# PERFORMANCE OF ULTRA HIGH PERFORMANCE CONCRETE BY USING PALM OIL CLINKER AS PARTIALLY AGGREGATE REPLACEMENT

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# ABSTRAK

Industri pembinaan semakin berkembang dari hari ke hari. Keperluan konkrit dalam bidang ini semakin meningkat dan perkembangannya dalam industri konkrit telah bertambah baik apabila terdapat beberapa jenis konkrit baharu iaitu konkrit berprestasi tinggi dan konkrit berpretasi ultra tinggi. Konkrit berprestasi ultra tinggi (UHPC) adalah salah satu jenis konkrit yang mempunyai ciri-ciri mekanikal yang cemerlang dan mempunyai katahanan yang baik dibandingkan dengan konkrit biasa. Walau bagaimanapun, konkrit jenis ini mempunyai beberapa batasan dari segi kos pengeluaran dan ketersediaan bahan mentah. Penghasilan UHPC memerlukan sejumlah besar simen, pasir dan batu. Pengunaan klinker minyak kelapa sawit sebagai separa pengganti aggregat dapat mengurangkan masalah yang timbul akibat penghasilan UHPC. Penggunaan klinker minyak kelapa sawit dalam kajian ini telah dirangsang daripada masalah alam sekitar yang timbul akibat pembuangan sisa indutri minyak kelapa sawit dan penghasilan aggregat semula jadi. Dalam kajian ini, ciri-ciri mekanikal bagi UHPC menggunakan klinker minyak kelapa sawit (POC) sebagai pengganti aggregat sebahagiannya telah disiasat. Empat (4) tahap peratusan berbeza POC sebagai pengganti aggregat kasar telah disediakan. 0%, 5%, 10% dan 15% POC daripada jumlah aggregat kasar digunakan. Specimen yang dilebelkan sebagai UHPC biasa mempunyai sebanyak 0% penggantian POC, manakala untuk konkrit yang mengandungi 5%, 10% dan 15% penggantian POC dilabelkan sebagai POC-UHPC5, POC-UHPC10, dan POC-UHPC15. Ujian kemusnahan dilakukan pada konkrit baru manakala ujian kekuatan mampatan dan ujian kekuatan lenturan dilakukan kepada konkrit yang keras. Ujian kemusnahan dilakukan sejurus selepas konkrit dibancuh dan ujian mampatan dan kekuatan lenturan diuji selepas 7, 28 dan 60 hari direndam didalam tangki air. Keputusan eksperimen menunjukkan pengurangan kekuatan mampatan dan kekuatan lenturan terhadap kesemua UHPC specimen yang mengandungi POC sebagai penggantian aggregat. Ia mendedahkan bahawa peningkatan peratusan POC menjurus kepada penurunan kekuatan mampatan dan kekuatan lenturan terhadap specimen. Secara keseluruhan, pengunaan 10% POC sebagai pengganti aggregate menunjukkan hasil yang sama dari segi kekuatan mampatan dan kekuatan lenturan konkrit.

## ABSTRACT

Construction industry has been growth from day to day. The requirement of concrete in this field has been increasing and the development in concrete industry has been improve when there is a new type of concrete which is high performance concrete and ultra-high performance concrete. Ultra-high performance concrete (UHPC) is a one of concrete type that has outstanding mechanical properties and a good durability as compared to normal concrete. However, this type of concrete has some limitation in terms of production cost and availability of raw materials. The production of UHPC, require the large amount of cement, sand and coarse aggregate. The use of palm oil clinker as partial aggregate replacement can reduce the problem arising due to the production of UHPC. The use of palm oil clinker in this study was stimulated from the environmental problem issue arising due to the disposal of palm oil industry waste and the production of natural aggregate. In this present study, the mechanical properties of UHPC incorporating with palm oil clinker (POC) as partially replacement of aggregate was investigate. Four (4) different percentage level of POC as partial replacement of coarse aggregate was prepared. 0%, 5%, 10%, and 15% of POC from the total of coarse aggregate were used. The specimens was label as plain UHPC with 0% of POC replacement, while for the concrete contain 5%, 10% and 15% POC replacement were label as POC-UHPC5, POC-UHPC10 and POC-UHPC15. Slump test was conduct on fresh concrete while compressive strength test and flexural strength test for hardened concrete. Slump test was conduct immediately after the mix and compressive strength test and flexural strength was tested after 7, 28 and 60 days of curing in water tank. The experimental result shows the reduction of compressive strength and flexural strength of UHPC contains POC as aggregate replacement specimens. It was revealed the increasing percentage of POC lead to decreasing the compressive strength and flexural strength of the specimens. Overall, the use of 10% POC as partial aggregate replacement show similar result on both compressive strength and flexural strength of the concrete.

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| | |
|---|---|
| MPa | Megapascal |
| mm | Millimetre |
| μm | Micrometre |
| kN | Kilo newton |
| $N/mm^2$ | Newton per millimetre square |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| $Al_2O_3$ | Aluminium Oxide |
| ASTM | America Standard For Testing And Material |
| BS | British Standard |
| $C_3A$ | Tricalcium Aluminate |
| CaO | Calcium Oxide |
| HPC | High Performance Concrete |
| MgO | Magnesium Oxide |
| OPC | Ordinary Portland Cement |
| OPS | Oil Palm Shell |
| HPC | High Performance Concrete |
| HRWR | High-Range Water Reducer |
| POC | Palm Oil Clinker |
| Plain-UHPC | Plain Ultra-High Performance Concrete |
| POC-UHPC5 | Ultra High Performance Concrete With 5% Palm Oil Clinker As Parti Replacement Of Coarse Aggregate. |
| POC-UHPC10 | Ultra High Performance Concrete With 10% Palm Oil Clinker As Par Replacement Of Coarse Aggregate. |
| POC-UHPC15 | Ultra High Performance Concrete With 15% Palm Oil Clinker As Partial Replacement Of Coarse Aggregate. |
| $SO_3$ | Sulfur Trioxide |
| UHPC | Ultra High Performance Concrete |
| w/c | Water to Cement Ratio |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

In the world, the production of concrete has increasing every year. It was estimated that the world consumes twenty-five billion tonnes of concrete every year (Kumar et al., 2017) . Concrete were used in construction field for various purpose such as for structural, highway and other. Concrete also known as the second most consumed material after water (Kumar et al., 2017).

The development in mineral admixture and chemical admixture have lead to the introduction of several type of high quality concrete (Alsalman et al., 2017). The high quality concrete is high strength concrete and high performance concrete. (Alsalman et al., 2017) also stated that, the further advancement in concrete technology has found a new type of concrete which is ultra-high performance concrete. Ultra-high performance concrete is a concrete that has compressive strength up to 100 MPa and high tensile strength. It is relatively new building material that has superior mechanical strength, ductility, impact resistance, fatigue resistance and durability (Li et al., 2018). In general, UHPC content of cementitious component such as Ordinary Portland cement, quartz powder, quartz sand, super plasticizer and fibers (Shi et al., 2015).

Other than the properties of ultra-high performance concrete, it has some limitations in terms of cost and accessibility of raw materials. The development of more durable and sustainable concrete in order to decrease life cycle cost of structures is in important trend in modern civil engineering (Janković et al., 2016). The production of UHPC require high amount of money which it is designed with a high content of powder as stated by (P. P. Li et al., 2018). Thus it becomes the greatest challenges to construction world due to the depletion of raw materials especially natural resource.

(Ambily et al., 2015) stated that depletion of natural resources at the same time new by products are being generated by various industries which could have a promising future in construction industry as partial or full substitute of either cement or aggregate. Natural aggregate also not only costly, but the production of it can cause environmental problem such as pollution and health problem to the human. Since it is a part of material used in the production of UHPC, it gives the idea to the researcher to find the alternative to replace fully or partially natural aggregate.

Malaysia had produced a various type of waste from a different industry such as bottle, glass, roof tiles, seramic, palm oil clinker and other. This type of waste has contributed to the environmental problem and been issued all around the world. Palm oil waste is one of the significant wastes that should be more concerned. Since Malaysia is the second largest palm oil producing country in the world, it expected that the waste produce from palm oil industry will be growth due to the on-going global consumption demand for palm oil (Abutaha et al, 2016). Usually the waste that is produce will be dumped off to sites and will lead to environmental pollution (Abutaha et al, 2018) . However, (Ibrahim et al, 2016) stated various studies has been shows that this waste can serve as potential construction materials and by this way it can reduce environmental problem before.

Several studies have been reported by previous researchers on possibility of the use of palm oil clinker as replacement material in concrete production. It was found that the palm oil clinker is suitable used to produce lightweight concrete if it is crush into desired size (Mohammed et al, 2014). Even POC will give the reduction in compressive strength and flexural strength, it still suitable to be used as the part of material replacement in concrete mix.

The studies regarding of palm oil clinker in concrete are abundant, but there is not much study regarding the incorporation of coarse aggregate as a material in ultra-high performance concrete. Therefore, the exploration on the performance of ultra-high performance concrete incorporating palm oil clinker as coarse aggregate replacement was conducted in the present study. In order to determine the performance of palm oil clinker on UHPC, the mechanical properties of a plain UHPC and the series of POC-UHPC were investigated.

## 1.2 Problem Statement

Malaysia is a one of developing countries in construction. They have their own production of cement and aggregate. The requirement of aggregate for the production of concrete require huge used of natural stone material. Due the high demand for production of aggregate, it has causes various issue especially in environmental problem. The environmental problems that happen caused by the production of coarse aggregate are getting worse. This production can cause environmental problem such as air pollution, noise pollution, destroy ecological balance and can cause global warming (Ismail et al., 2013). It also can easily affect the human being health through respiration system where they will inhale the fine particle produce by quarry process.

From the issue that arises, previous researchers have found the solution to overcome the problem in order to save the environment and human being. They were concentrate on the use of waste materials in construction industry especially in concrete production (Serniabat et al., 2014). In Malaysia, the production of palm oil in 2016 is around 17,320,000 tonnes a year (Varqa S. , 2017). Imaging that the wastage from palm oil industry is huge for a year. The wastage that produced via this production can be used as coarse aggregate in concrete namely palm oil clinker. This was proven through the study by (Abutaha et al., 2016b) on the use of palm oil clinker as partially replace of natural aggregate in concrete production. Thus, the consumption of natural aggregate can be reduced along with the environmental problem.

## 1.3 Objective of Study

This study is conducted to achieve the following objectives:

i) To determine the workability of ultra-high performance concrete (UHPC) containing various percentage of palm oil clinker (POC) as aggregate replacement

ii) To determine the performance of ultra-high performance concrete (UHPC) partially replaced by palm oil clinker as coarse aggregate through compressive strength test and flexural strength test.

iii) To determine the optimum mix proportion of ultra-high performance concrete (UHPC) incorporating palm oil clinker.

## 1.4 Scope of Study

This study will be focused on the performance of ultra-high performance concrete (UHPC) containing various percentage of palm oil clinker as partial coarse aggregate replacement. In this study, a few tests were conducted to measure the mechanical properties of ultra-high performance concrete (UHPC) containing palm oil clinker which is slump test, compressive strength test and flexural test. Four (4) different percentage of palm oil clinker as aggregate replacement were prepared. There are 0%, 5%, 10% and 15% of palm oil clinker from the total weight of natural coarse aggregate. The UHPC and a series of palm oil clinker-UHPC were labelled as plain-UHPC, POC-UHPC5, POC-UHPC10 and POC-UHPC15 respectively.

The materials that are used for control mix in this study is Ordinary Portland Cement (OPC), coarse aggregate, sand, water and chemical admixture. In this study, palm oil clinker was taking from Kilang Felda Lepar Hilir, Gambang. Palm oil clinker was crushed into the 5mm in size. Sieve analysis test was done in accordance to BS EN 933-1:1997 to determine the particle size distribution of palm oil clinker. The amount of each material was weighed accordingly to the total raw materials required for the preparation of plain UHPC and a series of POC-UHPC specimens. The water cement (w/c) ratio was kept constantly with the value of 0.18. While, the amount of super plasticizer for plain UHPC is 4% and for other POC-UHPC specimen is 3% by the weight of cement.

To prepare ultra-high performance concrete (UHPC) specimens, a total number of 36 cubes with dimensions of 100 mm x 100 mm x 100 mm are prepared. This specimen is used for compressive strength test. The test was conducted according to BS EN 12390-3:2009. On the other hand, for flexural strength test, a total of 36 prisms with dimension of 100 mm x 100 mm x 500 mm are casted. The test was done accordance with ASTM C78-84. The specimens were cured in water tank for 7 days, 28 days and 60 days before tested.

## 1.5 Significant of Study

In production of concrete, coarse aggregate is a one of material that is needed. The requirement of coarse aggregate increasing since the development of concrete in industry such as high strength concrete (HPC) and ultra-high performance concrete (UHPC). Due to the high demand for natural aggregate, it has cause the depletion of natural resources. The reduction of natural sources has given big challenges to construction field. Thus, to overcome this problem some alternative material has been introduced to partially or fully replace the natural aggregate. This alternative material not only can replace the aggregate but it also can reduce the environmental problem. The main reason of use this material other than that is to manage the waste by recycling and reuse the waste product for construction material.

The significant of the study is to determine the possibility of waste material such as palm oil clinker (POC) as partially replacement for coarse aggregate in production of UHPC. Palm oil clinker was selected due to increasing palm oil waste production in Malaysia. Hence, it can lead to environmental problem in Malaysia. In order to measure the palm oil clinker as partially replacement for aggregate in UHPC, three (3) type of testing were conducted to evaluate mechanical properties of plain UHPC and POC-UHPC.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The literature review is made to understand and to obtain more knowledge about these research topics beginning of the subject tittle. There are various studies that have been conducted on the concrete including their source of the material. Furthermore, there are various type of aggregate that has been used in the production of the concrete including from the waste product such as palm oil clinker, tyre and more. The usage of palm oil clinker as aggregate has been taken in our country, Malaysia and this material available in palm oil industry.

The alternative for replacement of coarse aggregate in the production of concrete has been introduced by various researches in the field of concrete production. It is because the use of natural aggregate has contributed to various problems such as environmental issue as stated by (Ismail et al., 2013). Thus, the production of concrete in the world has come to the environmental friendly.

This study will focus more on a palm oil waste which is palm oil clinker as coarse aggregate replacement in term of its performance. The information for literature review was getting from studying through journal, articles, websites, newspaper and previous student's thesis.

## 2.2 Ultra high performance concrete

According to (Shelke et al., 2014) concrete is the premier civil engineering material. Concrete is recognized as one of the most important construction materials widely and extensively used in structures and the second most consumed material in the world after water as stated by (Keshavarz & Mostofinejad, 2019). The production of concrete around the world remarkably increases during the last century and it is expected that the demand for concrete will continue to rise in the future. The production of concrete across the world has been used in construction development for building, bridge, road and other.

Concrete has been used in construction field in Malaysia and it has been innovate to the various type of concrete with various grades. There are many type of innovation of concrete, which is high strength concrete, ultra high performance concrete and other concrete. In this study, ultra high performance concrete (UHPC) were used as the type of the concrete.

As the new cementitious material, ultra-high performance concrete (UHPC) has seen a rapid growth in construction (Pourbaba et al., 2018). In 2018, Li.P.P et al also said that ultra-high performance concrete relatively a new building material, which has high mechanical strength, ductility, impact resistance, fatigue resistance and durability. This type of concrete can achieve higher than 150 MPa in strength as stated by (Shi et al., 2015) before. The performances of ultra-high performance concrete (UHPC) is depend on the properties and the mixing method of material inside it.

Ultra-high performance concrete (UHPC) contain various advantages as compared to conventional concrete. The main advantage of UHPC is it has a superior strength as compared to other concrete. As mentioned by (Y. Li et al., 2018) UHPC greatly reduces the porosity and permeability of the cement matric that lead to increasing strength, excellent abrasion resistance, enhanced durability of the concrete and vulnerable to explosive spilling under fire condition.

UHPC usually used for precast and prestressed concrete structure and it has been confirmed in a number of projects in United States, Germany, Canada, France and Australia (Alsalman et al., 2017). According to (Zhou et al., 2018) UHPC is used as a major or part of building material in bridge and it is has been used in Asia, Europe and

North America. This has been proved that UHPC can be used in construction especially for bridge and high rise building. However, UHPC is not commonly used in this industry due to the higher production cost.

### 2.2.1 Effect of Different Type of Aggregate in UHPC

Aggregate are important ingredient for highway and structural concrete, accounting for 30% of the cost, and comprising by volume 65 to 85% of concrete as stated by (West & Cho, 2006). It is inert granular material such as sand, gravel, granite or crushed stone. Aggregate is one of the materials that influenced the properties of the concrete. To produce a good concrete mix, aggregate need to be in a clean, hard, strong particles free of absorbed chemicals and other fine material that could cause the deterioration of concrete (Portland Cement Association, 2018). Aggregate can be divided into two categories which is fine aggregate and coarse aggregate.

Coarse aggregate consist of gravel, crushed stone or manufactured aggregate with particle size equal to or larger than 4.75 mm and the size of fine aggregate is smaller than 4.75 mm or larger than 75 μm.(Shi et al., 2015) indicated that the aggregate is relatively inexpensive concrete making but in production of UHPC, it is quite costing due to the used of refined quartz sand with diameter less than 0.6 mm. (Li et al., 2018) study that coarse aggregate can improve the elastic modulus and alter the workability of UHPC more easily, as well as reduce the cost. They also conclude with utilization of coarse aggregate, the autogenously shrinkage was reduced by approximately 40%. They also found the cracks form quickly and can propagate through aggregate at higher loading rates and consequently increasing the impact resistance. Thus, these contradictions should be well balanced for utilization of coarse aggregate in UHPC.

### 2.2.2 Effect of Chemical Admixture to UHPC

Chemical admixture usually include of accelerator and super plasticizer.(Shi et al., 2015) reported that the decrease in w/c will low porosity and increase of hardened cement based material. They also found the use of super plasticizer can significantly reduce the amount of w/c for a given workability. The most effective super plasticizer for UHPC is polycarboxylates and the dosage in range 0.5-2.0%. Table 2.1 shows the super plasticizer used in previous study.

**Table 2.1** Super plasticizer used in previous study

| Author ( year) | Type of Superplasticizer |
|---|---|
| Bartosz et al, 2016 | ISOFLEX 7130 |
| Alsalami et al, 2018 | Flocrete PC200 |
| Li et al, 2018 | Polycarboxylate Ether |

In this recent study, the super plasticizer used is Sika VisoCrete 2008 PC with dosage 4% for plain UHPC and 3% for three (3) series of POC-UHPC.

### 2.2.3 Effect of Low Water Cement (w/c) Ratio to UHPC

Water cement ratio can affect the porosity and the strength of hardened concrete. In UHPC, the amounts of water cement ratio need to be lower because of the present of super plasticizer for workability of the concrete. As stated by (Shi et al., 2015) the decrease in w/c will low the porosity and increase strength of hardened cement based material. Thus water to cement ratio for UHPC ranges between 0.14-0.20 as compared with normal concrete which is 0.4 to 0.5 (Shi et al., 2015).

### 2.2.4 Effect of Different Curing Condition to UHPC

Curing condition also can affect the performance of the concrete in term of the strength and quality of the concrete. According to (Shi et al., 2015) for ultra-high performance concrete there are 3 type of curing method that commonly used which is standard room temperature curing, heat curing under atmospheric pressure, and autoclave curing method.

Standard room temperature curing is one of the curing methods that is more economical and environmental friendly. The concrete was cured in a room temperature at 20°C. it will make UHPC to achieve the strength up to 150 MPa when the curing ages was reasonably prolonged based on (Shi et al., 2015). Heat curing under atmospheric pressure is where the concrete was put under 24 hour steam curing at 90℃ will improved the strength of the concrete. While for autoclave curing, it will increase the compressive strength of UHPC higher than other curing method. Thus it most effective and usually used to cured UHPC even this method quite expensive.

Based on previous research, there is a various type of curing method other than above. This can be concluding as Table 2.2:

**Table 2.2** Type of curing in previous study

| Author ( year) | Type of Curing |
|---|---|
| Jankovic et al (2016) | Curing in the water at 20℃ |
| Gonzales-Corominas.A et al(2014) | Cured in a humidity room at 23℃ |
| Ambily et al(2015) | Cured in a water and cured in thermal cyclic chamber at 150℃ |
| Li et al(2018) | Cured in water under room temperature of 20℃ |

Thus in this study, the curing regimes used is curing in the water tank for a selected days which is 7days, 28 days and 60 days.

## 2.3 Palm Oil Industry Waste

In this topic, the introduction of palm oil industry waste and production of palm oil clinker had been reviewed in details.

### 2.3.1 Introduction

Malaysia is a one of the country that has the largest producers of palm oil in the world and the second largest countries that produce palm oil after Indonesia. There is almost 200 palm oil mills that operate in Malaysia and generate about 100 tons of palm oil fuel ash (POFA) annually (Kabir et al., 2017). Due to the high production of palm oil, Malaysia has generated a significant amount of waste (Mohammed et al., 2014).

The waste from the palm oil industries are oil palm shell (OPS), empty fruit bunches, palm oil fibres, palm oil fuel ash and palm oil clinker (Ahmmad et al., 2016). (Abutaha et al., 2016) stated, Malaysia generates about 3.13 million tons of palm shell as waste from the production of palm oil. While (Kabir et al., 2017) said Malaysia generated about 4.0 million tonnes oil palm shell (OPS) and huge amount of palm oil clinker as waste material. From the statement, it shows that the amounts of waste from palm oil industry especially palm oil clinker and palm oil shell in Malaysia will increase every year due to high demand of the palm oil.

The large amount of waste produced is one of the main contributions to the nation's pollution problem as mentioned by (Mohammed et al., 2014). The waste from the palm oil industry will cause environmental problem because this material does not has any value in a market as stated by (Kabir et al., 2017). This also can be supported by the statement from (Abutaha et al., 2016) where he said that palm oil industry is a major contribution to the pollution problem occurring in the country where they tend to compose this waste into the land fill and lakes or river due to the small commercial value in Malaysia. (Ibrahim & Abdul Razak, 2016) also stated that POC can be found in abundance and have little or no commercial value, thus it is one of the main contributors to the environmental problem.

Hence, the researcher found the way to minimize the environmental problem from the palm oil industry waste by using the palm oil clinker as coarse aggregate in the concrete production.

### 2.3.2 Production of Palm Oil Clinker

Palm oil clinker (POC) is a waste product from palm oil industry. (Ibrahim & Abdul Razak, 2016) stated that POC can be found in abundance and have little or no commercial value. Palm oil mill in Malaysia incinerate palm oil waste to produce steam that are needed for milling process (Mohammed et al., 2014). As a result from incineration, palm oil clinker was produce as a waste. As cited by (Kanadasan & Razak, 2015) palm oil clinker is a waste by-product gathered after the complete incineration process of oil palm shell and fibre. While, according to (Kanadasan et al., 2015) the burning process of OPS and oil palm fibre produces palm oil clinker, which is obtained in large chunks ranging between 100 and 400 mm before being crushed into require size.

Palm oil clinker (POC) is highly porous, irregularly shaped with good lightweight characteristic as mentioned by (Ibrahim & Abdul Razak, 2016). Based on (Abutaha et al., 2016) POC is a light, solid and fibrous material which may be used as a potential lightweight aggregate for concrete when crushed. Other than that, the characteristic of palm oil clinker has higher tendency in absorbing water.

In this recent study, POC used was supplied from Kilang Sawit Lepar Hilir, Gambang in large chunk as Figure 2.1. Figure 2.2 illustrate the flow diagram palm oil mill process.

**Figure 2.1** Palm oil waste (source by: Abutaha et., 2018)

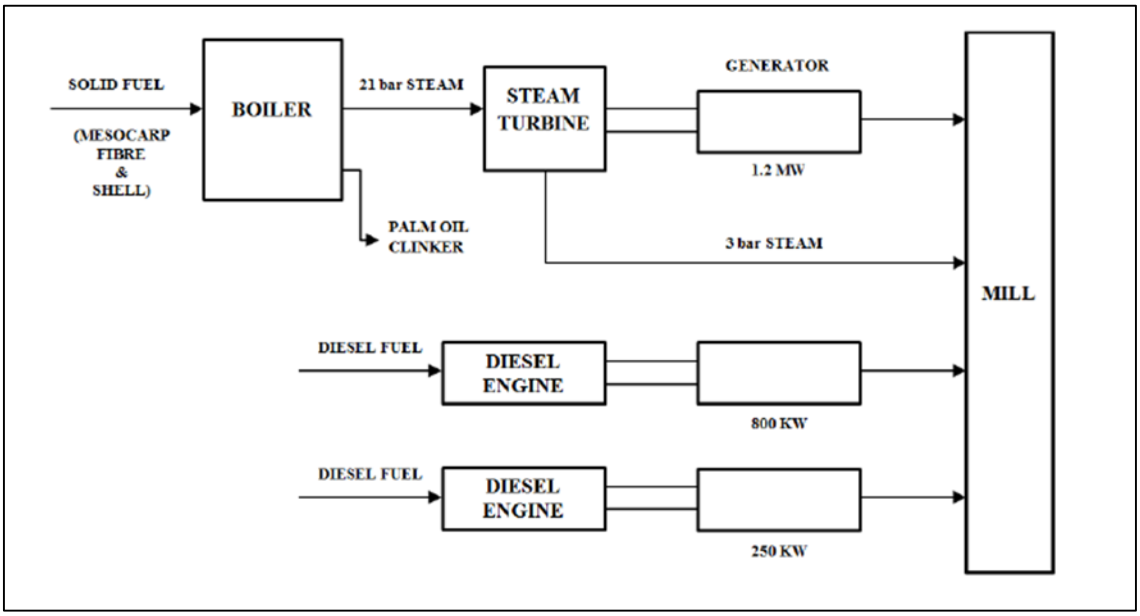


**Figure 2.2** Flow diagram palm oil mill process

## 2.4 The Importance of Concrete Properties

Several studies had been conducted on the properties of concrete incorporating palm oil waste as aggregate and sand replacement. The effect of these properties will be discussed in the next sub-sections. Palm oil clinkers serve as an ideal alternative aggregate when crushed and sieved into suitable sizes and can be used in production of concrete (Ibrahim & Abdul Razak, 2016).

### 2.4.1 Effect of Palm Oil Clinker To Workability Of Concrete

Concrete workability test was done to determine the slump of cohesive concrete of low to high workability of concrete. There are three (3) types of concrete workability test which is slump test, vebe test and compacting factor test. Slump test was carried out to measure the consistency of plastic concrete and it is suitable for detecting changes in workability. Vebe test is a good laboratory test and particularly from very dry mixes and for compacting factor test it is suitable used for concrete with maximum size of aggregate up to 40 mm as stated by (Nor). The Figure 2.4 shows the type of workability test used from previous study. Thus in this study, slump test was used to determine concrete workability.

**Table 2.3** Type of workability test used in previous study

| Author ( year) | Type of Workability test |
|---|---|
| Kanadasan et al, 2015 | Slump Test |
| Ahmmad et al, 2015 | Slump Test |
| Abutaha et al, 2016 | Slump Test |

(Kanadasan & Razak, 2015) reported that the slump test provide an insight into the possible stress from the materials that are utilized for mortar production. The slump values of concrete that containing 0%, 25%, 50%, 75% and 100% of POC show consistent values since the surface of POC is rougher compared to OPS as stated by (Ahmmad et al., 2016). While, according to (Abutaha et al., 2016) the workability of the mixes will be affected by the replacement of coarse POC due to the particle shape and rough surface, as well as the spiny broken edges. They also conclude that, the increasing of POC substitution ratio will decrease the workability of the mix. On other hand, (Abutaha et al., 2018) revealed that the concrete mixes workability was negatively with the incorporation of POC coarse aggregate. Due to the properties of palm oil clinker, the workability of the concrete is reducing as increasing the content of POC in the concrete.

### 2.4.2 Effect of Palm Oil Clinker to Compressive Strength of Concrete

For strength properties of hardened concrete, a few researchers proved that the replacement of palm oil clinker as coarse aggregate caused the reduction strength of the concrete. (Abutaha et al., 2016) proved that the strength reduction of the concrete as increasing POC replacement as coarse aggregate due to the highly porous nature of the POC coarse aggregate and the large amount of void in the internal structure of POC. (Ibrahim & Abdul Razak, 2016) expect that the increase of natural aggregate replacement with POC will increase the strength of the concrete gradually, but the loss in strength occurred with increasing POC replacement level. It can be said that, the used of POC will reduce the strength of the concrete at a certain replacement level. The direct substitution of natural aggregate with POC coarse resulted in a lower compressive strength at all ages compared to the control concrete as mentioned by (Abutaha et al., 2018).

The reduction strength of the concrete containing palm oil clinker as coarse aggregate replacement has lead to further study to determine the possible reason for reduction of concrete strength when palm oil clinker was used as aggregate replacement. (Ibrahim & Abdul Razak, 2016) stated aggregate crushing value of the POC aggregate influence the maximum load the concrete can take and the loading capacity of the concrete is low due to the high void present on the surface and inside the POC aggregate. Other than that, the inconsistence shape of the POC also can affect the reduction in strength of concrete, where POC is flaky and irregular in nature as compared to granite which has a smooth surface. (Abutaha et al., 2018) agree that the decreasing strength of the concrete due to POC characteristic which is porous and contain many groove and opening pores on its surface. This has been explained why the strength reduce as increasing the amount of POC replacement.

### 2.4.3 Effect of Palm Oil Clinker To Flexural Strength Of Concrete

Previous research found that the presence of palm oil clinker as coarse aggregate replacement in concrete contribute to the decreasing of flexural strength. (Kanadasan et al., 2015) cited the flexural strength result of the concrete was not significantly affected even there is variation in terms of the physical and chemical properties of the POC. On other hand, (Abutaha et al., 2018) stated a significant drop in flexural strength up to 39% was observed as compared to control concrete. They conclude the reduction of flexural strength for the concrete containing POC aggregate may be attributed to the high POC aggregate crushing value, which when subjected to flexural load, induces premature failure as compared to the control mix. Early propagation of crack may occur across the specimens where it will allow the aggregate to fail faster compared to cement paste. The irregular shape of POC also can affect the interface between aggregate and the cement paste. This conclusion had been reached by analysing the failed specimens visually.

## 2.5 Summary

This chapter discussed the previous study that was carried out on the production of UHPC. The production of concrete incorporating with palm oil clinker also been reviewed. To produce UHPC that has advance strength and durability, the selection of raw material must been choosing carefully. In production of UHPC, the basic principle must be considered since UHPC contain very low water to cement ratio with high amount of cement content. In this recent study, a few principle has been adopted by modified the mix design proportion and the raw material selection. The selection of raw material is same as conventional UHPC which containing Ordinary Portland Cement (OPC), coarse aggregate, sand, super plasticizer and water. The mix proportion in this research was adopted from (Jaafar et al., 2017)

## CHAPTER 3

## METHODOLOGY

### 3.1 Introduction

In this chapter, the procedures that will carry out on the experimental works were described in details to achieve the objective of study. The methodology was drawn to ensure the study in line with the scope of study. The process-flow for plain-UHPC and all the POC-UHPC specimens were outlined in Figure 3.1.

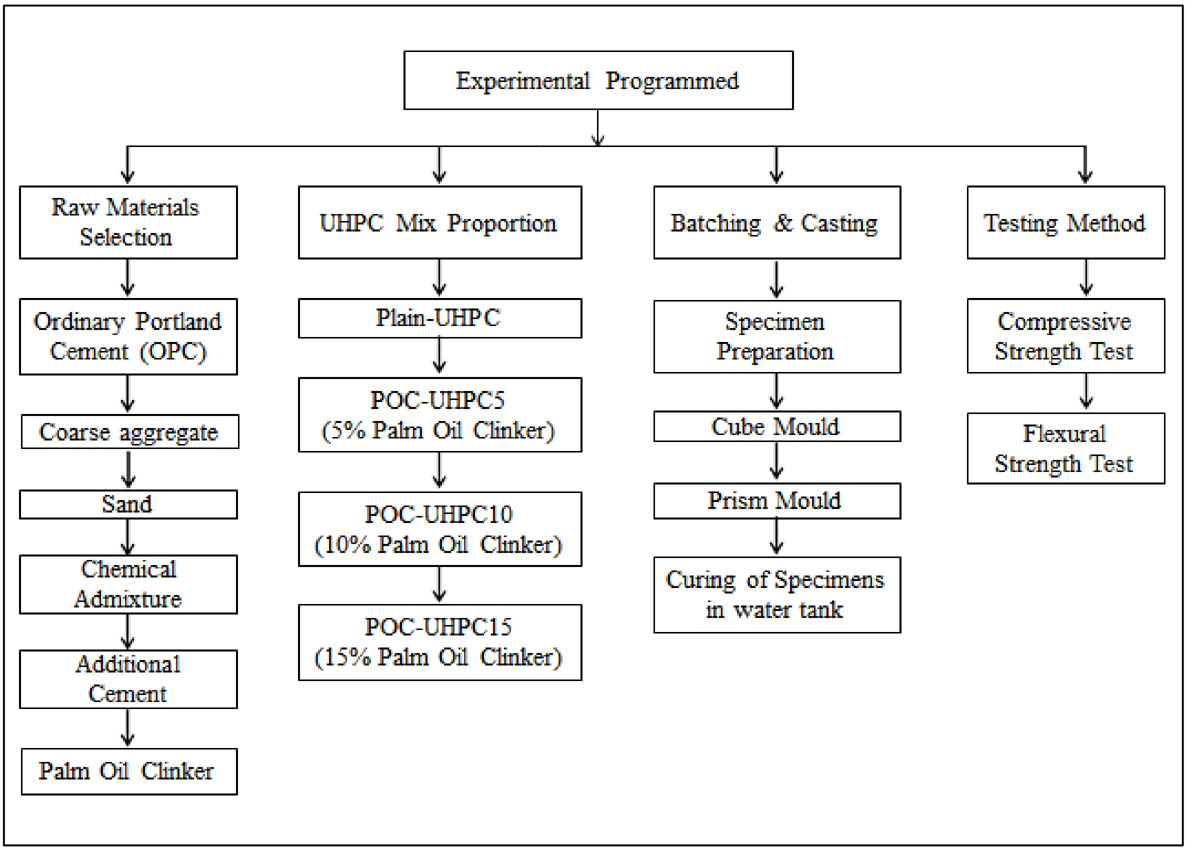


**Figure 3.1** Flow-chart process for experimental programme

### 3.1.1 Ordinary Portland Cement.

Cement is the basic material in the production of the concrete in the world. It is a material that has a cohesive and adhesion properties that enable binding the rock into one cohesive body. It is functioning to fill in the void between sand and coarse aggregate and will form a compact mass of concrete. Cement has a low alkali content, low to medium fineness, and a low $C_3A$ content can reduce water content, ettringite formation, and heat of hydration. For production of ultra-high performance concrete (UHPC), CEM I 52.5, ASTM Type I or II and GB P.I cement are recommended to be used as stated by (Shi et al., 2015). This can be proved by following Table 3.1 below:

**Table 3.1** Type of cement used by previous study

| Author ( year) | Type of cement |
|---|---|
| Li et al (2018) | Portland Cement CEM I 52.5 |
| Wong. C. et al (2011) | Ordinary Portland Cement grade 52.5 |
| Jankovic et al (2016) | CEM I 42.5 R |
| Liu. J. et al (2016) | Portland Cement grade 52.5 |

The chemical materials that contain in Portland cement are CaO, $SiO_2$, $Al_2O_3$, MgO and $SO_3$. Cement will go through a chemical reaction process when it is contact with water which is hydration process. This hydration process will produce calcium silicate hydrate gel (CSH) and calcium hydroxide (CaOH) where this chemical will contribute to the strength of the concrete. Thus, the amount of cement need to measure accurately in order to produce the desire strength of the concrete.

The cement content in production of UHPC is generally about 800-1000 kg/m. The high cement content will affect the production cost, the heat of hydration and dimensional stability of the concrete (Shi et al., 2015). Thus in this study, the cement that was choose is Ordinary Portland cement (OPC) Type I which provided by the local supplier as a binder to produce plain UHPC and other POC-UHPC mixture. The cement was procured and stockpiled carefully and properly to avoid hardening of cement. The cement content in this research was constant for four (4) mixtures that is 880 kg/m$^3$. Figure 3.2 below show the Ordinary Portland cement (OPC) Type I.


**Figure 3.2** Ordinary Portland Cement (OPC) type I

### 3.1.2 Coarse Aggregate

Aggregate functioning to reduce the heat of hydration of concrete since it is normally chemically inert and act as a heat sink for hydrating cement. They also act as inner filler within a concrete mix. The function of the aggregate still same even the formulation of UHPC is different from conventional concrete. The performance of concrete depends on the size gradation, shape and texture, moisture content and density of aggregate.

In production of UHPC, usually, the size of aggregate used tends to be relatively small. Other than that, the proportion of aggregate in production of UHPC must low as compared with conventional concrete. Thus, in this study, the natural crushed gravel was used as coarse aggregate with nominal size of aggregate must passing 10 mm and retained on 5 mm sieve as shown on Figure 3.3. Sieve analysis test was conducted for particle size distribution of coarse aggregate used in this study as per BS EN 933-1:1997 and was illustrated in Figure 3.4.

**Figure 3.3** Natural crushed gravel with 5 mm in size

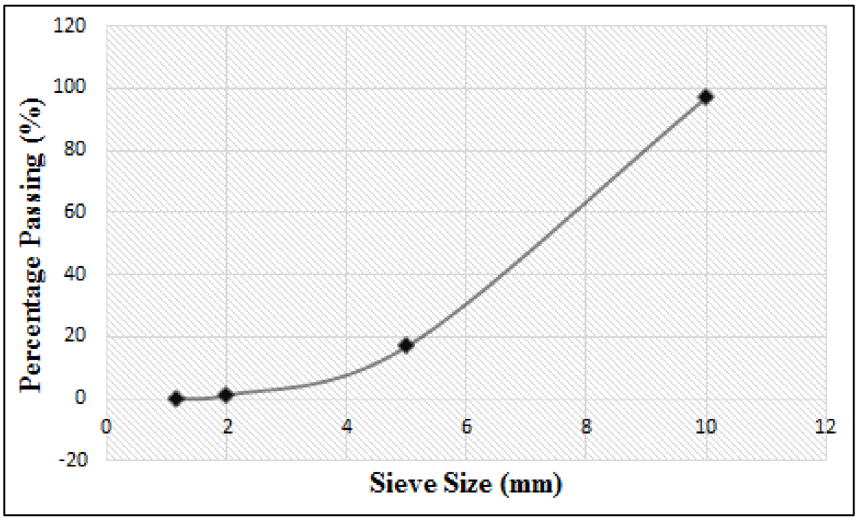


**Figure 3.4** Particle size distribution of coarse aggregate

### 3.1.3 Sand

Natural river sand is generally used as fine aggregate. The sand was taken from the river and been dried in temperature room. In this study, natural river sand with nominal size 5 mm and retained on 300 µm sieve was used as show in Figure 3.5. To determine the particle size distribution of the sand, sieve analysis was conducted accordance BS EN 933-1:1997 as showed in Figure 3.6.

**Figure 3.5** Natural river sand with nominal size of 300 μm

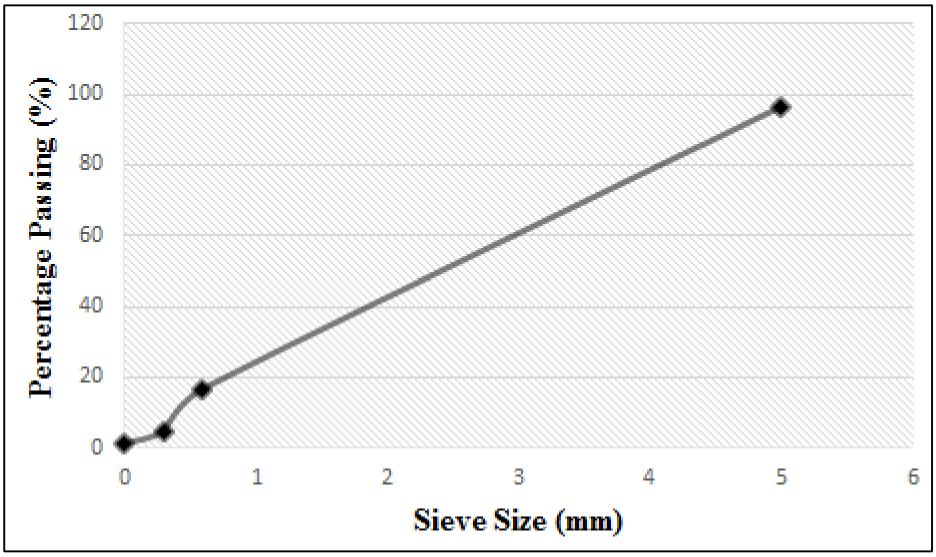


**Figure 3.6** Particle size distribution of sand

### 3.1.4 Water

In this study, the amount of water used for the UHPC mixture is constant to the all specimens. Ordinary tap water was choosing to be used for mixing and curing process. The water used must not contaminated, clean and free from impurities. This is because contaminated water can disturbed the performance of the concrete from the hardened process, durability and also volume stability. Thus it will affect the strength of the concrete in compressive strength and in flexural strength.

### 3.1.5 Chemical Admixture

In the production of UHPC, chemical admixture such as super plasticizer is must to accelerate the workability of the concrete. (Shi et al., 2015) state that the use of super plasticizer can reduce the required water to cement ratio for a given workability and also effectively reduce the porosity and increase the strength of the concrete. Thus the selection of super plasticizer is important in order to produce high quality of UHPC.

In this recent study, the super plasticizer used is Sika VisoCrete 2008 PC for early strength of the concrete. The quantity of super plasticizer used is 4% from the total weight of cement for plain UHPC and 3% by the weight of cement for three (3) series of POC-UHPC.

### 3.1.6 Palm Oil Clinker

Palm oil clinker from palm oil waste was supplied from Kilang Sawit Lepar Hilir located at Gambang, Pahang. Palm oil clinkers were used as partially replacement of coarse aggregate in production of UHPC. A total 5%, 10% and 15% of palm oil clinker replacement from the total weight of coarse aggregate to produce POC-UHPC specimens. The nominal size for palm oil clinker is 10 mm and retained on 5 mm sieve as Figure 3.7. The particle size distribution of palm oil clinker was determined through sieve analysis accordance to BS EN 933-1:1997 as Figure 3.8.

**Figure 3.7** Palm oil clinker with nominal size 5 mm

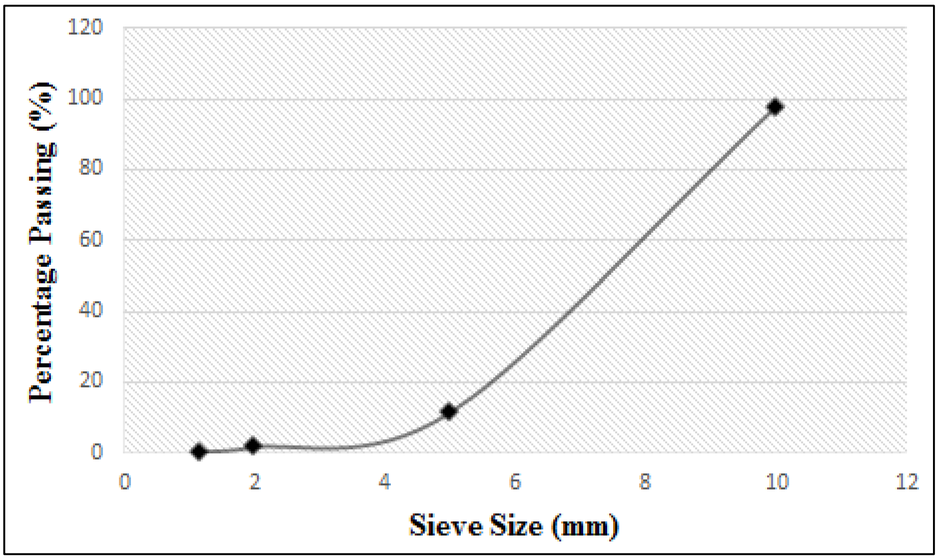


**Figure 3.8** Particle size distribution of palm oil clinker

## 3.2 Mix Proportion Design

In this research, the mix proportion of a plain UHPC and the other specimens was prepared. Plain UHPC was prepared as a normal ultra-high performance concrete (UHPC) mix without palm oil clinker as aggregate replacement. This concrete was designed as control concrete. While, 5%, 10%, 15% of palm oil clinker (POC) were used as partial aggregate replacement and was categorize as POC-UHPC5, POC-UHPC10 and POC-UHPC15 respectively. The palm oil clinker used in this mixes in size of 10 mm to 5 mm and addition of chemical admixture known as Sika VisoCrete 2008 PC as super plasticizer. While the water cement ratio for all specimens is constant with 0.18. The mix proportion was tabulated in the Table 3.2 for all specimens included plain UHPC and adapted from (Jaafar et al., 2017)

**Table 3.2** Mix proportion of plain UHPC and POC-UHPCs

| **Mix Designation** | **Raw Material(kg/m$^3$)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **OPC** | **w/c** | **Aggregate** | **Sand** | **Water** | **Super Plasticizer** | **Palm Oil Clinker** |
| Plain UHPC | 880 | 0.18 | 433 | 800 | 160 | 32 | 0 |
| POC-UHPC5 | 880 | 0.18 | 411.35 | 800 | 160 | 24 | 21.65 |
| POC-UHPC10 | 880 | 0.18 | 389.70 | 800 | 160 | 24 | 43.30 |
| POC-UHPC15 | 880 | 0.18 | 368.05 | 800 | 160 | 24 | 64.95 |

### 3.3 Preparation of Specimens

In this topic, the preparation of UHPC specimens was done carefully and properly. The amount of the material needed for the mixture such as Ordinary Portland Cement (OPC), chemical admixture, water, coarse aggregate and sand was weighted according to the mix proportion as specified in Table 3.2. To determine particle distribution of coarse aggregate, sand and palm oil clinker, sieve analysis was done in this stage. Palm oil clinkers from palm oil industry waste were incorporated as partial replacement of coarse aggregate. For mixing process, concrete pan mixer was used. While, batching, mixing and casting process of the concrete specimens were discussed at the following sub-sections. Lastly, the dimension and curing ages for the ultra-high performance concrete also were discussed.

#### 3.3.1 Batching, Mixing and Casting

The four (4) series of mix designed was prepared in this study which contain a plain ultra-high performance concrete (UHPC) and three (3) series of POC-UHPC with different percentage of palm oil clinker (POC) as partial replacement of coarse aggregate. Plain UHPC was designed as a control mix without any replacement of aggregate. Pan mixer was used for the mixing process as Figure 3.9 below.

During the mixing process, the Ordinary Portland Cement (OPC) was mixed together with water until uniformly. After the mix become cement paste, the sand was poured into the mixer followed by coarse aggregate. Once the mix homogeneously, the High Range Water-Reduce (HRWR) admixture known as Sika VisoCrete 2008 PC was added gently into the concrete pan mixer and mix continuously. The amount of HRWR used for plain UHPC is 4% and the amount for series POC-UHPC was kept constant at 3%. The concrete mixture was poured into plastic mould about quarter (1/3) from the total volume of concrete. Then the plastic moulds were placed on vibrator table to compact the fresh concrete mix. The process was repeated for two (2) times for each plastic mould. The excess material on surface of the steel moulds was removed using a trowel. The plastic mould was stored at dry area with room temperature for 24 hours before being removed from the moulds as shown in Figure 3.10 after casting the concrete.

For series of POC-UHPC mixture, various percentage of palm oil clinker was incorporated as partial coarse aggregate replacement. The basic mixing procedures are similar as plain UHPC mixture. Firstly, OPC and water mixed simultaneously until the mixture become cement paste. Then, it was followed by adding sand and coarse aggregate. After the mixture become uniformly flowable, it was followed by pouring palm oil clinker into concrete mixer pan according to the various percentage of POC. There are 3 level of coarse aggregate replacement which is 5%, 10% and 15% of POC. Then HRWR was added gently into the mixture and mix continuously. When the mix homogenous, the fresh concrete mix were casting into plastic moulds and being compacted on vibrator table as similar with casting procedure in preparing plain UHPC.

**Figure 3.9** Concrete pan mixer used for mixing process

**Figure 3.10** Plastic mould was stored in room temperature for 24 hour

### 3.3.2 Dimension of Specimens

The concrete with the dimension of 100 mm x 100 mm x 100 mm was casted in total of nine (9) cubic for each mixture for compressive strength test as shown in Figure 3.11 below. While, a total of nine (9) prism specimen with the size 100 mm x 100 mm x 500 mm were casted for flexural strength test as display in Figure 3.12.

**Figure 3.11** UHPC specimens for compressive strength test

**Figure 3.12** UHPC specimens for flexural strength test

### 3.3.3 Curing Age

The specimen was demoulded after the concrete hardened for 24 hours. The concrete specimen was kept in curing water tank for 7, 28 and 60 days before subjected to the compressive strength and flexural strength test, respectively. Curing in the water tank is a method to prevent the hydration process from stopping to enhance the strength of the concrete.  The Figure 3.13 below shows the plain UHPC and other specimens in curing water tank for curing process.

**Figure 3.13** The specimens cured in water tank

### 3.4 Testing Procedures

The testing method conducted had been focused on the mechanical properties of fresh and hardened specimens compromising of plain UHPC and three (3) series of POC-UHPC specimens. The mechanical properties of fresh concrete was determined by conducting slump test and for determination of mechanical properties for hardened concrete by conducted compressive strength test and flexural strength test. The modes of failure of hardened concrete also were observed to make comparison in term of toughness of plain UHPC and other specimens. The procedures of testing were explained in the sub-topic below.

#### 3.4.1 Slump Test

Slump test was conducted on fresh UHPC as per BS EN 12350: Part 2 (2009) after the concrete mixing. The concrete were poured into the slump cone for fill in the three layers which each layer approximately one-third of the high of the mould. Each layer was tamped with 25 strokes of the tamping rod and the stroke was uniformly distributed over the cross-section of the layer.

The mould was removed from the concrete after the top layer has been tamped by raising the mould vertically and carefully. The slump was measured and has been recorded to the nearest 5 mm using measuring scale.

### 3.4.2 Compressive Strength Test

Compressive strength test was conducted on UHPC specimens as per BS EN 12390-3:2009 on cubic specimens with dimension of 100 mm x 100 mm x 100 mm. The cubic specimen was demoulded after 24 hour casting. After the concrete was taken out from the mould, the cubic specimens were kept in water tank for curing purposes for 7, 28 and 60 days.

The specimen was taken out from water tank after 7, 28 and 60 days and being dry at room temperature before doing the testing. The weight and dimension of the specimen were measured. The compressive strength of the specimens was evaluated using an automatic compression testing machine with loading capacity of 1000 kN. The average reading of maximum strength for tested three (3) cubic specimens was recorded as the compressive strength of the specimens. The compressive strength of the specimens was calculated by using Equation 3.1

$$Compressive\ strength, fc = \frac{Load, P}{Cross\ Sectional\ Area, A} \qquad (3.1)$$

**Figure 3.14** Compressive strength machine

### 3.4.3 Flexural Strength Test

Flexural strength test is a way to determine the flexural strength of hardened concrete specimens by using the beam with reference to the standardized third point loading method. Flexural strength test on plain UHPC and three (3) series of POC-UHPC specimens were conducted as per ASTM C78-84. A prism specimen with size 100 mm x 100 mm x 500 mm was casted with and without palm oil clinker (POC).

The specimens were taken out from water tank after cured for 7, 28 and 60 days for testing purpose. Before conducted the flexural strength test, the weight and dimension of the prism were recorded. The specimens were tested in flexural testing machine by placing the specimens at the centre of support and loading point. The maximum load and specimen cross section at one of the fracture faces were noted. Basically, flexural strength test of the specimens was calculated based on the Equation 3.2.

$$Flexural\ Strength, R = \frac{PL}{bd^2} \tag{3.2}$$

Where

P = Maximum load carried by the specimens (N)

L = Span Length (mm)

b = Average width of specimens at the fracture (mm)

d = Average depth of specimens at the fracture (mm)


**Figure 3.15** Flexural strength machine

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter was discussed on the results of the mechanical properties in terms of slump ratio, compressive strength and flexural strength. The performance from each type of testing was presented in form of tables and graphical.

## 4.2 Slump Test Result

Slump test was carried out according to BS EN 12350: Part 2 (2009) on the fresh concrete for plain UHPC and series of POC-UHPCs. For production of plain UHPC the amount of HRWR use is 4% by the weight of cement and for three (3) series of POC-UHPC the amount of HWRW used is 3% by the weight of cement. Table 4.1 and Figure 4.1 illustrate the results on slump test for entire specimens.

**Table 4.1 Slump ratio of plain UHPC and series POC-UHPCs**

| Mix Designation | Height of Slump (mm) |
|---|---|
| Plain UHPC | 180 |
| POC-UHPC5 | 180 |
| POC-UHPC10 | 170 |
| POC-UHPC15 | 150 |

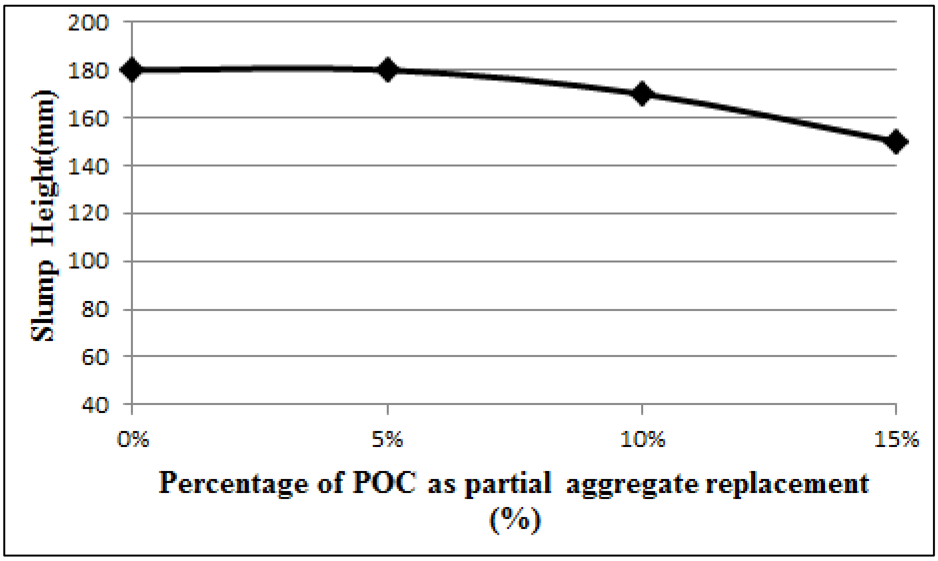


**Figure 4.1** Slump ratio for UHPC specimens at different level of coarse aggregate replacement

It can be seen from table 4.1 and figure 4.1 that the highest slump ratio is at 0% and 5% of aggregate replacement. There is decreasing in slump ratio as increasing the level of coarse aggregate replacement. The result showed that the control mix of UHPC exhibited better workability as compared with POC-UHPC. In previous findings, the slump ratio was proved reduced when incorporating POC as partial replacement of coarse aggregate in UHPC mixes.

## 4.3 Compressive Strength Test Results

The compressive strength test was performed on the cube specimens after curing at 7, 28, and 60 days. These tests were conducted to full fill the objective of the study. The results of compressive strength of the specimens in terms of curing ages and percentage of palm oil clinker (POC) will be discussed in detail for this section.

### 4.3.1 Effect of Different Curing Ages Subjected to Compressive Strength

Compressive strength test were done by followed to BS EN 12390-3-2009 on the cubic specimens with 100 mm x 100 mm x 100 mm in size. The cubic specimen was loaded at constant strain rate until the failure occurs. Table 4.2 to 4.5 shows the results on compressive strength of cube specimens of UHPC with different percentage of POC. It was found that the compressive strength of plain UHPC and series of POC-UHPCs increase as increasing the age of concrete curing. Figure 4.2 display the comparison of compressive strength of the specimens at different curing ages.

**Table 4.2** Compressive strength of UHPC specimens with 0% POC (plain UHPC)

| Curing Ages | Compressive Strength ($N/mm^2$) | Increment in Strength (%) |
|---|---|---|
| 7 | 52.69 | - |
| 28 | 80.39 | 52.57 |
| 60 | 81.96 | 1.95 |

**Table 4.3** Compressive strength of UHPC specimens with 5% POC (POC-UHPC5)

| Curing Ages | Compressive Strength ($N/mm^2$) | Increment in Strength (%) |
|---|---|---|
| 7 | 74.95 | - |
| 28 | 78.97 | 5.36 |
| 60 | 81.05 | 2.63 |

**Table 4.4** Compressive strength of UHPC specimens with 10% POC (POC-UHPC10)

| Curing Ages | Compressive Strength ($N/mm^2$) | Increment in Strength (%) |
|---|---|---|
| 7 | 75.36 | - |
| 28 | 79.65 | 5.69 |
| 60 | 80.57 | 1.16 |

**Table 4.5** Compressive strength of UHPC specimens with 15% POC (POC-UHPC15)

| Curing Ages | Compressive Strength ($N/mm^2$) | Increment in Strength (%) |
|---|---|---|
| 7 | 58.30 | - |
| 28 | 60.22 | 3.29 |
| 60 | 69.26 | 15.01 |

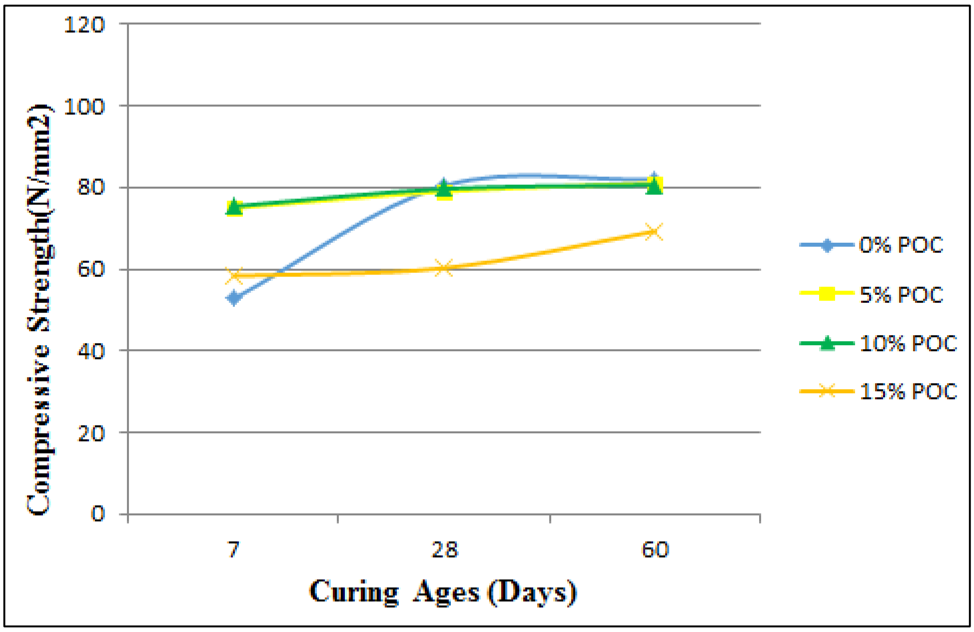


**Figure 4.2** Compressive strength of UHPC specimens at different curing ages

From the figure 4.2, it can be observed that compressive strength of the plain UHPC and the series of POC-UHPC specimens increased as increasing the curing ages. At the ages of 28 days, the result of plain UHPC, POC-UHPC5, POC-UHPC10 and POC-UHPC15 shows an increment which is 52.57%, 5.36%, 5.69% and 3.29% respectively. While at the ages 60 days, the cube specimens show the increment of 1.95%, 2.63%, 1.16%, and 15.01% respectively.

Plain UHPC has the lower early strength at 7 days with 52.69 $N/mm^2$ but the strength increase gradually at 28 days and 60 days with compressive strength 80.39 $N/mm^2$ and 81.96 $N/mm^2$. Meanwhile, a series of POC-UHPC exhibit high early strength at 7 days as compared with plain UHPC with compressive strength 74.95 $N/mm^2$, 75.36 $N/mm^2$ and 58.30 $N/mm^2$ for POC-UHPC5, POC-UHPC10 and POC-

UHPC15 respectively. However, the development of compressive strength of POC-UHPC specimens start to slow down as increasing the curing ages.

### 4.3.2 Effect of Different Percentage of Palm Oil Waste Subjected to Compressive Strength

**Table 4.6** Compressive strength of UHPC specimens at 7 days

| Composition | Percentage of POC (%) | Compressive Strength ($N/mm^2$) | Reduction in Strength (%) |
|---|---|---|---|
| Plain UHPC | 0 | 52.69 | - |
| POC-UHPC5 | 5 | 74.95 | -42.25 |
| POC-UHPC10 | 10 | 75.36 | -0.55 |
| POC-UHPC15 | 15 | 58.30 | 22.64 |

**Table 4.7** Compressive strength of UHPC specimens at 28 days

| Composition | Percentage of POC (%) | Compressive Strength ($N/mm^2$) | Reduction in Strength (%) |
|---|---|---|---|
| Plain UHPC | 0 | 80.39 | - |
| POC-UHPC5 | 5 | 78.97 | 1.80 |
| POC-UHPC10 | 10 | 79.65 | -0.86 |
| POC-UHPC15 | 15 | 60.22 | 24.39 |

**Table 4.8** Compressive strength of UHPC specimens at 60 days

| Composition | Percentage of POC (%) | Compressive Strength ($N/mm^2$) | Reduction in Strength (%) |
|---|---|---|---|
| Plain UHPC | 0 | 81.96 | - |
| POC-UHPC5 | 5 | 81.05 | 1.11 |
| POC-UHPC10 | 10 | 80.57 | 0.60 |
| POC-UHPC15 | 15 | 69.26 | 14.04 |

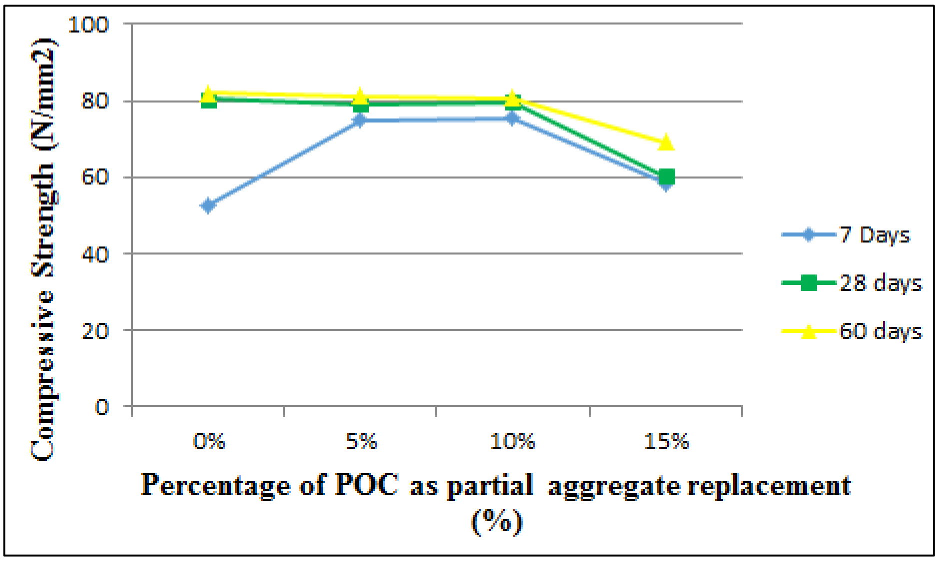


**Figure 4.3** Compressive strength of UHPC specimens at different percentage of POC as partial aggregate replacement

From Table 4.6, the result show that the strength of concrete is increasing as increasing the level of aggregate replacement up to 10% but it start to decrease when the level of POC replacement at 15% at 7 days. The reduction in strength for 15% POC replacement is 22.64%. At 28 days, the result from Table 4.7 shows that the strength of the concrete decreasing until 5% of POC with reduction 1.80% and slightly increase at 10% of POC replacement with increment 0.86% then decreases at 15% of POC replacement with reduction 24.39 %. From this result, it is clearly show that at 28 days the reduction of strength for the specimens is not constantly. However strength of the specimens decrease constantly as increasing the level of replacement at 60 days with reduction strength 1.11%, 0.60% and 14.04% for POC-UHPC5, POC-UHPC10, and POC-UHPC15 respectively as shown in Table 4.8.

It can be conclude that, the increasing percentage of palm oil clinker replacement as coarse aggregate will decreasing the strength of the concrete. This result has proved the statement from (Abutaha et al, 2016) in previous study. This strength decreases occur due to the porous structure of palm oil clinker that will make the concrete less dense and less rigid that allowed the water to fill in the void in the POC those lead to decreasing of the concrete strength.

## 4.4 Flexural Strength Test Results

Flexural strength test was conducted to the prism specimens at ages 7, 28 and 60 days. The testing was conducted to full fill the objective of this study which is to determine the mechanical properties of the UHPC incorporating with POC as partial aggregate replacement. The testing were performance according to ASTM C78-84 on 3 prism specimens with size 100 mm × 100 mm × 500 mm for each curing ages.

### 4.4.1 Effect of Different Curing Ages Subjected to Flexural Strength Test

Table 4.9 to Table 4.12 shows the result of flexural strength of the concrete with different curing ages. The different amounts of palm oil clinker that are used as partial replacement of aggregate give effects to the flexural strength of the concrete. The flexural strength of the concrete increasing as increasing the curing ages. The comparison of flexural strength at different curing ages were illustrate in Figure 4.4.

**Table 4.9** Flexural strength of UHPC specimens with 0% POC (plain UHPC)

| Curing Ages | Flexural Strength (MPa) | Increment in Strength (%) |
|---|---|---|
| 7 | 14.60 | - |
| 28 | 15.82 | 8.36 |
| 60 | 16.65 | 5.25 |

**Table 4.10** Flexural strength of UHPC specimens with 5% POC (POC-UHPC5)

| Curing Ages | Flexural Strength (MPa) | Increment in Strength (%) |
|---|---|---|
| 7 | 13.60 | - |
| 28 | 13.66 | 0.44 |
| 60 | 15.46 | 13.18 |

**Table 4.11** Flexural strength of UHPC specimens with 10% POC (POC-UHPC10)

| Curing Ages | Flexural Strength (MPa) | Increment in Strength (%) |
|---|---|---|
| 7 | 14.40 | - |
| 28 | 15.59 | 8.26 |
| 60 | 16.14 | 3.53 |

**Table 4.12** Flexural strength of UHPC specimens with 15% POC (POC-UHPC15)

| Curing Ages | Flexural Strength (MPa) | Increment in Strength (%) |
|---|---|---|
| 7 | 12.84 | - |
| 28 | 13.10 | 2.02 |
| 60 | 14.38 | 9.77 |

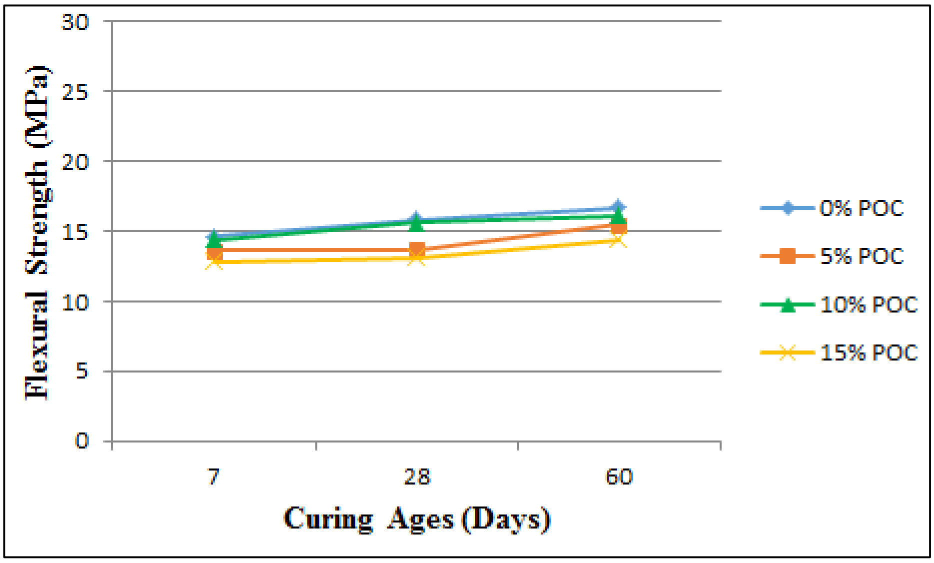


**Figure 4.4** Flexural strength with different curing ages

The result show the highest flexural strength of the prism at 7 days, 28 days and 60 days is 14.60 MPa, 15.83 MPa and 16.65 MPa for plain UHPC respectively. At 28 days curing ages, plain UHPC, POC-UHPC5, POC-UHPC10 and POC-UHPC15 show the increment in strength of 8.36%, 0.44%, 8.26% and 2.02% respectively. While at the ages of 60 days, the specimens also shows the increment in strength which is 5.25%, 13.18%, 3.53% and 9.77% for plain UHPC and the series of POC-UHCs respectively. It can be conclude that the flexural strength of the specimens is increasing when the curing ages prolonged. This can be explained due to the hydration process where the longer the period of curing, the higher the number of C-S-H gel can be produced through hydration process. This C-S-H gel will contribute to the increasing the strength of the concrete. From the result also the optimum content of UHPC is at 10% of POC replacement. This is because the result of UHPC with 10% of POC replacement as coarse aggregate gives nearly flexural strength as control concrete which is plain UHPC.

### 4.4.2 Effect of Different Percentage of Palm Oil Clinker Subjected to Flexural Strength

Table 4.13 to Table 4.15 was tabulated to represent the result of flexural strength of plain concrete and the series of POC-UHPCs at 7, 28 and 60 days of curing ages. Figure 4.5 illustrate the flexural strength with different percentage of POC as partial aggregate replacement.

**Table 4.13** Flexural strength of UHPC specimens at 7 days

| Composition | Percentage of POC (%) | Flexural Strength (MPa) | Reduction in Strength (%) |
|---|---|---|---|
| Plain UHPC | 0 | 14.60 | - |
| POC-UHPC5 | 5 | 13.60 | 6.85 |
| POC-UHPC10 | 10 | 14.40 | -5.88 |
| POC-UHPC15 | 15 | 12.84 | 10.83 |

**Table 4.14** Flexural strength of UHPC specimens at 28 days

| Composition | Percentage of POC (%) | Flexural Strength (MPa) | Reduction in Strength (%) |
|---|---|---|---|
| Plain UHPC | 0 | 15.82 | - |
| POC-UHPC5 | 5 | 13.66 | 13.65 |
| POC-UHPC10 | 10 | 15.59 | -14.13 |
| POC-UHPC15 | 15 | 13.10 | 15.97 |

**Table 4.15** Flexural strength of UHPC specimens at 60 days

| Composition | Percentage of POC (%) | Flexural Strength (MPa) | Reduction in Strength (%) |
|---|---|---|---|
| Plain UHPC | 0 | 16.65 | - |
| POC-UHPC5 | 5 | 15.46 | 7.15 |
| POC-UHPC10 | 10 | 16.14 | -4.40 |
| POC-UHPC15 | 15 | 14.38 | 10.90 |

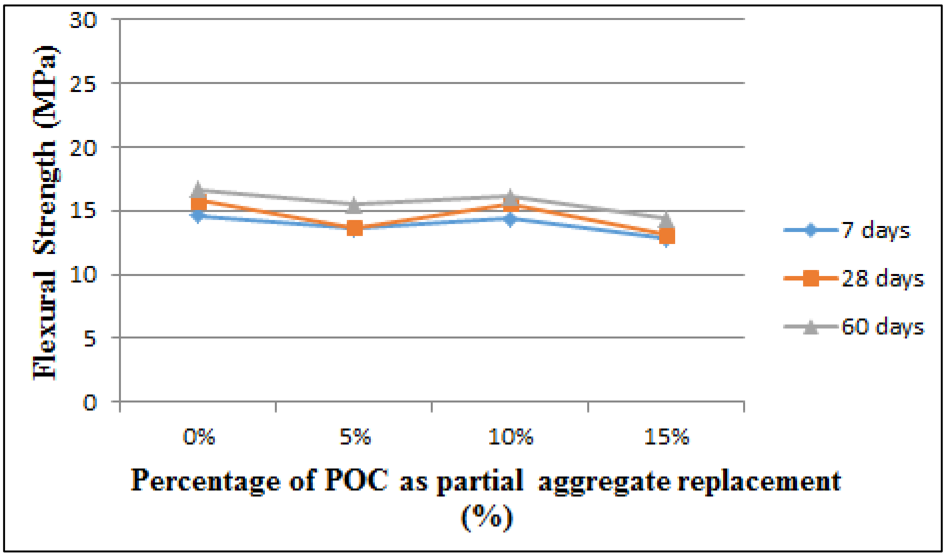


**Figure 4.5** Flexural strength with different percentage of POC as aggregate replacement

From the result in this study, the reduction of strength for POC-UHPC5, POC-UHPC10 and POC-UHPC15 occur with 6.85%, -5.88% and 10.83% respectively at the ages of 7 days.  At the 28 days, the reduction of flexural strength was 13.65% and 15.97% for POC-UHPC5 and POC-UHPC15 respectively while there is increment of flexural strength which is 14.13% for POC-UHPC10. Similarly to 60 days of the specimens, the reduction in strength were occur to concrete specimens that contain 5%, and 15% of POC replacement with 7.15% and 10.90 % each but there is increment in strength for specimen that contain 10% of POC with4.40%. The instable pattern of flexural strength because the use of cement that not properly store and exposed to the air for a long time. From the result, the higher percentage of reduction in strength of the concrete from specimens that contain 15% replacement of POC as coarse aggregate as compared to 5% and 10% POC replacement specimens. From previous finding, the flexural strength of the specimens will decreasing as increasing the level of replacement palm oil clinker and has been proved through this study. These decreasing flexural strength phenomena happened due to the character of the palm oil clinker that has the porous structure that will lead to the less dense of the concrete. It can be conclude that 10% replacement level of POC in UHPC production is the optimum content.

## 4.5 Summary

In this study, the performance of ultra-high performance concrete (UHPC) incorporating palm oil clinker as aggregate replacement was highlighted. It is clearly observed that the compressive strength and flexural strength of UHPC specimens were increasing when the ages of the curing were prolonged. However, both compressive strength and flexural strength of the specimens would decrease as increasing the replacement level of the palm oil clinker. The optimum content of palm oil clinker as partial replacement of coarse aggregate in production of UHPC is 10% of replacement. From the result, the specimens cannot be classified as ultra-high performance concrete (UHPC) because the strength of the concrete is lower than 150 Mpa. The specimens in this study can be categories as high performance concrete (HPC). This can be explained due to unused of silica fume in this mixture. The used of silica fume as a part of the material could achieve the strength of 150 MPa – 200 MPa (Shi et al., 2015).(Dembovska et al, 2017) state that silica fume lead to increment of mechanical properties of the concrete. This has shown that the used of silica fume in the production of UHPC is needed to achieve the compressive strength up to 150 MPa. Last but not least, the used of palm oil clinker in the production of UHPC is applicable but it is more suitable to be used for production of lightweight concrete.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Introduction

To achieve the objective for this study, the slump test were conducted to full fill the first objective which is to determine the workability of ultra-high performance concrete (UHPC) containing various percentage of palm oil clinker (POC) as aggregate replacement. While compressive strength test and flexural strength test was conducted to full fill second and third objective in this study which is to determine the performance of ultra-high performance concrete (UHPC) partially replaced by palm oil clinker as coarse aggregate and to determine the optimum mix proportion of ultra-high performance concrete (UHPC) incorporating palm oil clinker.

## 5.2 Conclusion

In this study, the mechanical properties of the plain UHPC and three (3) series of POC-UHPCs were investigated. Plain UHPC were used as control mix without any replacement of the palm oil clinker (POC) and the series of POC-UHPC is content a various percentage of POC replacement. Based on the analysis of the results, the conclusion can be drawn out.

1) There is increasing in compressive strength and flexural strength for the entire specimens as increases the curing ages.

2) The compressive strength and flexural strength of plain UHPC and the series of POC-UHPC was reduce as increasing the percentage of POC as partial replacement of coarse aggregate. These decreases were expected from the

previous findings that conducted on normal concrete and high performance concrete.

3) The strength reduction of the concrete was due to the characteristic of palm oil clinker that has a porous structure. This porous structure will made the concrete less dense and lead to the decreasing of strength.

4) The optimum mix proportion of POC replacement as coarse aggregate is 10% level replacement due to the similar result on both compressive strength and flexural strength with the control concrete which is plain UHPC.

5) The specimens cannot be classified as ultra–high performance concrete (UHPC) because the strength of the specimens is lower than 150 MPa. This is because the absent of silica fume in the mixture. Thus it only can be categorized as high performance concrete (HPC).

6) This study shows the POC has the potential as partial coarse aggregate material.

## 5.3 Recommendation

There are several recommendations that can be employed in this study if this study continues in more detail in future. The recommendations can be used to improve this study in the future is:

1) The used of silica fume is needed in the production of UHPC to achieved the strength of the concrete up to 150 MPa.

2) The number of specimens needs to be increase to get more accurate data for the study.

3) Further investigations are needed to investigate the properties of the palm oil clinker on the mechanical property of UHPC.

4) Investigate the performance of UHPC containing POC by conducting various tests such as Fire Resistance test.

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BS EN 933-1:199 Determination of Particle Size Distribution - Sieving Method

BS EN 12350 : Part 2 Testing Fresh Concrete

BS EN 12390-3:2009 Testing Hardened Concrete

ASTM - C78 Standard Test Method for Flexural Strength of Concrete

Civil Engineering Laboratory Manual Book

# APPENDIX A
# DATA FOR SAMPLES

### Calculation Total Volume

| Mix ID | 9 cube ($m^3$) | 9 prism ($m^3$) |
|---|---|---|
| Plain UHPC | 0.01035 | 0.05175 |
| POC-UHPC5 | 0.01035 | 0.05175 |
| POC-UHPC10 | 0.01035 | 0.05175 |
| POC-UHPC15 | 0.01035 | 0.05175 |
| Total | 0.0414 | 0.2070 |

### Date for Casting Sample and Testing Sample for Cube Specimens

| Mix ID | Date Casting | Date Testing For 7 Days | Date Testing For 28 Days | Date Testing For 60 Days |
|---|---|---|---|---|
| Plain UHPC | 29 / 01 / 2019 | 07 / 02 / 2019 | 26 / 02 / 2019 | 01 / 04 / 2019 |
| POC-UHPC5 | 15/ 02 / 2019 | 22 / 02 / 2019 | 15 / 03 / 2019 | 16 / 04 / 2019 |
| POC-UHPC10 | 13 / 02/ 2019 | 20 / 02 / 2019 | 13 / 03 / 2019 | 15 / 04 / 2019 |
| POC-UHPC15 | 21 / 02 / 2019 | 28 / 02 / 2019 | 21 / 03 / 2019 | 22 / 04 / 2019 |

# APPENDIX B
# RESULT

### Result of Particle Size Distribution of Coarse Aggregate

| Sieve Size (mm) | Weight of Sieve (g) | Weight of Sample (g) | Percentage Retained (%) | Cumulative Percentage Retained (%) | Percent Passing (%) |
|---|---|---|---|---|---|
| 10 | 689.54 | 60.66 | 3.01 | 3.01 | 96.99 |
| 5 | 958.01 | 1613.79 | 80.12 | 83.13 | 16.87 |
| 2 | 678.51 | 315.59 | 15.67 | 98.8 | 1.2 |
| 1.16 | 947.3 | 22.3 | 1.11 | 99.91 | 0.09 |
| Pan | 466.6 | 1.9 | 0.09 | 100 | 0 |

### Result of Particle Size Distribution of Sand

| Sieve Size (mm) | Weight of Sieve (g) | Weight of Sample (g) | Percentage Retained (%) | Cumulative Percentage Retained (%) | Percentage Passing (%) |
|---|---|---|---|---|---|
| 5 | 945.5 | 71.84 | 3.52 | 3.52 | 96.48 |
| 0.6 | 895.9 | 1627.18 | 79.75 | 83.27 | 16.73 |
| 0.3 | 775.1 | 241.49 | 11.84 | 95.11 | 4.89 |
| 0.00212 | 760.5 | 73.22 | 3.59 | 98.7 | 1.3 |
| Pan | 466.6 | 26.63 | 1.31 | 100 | 0 |

**CONTINUED**

**Result of Particle Size Distribution of Palm Oil Clinker**

| Sieve Size (mm) | Weight of Sieve (g) | Weight of Sample (g) | Percentage Retained (%) | Cumulative Percentage Retained (%) | Percentage Passing (%) |
|---|---|---|---|---|---|
| 10 | 689.54 | 31.06 | 2.47 | 2.47 | 97.53 |
| 5 | 958.01 | 1084.29 | 86.24 | 88.71 | 11.29 |
| 2 | 678.51 | 122.49 | 9.74 | 98.45 | 1.55 |
| 1.16 | 947.3 | 17 | 1.35 | 99.8 | 0.2 |
| Pan | 466.6 | 2.4 | 0.19 | 100 | 0 |

**Result for Slump Test**

| Mix Designation | Height of Slump (mm) |
|---|---|
| Plain UHPC | 180 |
| POC-UHPC5 | 180 |
| POC-UHPC10 | 170 |
| POC-UHPC15 | 150 |

**Result for Compressive Strength Plain UHPC**

| Curing Ages | Compressive Strength ($N/mm^2$) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Average |
| 7 | 50.91 | 68.89 | 38.27 | 52.69 |
| 28 | 77.79 | 86.69 | 76.68 | 78.97 |
| 60 | 87.06 | 85.06 | 73.77 | 81.96 |

**CONTINUED**

**Result Compressive Strength POC-UHPC5**

| **Curing Ages** | **Compressive Strength ($N/mm^2$)** | | | |
|---|---|---|---|---|
| | **Sample 1** | **Sample 2** | **Sample 3** | **Average** |
| 7 | 74.10 | 74.74 | 76.00 | 74.95 |
| 28 | 78.91 | 72.22 | 85.78 | 78.97 |
| 60 | 82.18 | 78.90 | 82.07 | 81.05 |

**Result Compressive Strength POC-UHPC10**

| **Curing Ages** | **Compressive Strength ($N/mm^2$)** | | | |
|---|---|---|---|---|
| | **Sample 1** | **Sample 2** | **Sample 3** | **Average** |
| 7 | 78.43 | 73.85 | 73.81 | 75.36 |
| 28 | 79.23 | 80.84 | 78.89 | 79.65 |
| 60 | 81.43 | 85.49 | 74.80 | 80.57 |

**Result Compressive Strength POC-UHPC15**

| **Curing Ages** | **Compressive Strength ($N/mm^2$)** | | | |
|---|---|---|---|---|
| | **Sample 1** | **Sample 2** | **Sample 3** | **Average** |
| 7 | 50.09 | 64.38 | 60.43 | 58.30 |
| 28 | 54.34 | 56.34 | 60.22 | 60.22 |
| 60 | 67.77 | 68.16 | 71.85 | 69.26 |

**CONTINUED**

**Result Flexural Strength Plain UHPC**

| Curing Ages | Flexural Strength (MPa) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Average |
| 7 | 14.87 | 11.79 | 17.14 | 14.60 |
| 28 | 14.51 | 15.18 | 17.77 | 15.82 |
| 60 | 14.49 | 17.24 | 18.22 | 16.65 |

**Result Flexural Strength POC-UHPC5**

| Curing Ages | Flexural Strength (MPa) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Average |
| 7 | 12.94 | 14.34 | 13.52 | 13.60 |
| 28 | 12.87 | 14.02 | 14.08 | 13.66 |
| 60 | 13.65 | 17.06 | 18.22 | 16.65 |

**Result Flexural Strength POC-UHPC10**

| Curing Ages | Flexural Strength (MPa) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Average |
| 7 | 14.54 | 15.13 | 13.52 | 14.40 |
| 28 | 15.18 | 16.55 | 15.04 | 15.59 |
| 60 | 14.08 | 17.27 | 17.06 | 16.14 |

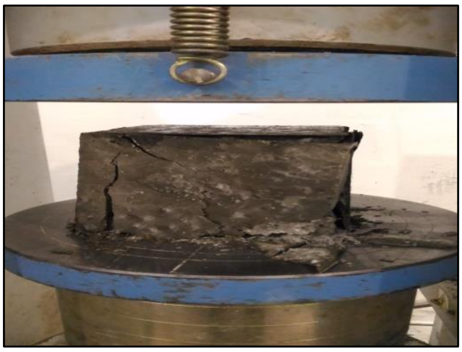
**CONTINUED**

**Result Flexural Strength POC-UHPC15**

| Curing Ages | Flexural Strength (MPa) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Average |
| 7 | 12.62 | 12.51 | 13.40 | 12.84 |
| 28 | 11.41 | 13.90 | 13.98 | 13.10 |
| 60 | 14.55 | 14.49 | 14.09 | 14.38 |

## APPENDIX C

### Photo of Laboratory Work

| | |
|---|---|
|  |  |
|  |  |
|  |  |