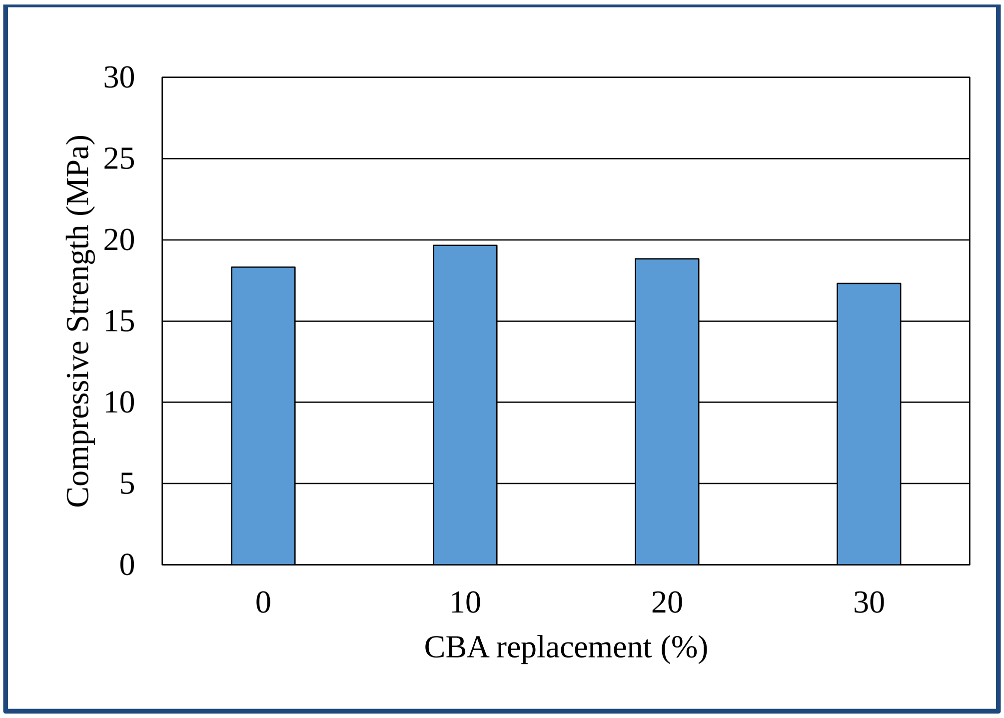

Figure 4.2 Compressive strength of cube specimen on 7 days

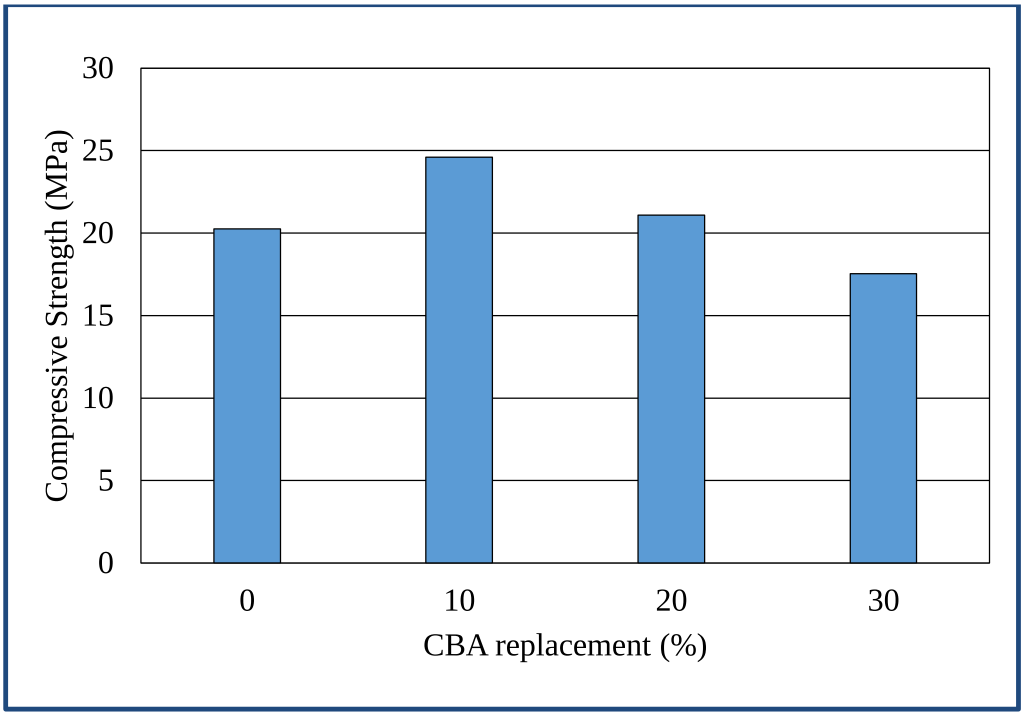

Figure 4.3 Compressive strength of cube specimen on 28 days

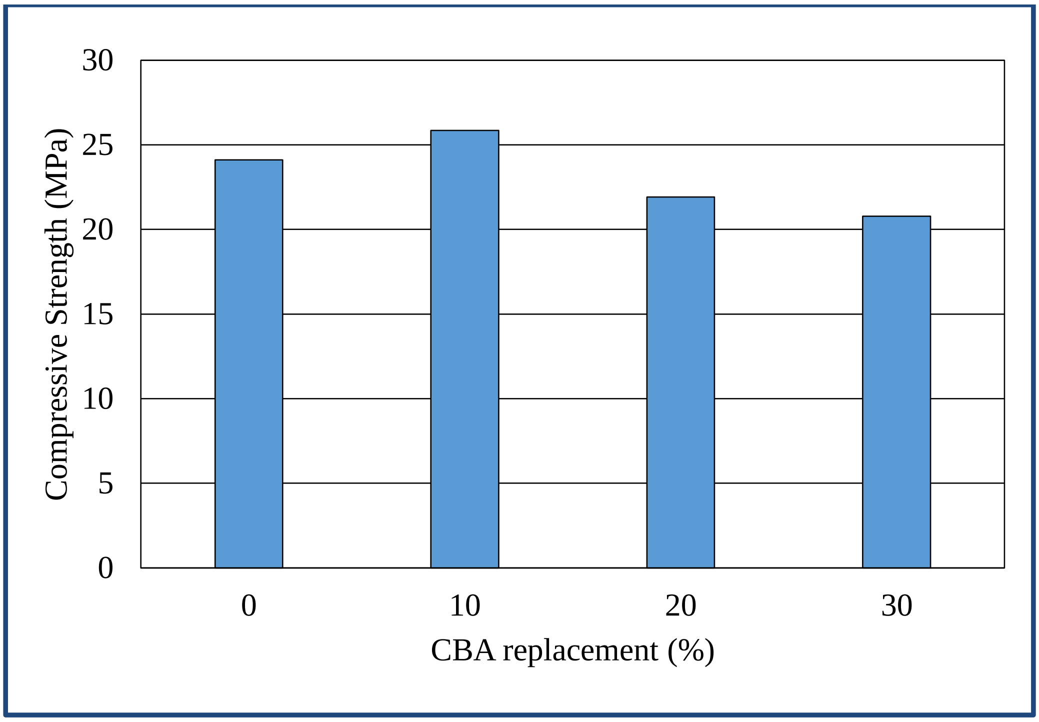

Figure 4.4 Compressive strength of cube specimen on 60 days

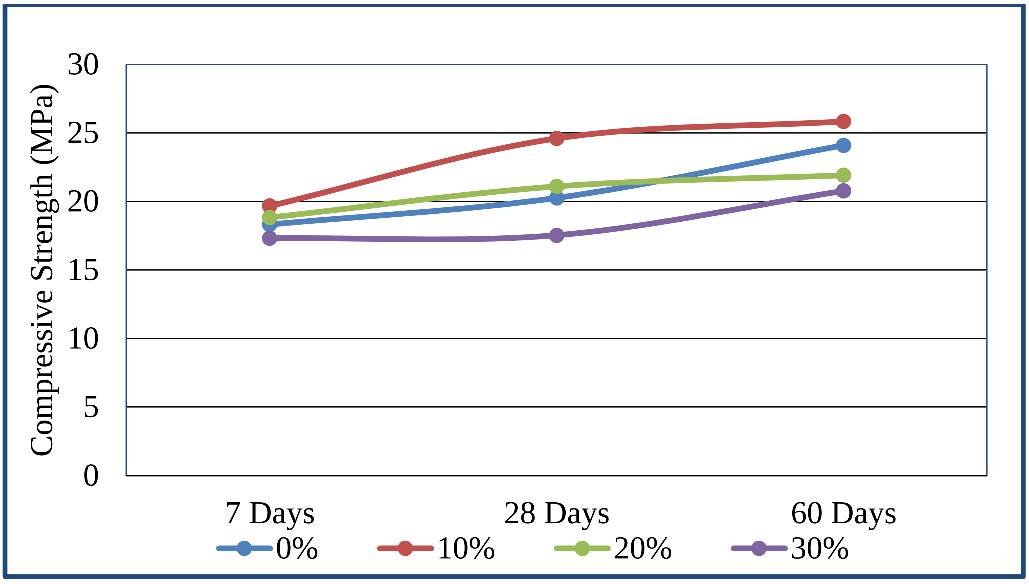

Figure 4.5 Compressive strength of cube specimens

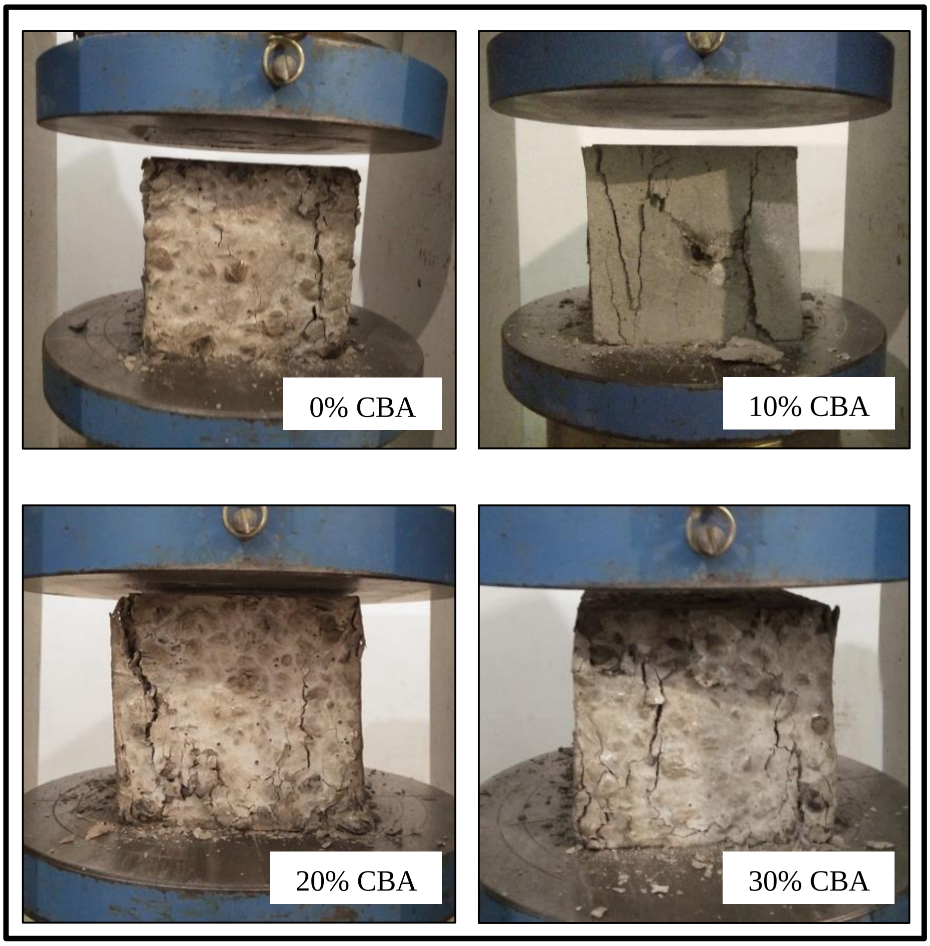

Figure 4.6 Concrete failure pattern

4.4 Splitting Tensile Strength

Figure 4.7, 4.8, 4.9 and 4.10 show the splitting tensile strength of 0, 10, 20 and 30% of CBA replacement concrete at 7, 28 and 60 days. From the figure, it show that at 0% to 10% of CBA replacement, the splitting tensile strength of concrete increased and then dropped until 30% of CBA replacement. For all of the days tested, it shown that the splitting tensile strength were highest at 10% of CBA replacement. At the curing age of 7 days, concrete mixtures containing 10%, 20% and 30% CBA as partial sand replacement gained 1.60 MPa, 1.24 MPa and 1.15 MPa respectively compared to 1.29 MPa for 0% of CBA replacement. After 28 days of curing, the splitting strength had increased to 1.59 MPa, 1.70 MPa, 1.34 MPa and 1.21 MPa for 0%, 10%, 20% and 30% respectively. Meanwhile, at the curing age of 60 days, the concrete gained 1.79 MPa, 2.08 MPa, 1.75 MPa and 1.34 MPa for 0%, 10%, 20% and 30% respectively. It was recorded that the splitting tensile strength for all percent of CBA replacement were highest at 10% CBA replacement for age of 60 days.

From the recorded results, it showed that concrete strength were highest at 10% CBA replacement. It was because the concrete were denser compared to other percent CBA replacement. Concrete had undergo hydration process in the presence of water to produce Calcium Silicate Hydrate (CSH) gel and Calcium Hydroxide ($Ca(OH)_2$). According to Siddique (2014), the concrete had higher compressive strength because presence of pozzolanic reaction. CBA particles contained pozzolan materials and reacted with $Ca(OH)_2$ from hydration process to produce secondary CSH gel. CSH gel were responsible towards the strength of concrete. Higher amount of CSH gel in concrete make it stronger than the control mixtures and other CBA replacement level.

At 20% and 30% of CBA replacement, it showed lower tension strength. Concrete mixtures at 20% and 30% CBA replacement level were denser compared to 10% replacement. The lower strength happened due to much replacement of stronger material which was sand with weaker material, CBA. It affect the overall strength of concrete make them lower in tension strength. Meanwhile, at 0% of CBA replacement it showed lower tension strength compared 0% CBA replacement. It happened due to absence of pozzolanic reaction. In this mixture, it only undergo hydration process where it produced primary CSH gel. Low amount of CSH gel affect the overall concrete strength. Figure

4.11 shows the failure of cylinder specimen for different CBA replacement after splitting tensile strength test was conducted.

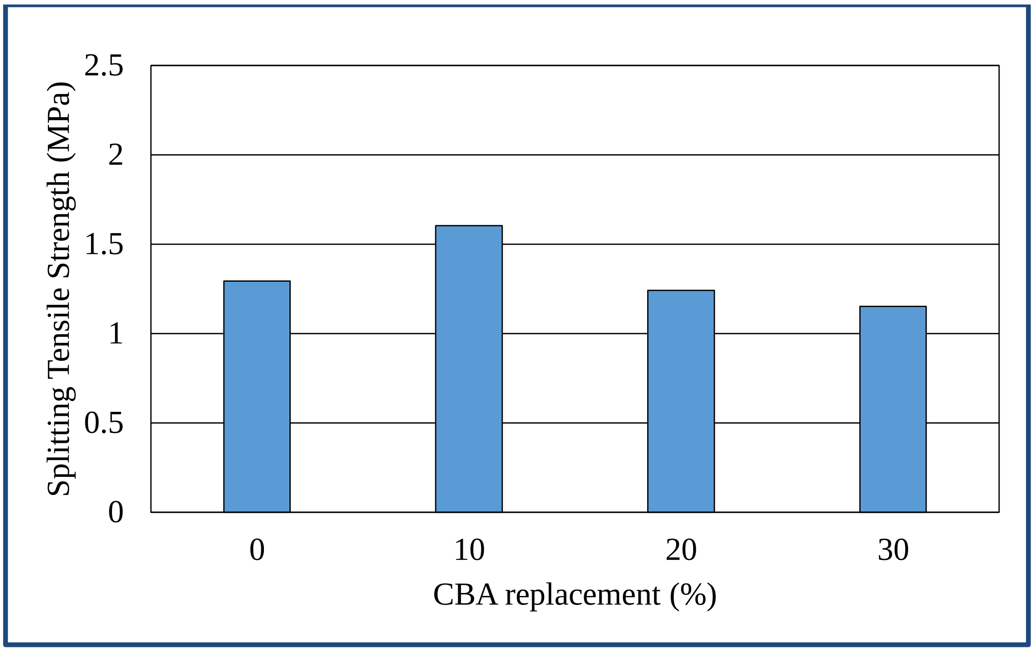

Figure 4.7 Splitting tensile strength of cylinder specimen on 7 days

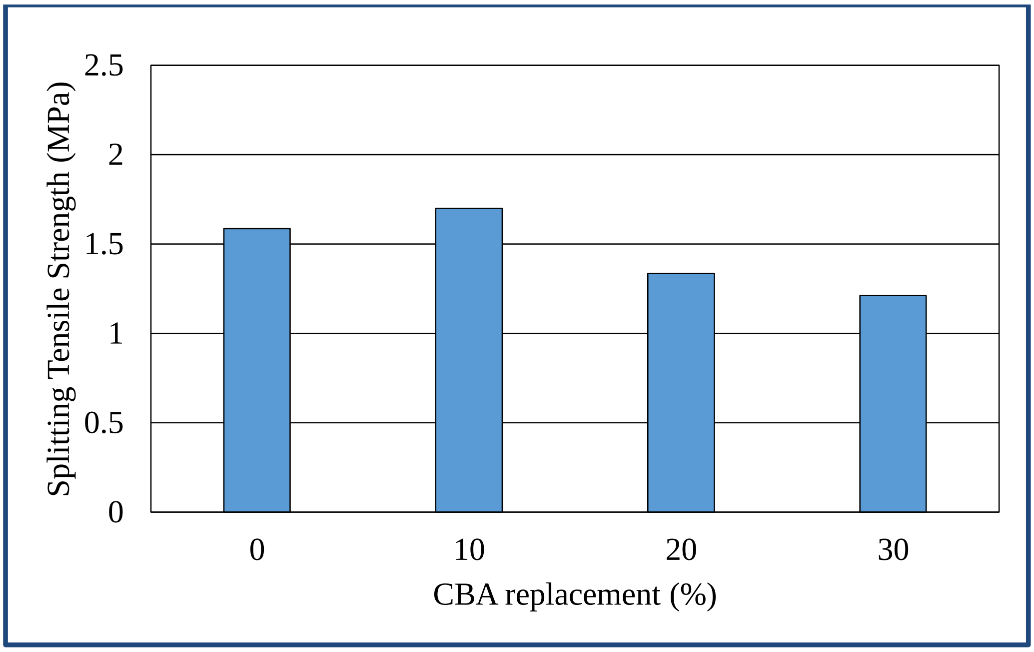

Figure 4.8 Splitting tensile strength of cylinder specimen on 28 days

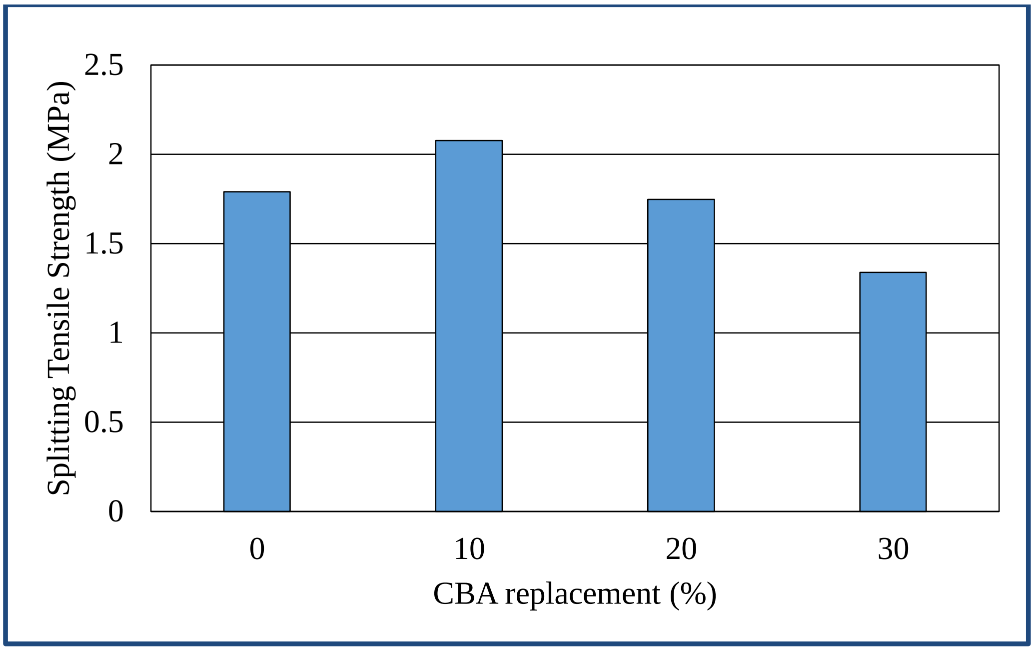

Figure 4.9 Splitting tensile strength of cylinder specimen on 60 days

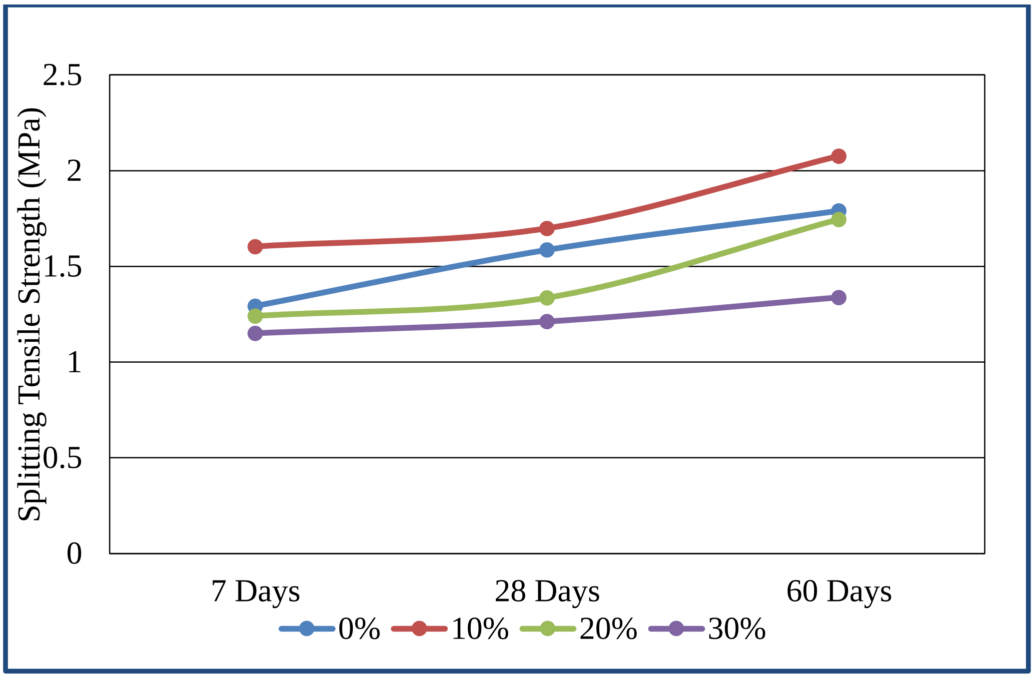

Figure 4.10 Splitting tensile strength of cylinder specimens

Figure 4.11 Concrete failure pattern

CHAPTER 5

CONCLUSION

5.1 Introduction

Based on the experimental results and analysis provided in previous chapter, conclusion are drawn in accordance to the objectives for this research. Conclusion is made to identify the objectives of research are able to be achieved. In this chapter, the outcome from each research objective will be discussed. In addition, related recommendations also inserted in this chapter to improve the results obtained. Other than that, recommendation for further research also included.

5.2 Conclusion

5.2.1 The effect of CBA as a partial sand replacement on dry density and compressive strength of OPS lightweight aggregate concrete

The dry densities of hardened OPS lightweight aggregate concrete linearly decreased as the replacement ratio of CBA increased. Control concrete mix shows highest dry density with 1767 kg/m^3. The lowest dry density is 1635 kg/m^3 at 30% CBA replacement. However, all the specimens' dry density are considered as lightweight aggregate concrete.

10% of CBA replacement recorded the highest compressive strength of concrete. At 28 days of curing age, the concrete has compressive strength of 24.6 MPa. Beyond that percentage of replacement reduce the concrete strength. As all the concrete passing the minimum strength of lightweight aggregate concrete which is 15 MPa, it can be conclude that, the concrete are suitable to be used for structural purpose.

5.2.2 The effect of CBA as a partial sand replacement on splitting tensile strength of OPS lightweight aggregate concrete

From the obtained result, the splitting tensile strength of OPS lightweight aggregate concrete has the same trend as compressive strength result. The result is highest at 10% of CBA replacement with 2.08 MPa of max load applied is recorded. At 20% and 30% of CBA replacement, the concrete tend to have lower strength. This situation same goes to 0% of CBA replacement. From the obtained result, it can be conclude that only optimum replacement of CBA will result concrete to have higher tensile strength.

5.3 Recommendation

The suggestions below can be considered for further study:

i. Investigate the structural performance of OPS lightweight aggregate concrete beam containing CBA as partial sand replacement.

ii. Investigate the effect of using CBA from different coal thermal plants towards mechanical properties.

iii. Investigate the effect of CBA fineness on OPS concrete strength.

REFERENCES

Abdullah N., Sulaiman F., 2011. Optimum Conditions for Maximising Pyrolysis Liquids of Oil Palm Empty Fruit Bunches. *Energy,* Volume 36, pp. 2352-2359.

Agamuthu P., Khidzir K. M., Fauziah S. H. , 2009. Drivers of Sustainable Waste Management in Asia. *Waste Management & Research,* 27(7), pp. 625-633.

Agrawal U. S., Wanjari S. P., Naresh D. N., 2019. Impact of replacement of natural river sand with geopolymer fly ash sand on hardened properties of concrete. *Construction and Building Materials,* Volume 209, pp. 499-507.

Anon., 2018. *Expanded Shale, Clay and Slate Institute.* [Online]
Available at: https://www.escsi.org/
[Accessed April 2019].

Anon., 2019. *Malaysia Palm Oil Board.* [Online]
Available at: http://www.mpob.gov.my/
[Accessed May 2019].

Anon., n.d. *ASTM C496 (2017).* s.l.:Test for lightweight concrete, splitting tensile strength test.

Anon., n.d. *BS EN 12390-3:2009.* s.l.:Test for hardened concrete, Compressive strength test.

Ashraf M. A., Maah M. J., Yusoff I., Wajid A., Mahmood K., 2011. Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. *Scientific Research & Essays,* 6(6), pp. 1216-1231.

Ayati B., Ferrándiz V., Newport D., Cheeseman C., 2018. Use of clay in the manufacture of lightweight aggregate. *Construction and Building Materials,* Volume 162, pp. 124-131.

Aydin E. , 2016. Novel Coal Bottom Ash Waste Composites for Sustainable Construction. *Construction and Building Materials,* Volume 124, pp. 582-588.

Cenni R., Janisch B., Spliethо H., Hein K.R.G., 2001. Legislative and Environmental Issues on the Use of Ash from Coal and Municipal Sewage Sludge. *Waste Management,* Volume 21, pp. 17-31.

Chenot J., Jaunatre R., Buisson E., Bureau F., Dutoit T., 2018. Impact of Quarry Exploitation and Disuse on Pedogenesis. *Catena,* Volume 160, pp. 354-356.

Clarke J.L, 2005. Structural Lightweight Aggregate Concrete, Blackie Academic & Professional. *Wester Cleddens Road, Bishopbriggs, Glasgow G64 2NZ, UK.*

Fauziah S. H., Agamuthu P. , 2011. Challenges and Issues in Moving Towards Sustainable Landfilling in a Transitory Country- Malaysia. *Waste Management & Research,* 29(1), pp. 13-19.

Gungat L., Putri E. E., Makinda J., 2013. Effects of Oil Palm Shell and Curing Time to the Load-Bearing Capacity of Clay Subgrade. *Procedia Engineering,* Volume 54, pp. 690-697.

Khankhaje E., Salim M. R., Mirza J., Hussin M. W., Rafieizonooz M., 2016. Properties of Sustainable Lightweight Pervious Concrete Containing Oil Palm Kernel Shell as Coarse Aggregate. *Construction and Building Materials,* Volume 126, pp. 1054-1065.

Kim H. K., Jeon J. H., Lee H. K., 2012. Flow, water absorption, and mechanical characteristics of normal and high-strength mortar incorporating fine bottom ash aggregates. *Construction and Building Materials,* Volume 26, pp. 249-256.

Kim H. K., Lee H. K. , 2015. Coal Bottom Ash in Field of Civil Engineering: A Review of Advanced Applications and Environmental Considerations. *KSCE Journal of Civil Engineering,* 19(6), pp. 1802-1818.

Kim H. K., Lee H. K., 2011. Use of power plant bottom ash as fine and coarse aggregates in high-strength concrete. *Construction and Building Materials,* Volume 25, pp. 1115-1122.

Liberman R. N., Knop Y., Moreno N., Cohen N., 2018. Environmental impact and potential use of coal fly ash and sub-economical quarry fine aggregates in concrete. *Journal of Hazardous Materials,* Volume 344, pp. 1043-1056.

Lomite H., Kare S., 2009. Impact of Construction Materials on Environment. *Quality & Environment management,* Volume 1, pp. 1-66.

McLellan B. C., Corder G. D., Giurco D., Green S., 2009. Incorporating Sustainable Development in the Design of Mineral Processing Operations – Review and Analysis of Current Approaches. *Journal of Cleaner Production,* Volume 17, pp. 1414-1425.

Nabinejad O., Sujan D., Rahman M. E., Davies I. J., 2015. Effect of Oil Palm Shell Powder on the Mechanical Performance. *Materials & Design,* Volume 65, pp. 823-860.

Nadesan M. S., Dinakar P., 2018. Influence of type of binder on high-performance sintered fly ash lightweight aggregate concrete. *Construction and Building Materials,* Volume 176, pp. 665-675.

Naganathan S., Sadon S. N., Beddu S., Kamal N. L. M., Hassan H., 2017. Coal Bottom Ash as Sustainable Material in Concrete – A Review. *Indian Journal of Science and Technology,* 10(36).

Navdeep S., Mithulraj M., Arya S. , 2018. Influence of Coal Bottom Ash as Fine Aggregates Replacement on Various Properties of Concretes: A Review. *Resources, Conservation & Recycling,* Volume 138, pp. 257-271.

Neville A. M., 2003. *Properties of Concreete.* 4th ed. England: Pearson Education Limited.

Neville A. M., 2011. *Properties of Concrete.* 6th ed. England: Pearson Education Limited.

Nikbin, M. Iman, R. R. Saman, A. Hamed, M. Damadi, 2016. A Comprehensive Analytical Study on the Mechanical Properties of Concrete Containing Waste Bottom Ash as Natural Aggregate Replacement. *Construction & Building Materials,* Volume 121, pp. 746-759.

Pasetto M. Baldo N., 2014. Fatigue Performance and Stiffness Properties of Stone Mastic Asphalts with Steel Slag and Coal Ash. *Asphalt Pavements,* pp. 881-889.

Ramme B.W., Tharaniyil M.P., 2013. *We Energies Coal Combustion Products Utilization Handbook.* 3rd ed. USA: We Energies.

Shafigh P., Alengaram U. J., Mahmud H., Jumaat M. Z., 2013. Engineering properties of oil palm shell lightweight concrete containing fly ash. *Materials and Design,* Volume 49, pp. 613-621.

Shafigh P., Chai L. J., Mahmud H., Nomeli M. A., 2018. A Comparison Study of the Fresh and Hardened Properties of Normal Weight and Lightweight Aggregate Concretes. *Journal of Building Engineering,* Volume 15, pp. 252-260.

Siddique R., Singh M. , 2013. Effect of Coal Bottom Ash as Partial Replacement of Sand on Properties of Concrete. *Resources, Conservation and Recycling,* Volume 72, pp. 20-32.

Siddique R., Singh M., 2014. Strength properties and micro-structural properties of concrete containing coal bottom ash as partial replacement of fine aggregate. *Construction and Building Materials,* Volume 50, pp. 246-256.

Siddique R., Singh M., 2015. Properties of Concrete Containing High Volumes of Coal Bottom Ash as Fine Aggregate. *Journal of Cleaner Production,* Volume 91, pp. 269-278.

Siddique R., 2013. Compressive strength, water absorption, sorptivity, abrasion resistance and permeability of self-compacting concrete containing coal bottom ash. *Construction and Building Materials,* Volume 47, pp. 1444-1450.

Torres A., Brandt J., Lear K., Liu J., 2017. A Looming Tragedy of the Sand Commons. *Science,* 357(6355), pp. 970-971.

Traore Y. B., Messan A., Hannawi K., Gerar J., Prince W., Tsobnang F., 2018. Effect of oil palm shell treatment on the physical and mechanical properties of lightweight concrete. *Construction and Building Materials,* Volume 161, pp. 462-450.

Wu T., Yang X., Wei H., Lin X. , 2019. Mechanical Properties and Microstructure of Lightweight Aggregate. *Construction & Building Materials,* Volume 199, pp. 526-539.

Xing Y., Guo F., Xu M., Li H. , 2019. Separation of unburned carbon from coal fly ash: A review. *Powder Technology,* Volume 353, pp. 372-384.

Zhang M. H., Gjorv O. E., 1990. Development of high-strength lightweight concrete. *ACI Spec. Publication*, 121(82), p. 667.