DURABILITY OF ULTRA HIGH PERFORMANCE CONCRETE INCORPORATING PALM OIL CLINKER AS AGGREGATE REPLACEMENT

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ABSTRAK

Kemajuan dalam industri pembinaan telah meningkatkan penggunaan konkrit. Hasilnya, permintaan untuk agregat kasar juga meningkat. Peningkatan dalam permintaan agregat kasar telah menyebabkan kepupusan dalam sumber mentah semulajadi seterusnya menyumbang kepada pencemaran. Satu alternatif kepada batuan kerikil sangat diperlukan untuk menyelesaikan masalah ini dan klinker minyak kelapa sawit adalah bahan yang sesuai untuk menggantikan batuan kerikil oleh kerana persamaan sifat bahan dengan agregat semula jadi. Ketahanan konkrit yang mengandungi klinker minyak kelapa sawit ditelusuri dalam kajian ini dan dibandingkan dengan ketahanan konkrit konvensional. Tambahan pula, kesesuaian klinker minyak kelapa sawit di dalam konkrit telah dikaji untuk mampu mengurangkan kebergantungan kepada agregat semula jadi di dalam penghasilan konkrit. Konkrit yang mengandungi klinker minyak kelapa sawit ialah sejenis konkrit yang mana mempunyai agregat semula jadi yang diganti dengan klinker minyak kelapa sawit sebanyak 5%, 10% dan 15% dan menghasilkan satu bancuhan konkrit yang baru. Ketahanan kedua-dua jenis konkrit ditentukan dalam tiga ujian ketahanan. Ujian ketahanan untuk kedua-dua jenis konkrit adalah ujian kuantiti, ujian penyerapan air dan ujian penembusan air. Saiz sampel yang digunakan dalam uji kaji ialah 100 mm x 100 mm x 100 mm. Kesemua sampel kiub telah diletakkan di dalam air untuk 7, 28 dan 60 hari sehingga kekuatan maksimum dicapai. Perubahan berat dan keliangan konkrit telah ditentukan dan ketahanan telah dibincangkan dan dibandingkan. Keputusan uji kaji menunjukkan bahawa konkrit konevensional adalah mempunya ketahanan yang lebih berbanding dengan konkrit yang mengandungi klinker minyak kelapa sawit. Dalam ujian penyerapan air, konkrit konvensional mencapai nilai penyerapan air sebanyak 0.651 sementara konkrit yang mengandungi klinker minyak kelapa sawit mencapai nilai sebanyak 0.662. Dalam ujian penembusan air, lebih banyak air yang menembusi ke dalam konkrit dengan klinker minyak kelapa sawit berbanding konkrit konvensional. Ketahanan konkrit dikaitkan dengan keliangan dan kebolehtelapan konkrit. Daripada kajian, ini menujukkan bahawa konkrit konvensional mempunyai ketahanan yang baik berbanding konkrit dengan klinker minyak kelapa sawit. Walaubagimanapun, ketahanan konkrit minyak kelapa sawit masih boleh diterima pakai dan penggunaan sebahagian klinker minyak kelapa sawit sebagai pengganti agregat kasar mampu mengurangkan kebergantungan kepada bahan semula jadi di dalam industri konkrit.

ABSTRACT

The advancement in the construction industry has promoted the utilization of concrete. Hence, the market for the coarse aggregate is also increased. The increase in demand on the coarse aggregate has led to the depletion of these natural resources thus contributed to the pollution. An alternative to the gravel is required to solve the problem and palm oil clinker is the appropriate substances that can replace the gravel because of its similar properties to the natural aggregate. The durability of the concrete incorporating palm oil clinker was studied in this research and being compared to the durability of the conventional concrete. Furthermore, the suitability of palm oil clinker in the concrete was studied to reduce the reliance of the natural aggregate in the production of concrete. Palm oil clinker concrete is a type of concrete where of the coarse aggregate was replaced by 5%, 10% and 15% of palm oil clinker and produce a new concrete mix. The durability of both of concretes was determined in three durability tests. The tests for durability of the concrete are water absorption test, sorptivity test and water penetration test. The size sample used for the test is 100x100x100 mm. All the cubes samples were cured in the water for 7, 28 and 60 days until it reach the maximum strength. The change in mass and the porosity of the concrete was determined and the durability properties was discussed and being compared. The result shows that the conventional concrete is more durable compared to the concrete incorporate palm oil clinker. In the sorptivity test, conventional concrete has sorptivity value about 0.651 while palm oil clinker concrete was about 0.662. In term of water penetration, more water was penetrated in palm oil concrete compared to the conventional concrete. The durability of the concrete was related to the porosity and permeability of the concrete. From the result, it shows that concrete with have higher porosity is more permeable to the solution and cause matrix destruction. That described that the conventional concrete has better durability than palm oil clinker concrete. Nevertheless, the durability of palm oil clinker is still acceptable and the partial used of the palm oil clinker as coarse aggregate replacement can reduce the dependency of natural resources in the concrete industry.

TABLE OF CONTENT

DECLARATION

TITLE **PAGE**

ACKNOWLEDGEMENTS **ii**

ABSTRAK **iii**

ABSTRACT **iv**

TABLE OF CONTENT **v**

LIST OF TABLES **ix**

LIST OF FIGURES **x**

LIST OF SYMBOLS **xi**

LIST OF ABBREVIATIONS **xii**

CHAPTER 1 INTRODUCTION **1**

1.1 BACKGROUND 1

1.2 PROBLEM STATEMENT 3

1.3 RESEARCH OBJECTIVES 4

1.4 SCOPE OF STUDY 4

1.5 RESEARCH SIGNIFICANT 5

CHAPTER 2 LITERATURE REVIEW **6**

2.1 INTRODUCTION 6

2.2 PALM OIL INDUSTRY 7

2.3 WASTE FROM PALM OIL INDUSTRY 7

2.4 CEMENT 8

2.5 AGGREGATES 10
2.6 PALM OIL CLINKER 11
2.7 WATER 11
2.8 DURABILITY TEST 11
  2.8.1 WATER ABSORPTION TEST 12
  2.8.2 SORPTIVITY TEST 13
  2.8.3 WATER PENETRATION TEST 13

CHAPTER 3 METHODOLOGY 15

3.1 INTRODUCTION 15
3.2 PREPARATION OF MATERIALS 16
  3.2.1 Ordinary Portland Cement 16
  3.2.2 Fine Aggregate 17
  3.2.3 Coarse Aggregate 17
  3.2.4 Water 18
  3.2.5 Super Plasticizer 18
  3.2.6 Palm Oil Clinker 19
3.3 CONCRETE MIX DESIGN 20
3.4 TEST FOR FRESH CONCRETE 21
  3.4.1 Slump Test 21
3.5 TEST FOR HARDENED CONCRETE 21
  3.5.1 Water Absorption Test 21
  3.5.2 Sorptivity Test 22
  3.5.3 Water Penetration Test 23

CHAPTER 4 RESULTS AND DISCUSSION 24

4.1 INTRODUCTION 24

4.2 AGGREGATE CHARACTERISATION 24

4.2.1 Sieve Analysis Test 25

4.3 FRESH CONCRETE PROPERTIES 28

4.3.1 Slump Test 28

4.4 DURABILITIES TEST 29

4.4.1 Water Absorption Test 29

4.4.2 Sorptivity Test 33

4.4.3 Water Penetration Test 37

4.5 CONCLUDING REMARKS 39

CHAPTER 5 CONCLUSION 40

5.1 INTRODUCTION 40

5.2 CONCLUSION 41

5.3 RECOMMENDATIONS 41

REFERENCES 42

APPENDIX A 45

APPENDIX B 46

APPENDIX C 47

APPENDIX D 48

APPENDIX E 51

APPENDIX F 55

APPENDIX G 58

APPENDIX H 59

APPENDIX I **60**

APPENDIX J **61**

LIST OF TABLES

Table 2.1 Types of cement according to ASTM C 150 9
Table 3.1 Mix proportion of UHPC and series of clinker-UHPC 20
Table 4.1 Coarse aggregates sieve analysis result 25
Table 4.2 POC sieve analysis result 26
Table 4.3 Fine aggregate sieve analysis result 27
Table 4.4 Slump Test 29
Table 4.5 Water Absorption for 7 days 30
Table 4.6 Water Absorption for 28 days 30
Table 4.7 Water Absorption for 60 days 31
Table 4.8 The weight of concrete according to time for 7 days 33
Table 4.9 The weight of concrete according to time for 28 days 34
Table 4.10 The weight of concrete according to time for 60 days 36

LIST OF FIGURES

Figure 2.1 Palm oil waste sources 8
Figure 3.1 Flow chart of this research 15
Figure 3.2 Ordinary Portland Cement 16
Figure 3.3 Fine Aggregate 17
Figure 3.4 Coarse Aggregate 18
Figure 3.5 Palm Oil Clinker 19
Figure 3.6 Water Absorption Test 22
Figure 4.1 Grading curve for coarse aggregates 26
Figure 4.2 Grading curve of POC 27
Figure 4.3 Grading curve of fine aggregates 28
Figure 4.4 Water Absorption Percentage for 7 days 30
Figure 4.5 Water Absorption Percentage for 28 days 31
Figure 4.6 Water Absorption Percentage for 60 days 32
Figure 4.7 Performances of sorptivity test for 7 days 34
Figure 4.8 Performances of sorptivity test for 28 days 35
Figure 4.9 Performances of sorptivity test for 60 days 36
Figure 4.10 Depth of water penetrate at 7, 28 and 60 days 38
Figure 4.11 Effect of POC on sorptivity of concrete 38

LIST OF SYMBOLS

mm	Millimetre
%	Percentage
kg/m^3	Kilogram per cubic metre
µm	Micrometre
N/mm^2	Newton per millimetres square
±	Plus-minus
ºC	Degree Celsius
mm/min$^{0.5}$	Milimeter per minutes$^{0.5}$
g	Gram

LIST OF ABBREVIATIONS

UHPC	Ultra High Performance Concrete
POC	Palm Oil Clinker
OPS	Oil Palm Shell
POFA	Palm Oil Fuel Ash
ASTM	American Society for Testing and Materials
BS	British Standard
HPC	High Performance Concrete
SiO2	Silicon Dioxide
Al_2O_3	Aluminium Oxide
Fe_2O_3	Iron (III) Oxide
OPSC	Oil Palm Shell Concrete
BCCFA	Bone China Ceramic Fine Aggregate
OPC	Ordinary Portland cement
NSC	Normal Strength Concrete
CSH	Calcium Silicate Hydrate
min	minutes

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Construction industry is now becoming a phenomenal in world. Every country in the world is competing to show who have the best development. The development in the property and buildings industries has a direct relationship with the rapid growth of construction industries. Urbanisation elementary has boosted the rate of population of people. Hence, construction industry growth is anticipated to rise in 10 years future ahead especially in infrastructures and housing segment.

As the construction industry is undergoing evolution, same goes to concrete technology which are known as ultra-high performance concrete (UHPC). UHPC has been characterized by a very low water- binder ratio, a very high cement content which is the amount is more than twice the amount in ordinary concrete and uniformly distribution of the reinforcing components (Liu, El-tawil, Hansen, & Wang, 2018). UHPC have been widely used in construction of bridges and highways (Li, Tan, & Yang, 2018). The material is likely to make a considerable contribution to handle the challenges in high capacity, mechanical strength, durability, ductility and energy absorption capacity (Zhou & Qiao, 2018).. Despite of every pro, the thought that the effect of this industrial growth will harm the environmental and changes in climate. For instance, the production of cement which is a vital raw material in construction will causes extreme production of carbon dioxide in environment which will cause increment in in temperature which known as greenhouse effect. Due to accumulation of construction needed, huge amount of concrete is needed. Cement has high demand rate in market. Due to this, research have been conducted in order to find suitable material that can replace the cement by investigating the effectiveness and efficiency of waste materials (E. Aprianti, P. Shafigh, S. Bahri et al.,2015). For instance, according to research by (S, 2016) , slag have been used to replace the cement in the research. Fly ash, palm oil fuel ash and silica fume are among popular raw material that can be used to replace the original cement because they are waste material that can be processed as cement replacement and they emit low amount of carbon dioxide.

As a reminder, cement is not the only material used in construction. An aggregate also is important raw material used in concrete. Amount of aggregate is quite worrying because it is getting depleted day by day as the use of aggregate is not only applicable to construction industry. Aggregate is non-renewable natural resources because it is been produced by the earth and sadly about to depleted in time. Aggregate that been used in construction industry is supplied from quarry. As the aggregate source is getting depleted, an alternative to this source is introduced.

Palm oil clinker (POC) is an alternative to the course aggregate due to suitability to replace the aggregate and can improve better in concrete mix. Replacement of POC in concrete mix produced a lightweight concrete. POC is waste material that been produced after the palm oil shell been processed. Uses of by-product from palm oil industry such as POC and oil palm shell (OPS) should be appraise as lightweight aggregates due to the limitation of natural waste and the output should be more sustainable (R. Ahmmad, M. Zamin, U. Alengaram et al., 2016). They carried out research on application of POC aggregate and POC powder to replace the coarse aggregate and filler materials to produce lightweight concrete.

POC is an option to the coarse aggregate due to its similarity physical characters which is hardened stone. POC comes in solid form and is a lightweight material with sharp and broken edges, and flaky and have irregular shape (F. Abutaha, H. Razak, H. Ibrahim et al., 2018). The cost of getting this waste very low since it has low commercial value in market. Hence, by using this by-product can reduce the cost of construction by reducing the cost of getting the raw material since the product is a waste product and we can get this material for free from the palm oil factory.

1.2 PROBLEM STATEMENT

Consciousness of environmental issues of waste disposal and high demand toward construction material like stone and pebbles. The argument that construction industry need to discover and acquire material replacement especially from recycle material or waste material. Exploitation towards the solid waste is very hassle. Using a waste material in construction industry is one of the approach to ensure that waste material have been manage correctly and may reduce the area of landfill for waste material disposal. Palm oil clinker (POC) is one of the waste materials that are available in Malaysia. Malaysia is the second largest producing country in producing palm oil in the world. There are about 200 palm oil mills that are operated in Malaysia and in a year they can produce about 100 tonnes of palm oil fuel ash (POFA) (Kabir et al., 2017a). Due to this enormous industry that contribute to the waste, Malaysia is responsible to handle the huge amount of the solid wastes such as OPS, POC, empty fruit bunches and palm oil mill effluent (Huda, Zamin, Jumat, & Islam, 2016). With amount of palm oil industry are expected to increase in the future, using POC as an alternative construction material is a right step to preserve the environment.

Reducing the number of natural aggregate used is also one of the ways to preserve the environment. Overuse of aggregate can give a bad impact to the environment. Thus, study on uses POC as an alternative coarse aggregate in construction industry with a view of effective utilization of the resources and environmental protection is essential. In order to examine the effectiveness of POC as a partial coarse aggregate replacement in UHPC and it applicability, research is conducted in order to solve the problems that may in future.

UHPC with normal aggregate may easily attack due to weak durability of concrete. The replacement of waste material into UHPC is fortified in order to improve the durability of the UHPC itself. POC is a type of coarse aggregate that is hard as aggregate but with better aspect which is light compared to the natural aggregates. Furthermore, POC have the potential to gain better durability compared when the normal aggregate is used to be prove in this matter.

1.3 RESEARCH OBJECTIVES

This study is conducted to achieve the following objective:

i) To investigate the effect of palm oil clinker as partial aggregate replacement in ultra-high performance concrete towards its durability on water absorption.

ii) To investigate the effect of palm oil clinker content as partial aggregate replacement towards durability of ultra-high performances concrete on mass loss in sorptivity test.

iii) To investigate the effect of palm oil clinker content as partial aggregate replacement in ultra-high performances concrete durability towards water penetration.

1.4 SCOPE OF STUDY

Durability study is the main focus in this research where durability of UHPC will be tested when normal aggregate is partially replace with the POC. There are four different percentages of POC that will be partially replace the coarse aggregate to test the durability of samples under different proportion in the mix which are 0%, 5%, 10% and 15% from total weight of natural aggregates. The samples will be labelled as UHPC0, UHPC5, UHPC10 and UHPC15 respectively. In this research the cube sample of 100 mm x 100 mm x100 mm will be used. The UHPC cube samples will be casted for 7, 28 and 60 days.

There are three test involved to test the durability of UHPC which are water absorption test, sorptivity test and also water penetration test. The test will conducted according to the specification on ASTM or BS stated in appendix. The mass loss of the concrete will be determined. The durability of normal UHPC concrete and UHPC containing POC will be established.

1.5 RESEARCH SIGNIFICANT

In the industry of construction, coarse aggregate is one of vital raw material in production concrete. In the conjunction of improvement in concrete commerce such as high performances concrete (HPC) and UHPC, the need of coarse aggregate such as gravel is plentiful. The exhaustion of natural resources will give big impact to the industry. So, in order to ensure the lacking of the resources can be preserved, the use of alternative materials is significant move to deal with the problems. This will help in preservation of environment by reducing the amount of natural aggregate used to produce concrete.

This study will investigate the chance of waste materials specifically POC as the partial aggregate replacement in UHPC. POC was selected due to accumulation of palm oil industry. Thus, expanding the capacity for landfill where POC is being dumped. To ensure that POC can be replaced the coarse aggregate in UHPC, two types of mixes were prepared during this study and the mixes are control mix and modified mix. The control mix consist 0% of palm oil clinker with 100% used of natural aggregate. The modified mix consist varies percentage of POC.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Concrete is made up of from the basic ingredients of cement. Usually Portland cement, coarse aggregates, fine aggregates and water is used. Besides these main ingredients, there are many materials that can be added up into the concrete mix to improve the quality or the microstructures and consequently the durability properties of concrete. These materials are consisting of admixtures and replacement materials.

In recent years, there are various studies on of concrete in diversifying sources of the material involved. Among the materials involved in the study of which is the aggregate. Among the resulting aggregate consist of crushed glass, material from industrial waste, the construction waste such as crushed brick and many more.

From the observation of several studies, most of the material used in this study consists of waste materials from industry. The evidence can be proved with the aggregate income by disposal of industrial waste material such as POC is likely to be use in concrete mixtures.

Malaysia is the second largest exporter in palm oil industry have produce waste by-product known as POC. The characteristics of clinker are lightweight, porous, have irregular shapes and have low bulk density and specific gravity. In Malaysia, the use of POC as aggregate replacement has been started 30 years ago. Prior to that, POC is only known as industrial waste material and if no effort to recycle this material into something useful it is such a waste as they will be dumped together with the ash and other waste. Since the amount of POC is abundant and have low commercial value in industry, attempts have been made to utilize the clinker as lightweight aggregate in concrete industry.

2.2 PALM OIL INDUSTRY

Malaysia is famously known for the palm oil industry since Malaysia is the second largest exporter of palm oil to the world. Malaysia is recorded has contributed about 37% of palm oil to the world (Dalton, Mohamed, & Chikere, 2017). As there are increases in palm oil cultivation, the demands for the palm oil also increase. According to McCarthy and Zen (2010), a huge amount of solid waste and waste water was produced while processing mill for crude palm oil (CPO). For the last five years, palm oil industry contributes a lot in the gross domestic product for Malaysia which about RM 64.24 billion annually with contribute percentage of 5 to 7 % (Muthusamy et al., 2019). In the first quarter of 2018, palm oil export rate is increase for about 2.37% compared to the previous year. The increasing demand for the palm oil is increase every year so the industry of palm oil is not worrying for the moment.

2.3 WASTE FROM PALM OIL INDUSTRY

With the advancement of palm oil industry, the waste of palm oil is getting worrisome as the waste will create pollution. In the journal article by (Dalton et al., 2017) stated that the solid wastes that been produced in 2015 is about 80 million. As as rough approximation, 1 kg palm oil can generates about 4kg dry biomass (Skariah, Kumar, & Sahan, 2017) The Figure 2.1 below shows that from a single palm oil fruit brunch can lead to many production of waste. Considering of various types of solid waste of palm oil, the management of waste is handling differently. About 70% of raw material of solid waste product is produce in the form of fibres, nutshells and empty fruit brunches. In order to generate electricity, the fibres and nutshells are widely used as a biomass fuel to replace fossil fuels (M. Karim, H. Hashim, H.Razak et al, 2017). If the disposal waste is not properly handling, it might create a lot of problem such as a disposal problem. Land in Malaysia is currently cannot handle the wastage that is being increased day by day.

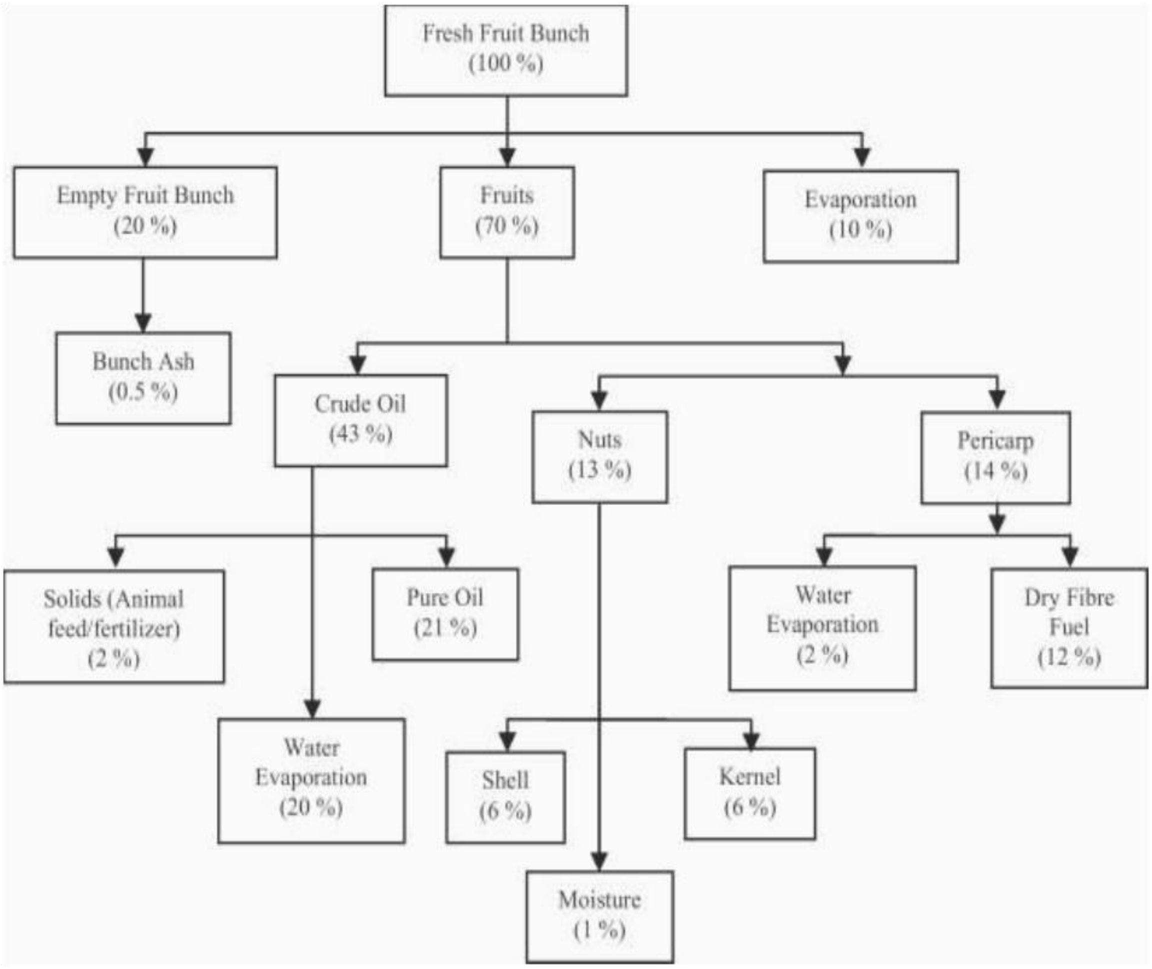


Figure 2.1 Palm oil waste sources

2.4 CEMENT

ASTM C 150 defines Portland cement as hydraulic cement produced by pulverizing clinkers containing hydraulic calcium silicates, normally involving one or more of the forms of calcium sulphate as an underground addition. Hydraulic cements not only harden by reacting with water but also form a water-resistant product. Table 2.1 has listed the types of cement according to ASTM C 150, Standard Specification for Portland Cement.

Table 2.1 Types of cement according to ASTM C 150

Types of Portland Cement	Characteristics
Type I	Used when the special properties specified for any other type are not required. No limits are imposed on any other of the four principal compounds.
Type IA	Air-entraining cement for the same uses as Type I, where air-entrainment is required.
Type II	Used when moderate sulphate resistance or moderate heat of hydration is needed. This will limits tricalcium aluminate, C_3A content of the cement to maximum 8%.
Type IIA	Air-entraining cement for the same uses as Type II, where air-entrainment is desired.
Type III	Being used when high early strength is required. Limits the C_3A content of the cement to maximum 15%.
Type IIIA	Air-entraining cement for the same function as Type III, where air-entrainment is needed.

Type IV	Use when low heat of hydration is needed. Requires maximum limits of 35% and 7% on C_3A and C_3S respectively. And also minimum of 40% of C_2S in the cement
Type V	Used when high resistance of sulphur is needed. Has a maximum limit of 5% on C_3A which applies when the sulphate expansion test is not required.

Adapted from: ASTM C150, Standard Specifications for Portland Cement.

2.5 AGGREGATES

Aggregates are generally natural mineral aggregates that consist of gravel and sand. Aggregates usually can be categorizes in coarse aggregates and fine aggregates subjected to the size of particles. Coarse aggregates usually is a larger particles of gravel which have size more than 4.75 mm while fine aggregate have a size smaller than 4.75 mm. According to the (Wilson & Kosmatka, 2016), particles shape and size and also surface texture of the aggregates will influenced the properties of the concrete mix especially the fresh mixed concrete and hardened properties. In order to produce a workable concrete, rough- textured, angular and elongated particles need more water. However, an angular and rough particle will strengthen the bond between the paste and aggregate in the mix. This is due to the interlocking effect. Reactive aggregates should be banned from used because it will activate alkali-aggregate reactivity known as alkali-silica reaction. The reaction will enhance the formation of gel that will cause swelling as it will attract water from the cement paste. As the result, the gel will create a pressure and cause expansion and lastly will crack the cement. Besides that, aggregates play an important role in liquid transport as the water absorption properties and quality of the interfacial transition zone which can accelerate and or decrease the entrance of liquid (Dodds et al., 2017).

2.6 PALM OIL CLINKER

Malaysia is now improved toward bio-technology industries which focus generates the large amounts of agriculture products. Palm oil is not left behind due to the advancement in technologies in palm oil industries. It was expected that palm oil industry growth will leap over tremendously. As the advancement of this industry will resulting in increasing of waste. POC is one the by-product from palm oil industry that is produce by the incineration process. Among the characteristics for POC are it is generally porous, have irregularly shape with good lightweight criteria and can be obtained in a large chunks. POC can be used as an ideal alternative aggregate when it is crushed and sieved into suitable sizes (Ibrahim, Razak, & Abutaha, 2017)

In this research, POC will be used as a partial conventional aggregate replacement in the mixture. POC have been used due to their property that is light and have hardened properties like a rock. The study will focus on the durability of UHPC that incorporated POC inside the concrete. There are many factors that might affect the durability of the UHPC such as aggregate quality, permeability, curing period, concrete compaction and else. In the research journal by (Kabir et al., 2017b).POC is in black colour, it is a non-biodegradable that contain SiO_2, Al_2O_3 and Fe_2O_3.

2.7 WATER

All type of water can be used for mixing as long as it is must be clear from any impurities. The water also must be free from odour and tasteless. For the making of UHPC, only a little amount of water is needed. So the water cement ratio for UHPC will lowered. Too many impurities in the water may effect the setting time of concrete as well as the concrete strength. It also will effect the staining, corrosion of reinforcements, the volume instability and also reduced the durability of the concrete.

2.8 DURABILITY TEST

2.8.1 WATER ABSORPTION TEST

Water absorption test is state to bulk the penetration of water inside the concrete in a certain period of time. Concrete that subjected to low permeability is vital in determine the durability of the concrete. The rate of uptake of water inside the concrete is relying on the number of pores in the concrete. Water will seeps through the pore that present in the concrete due to the aggregate size and uneven angle which create void between them. The higher the number of pore inside the concrete the higher the chances for water to penetrate inside the concrete and more water will be absorbed by the concrete.

Water absorption test will require the specimen to be dried until the samples achieve a constant weight or until all the water is totally removed from the specimen. The specimens need to be fully dried and weighted before them being immersed in the water. The changes in weight of the specimens after the concrete being immersed in water for a certain times is recorded as the percentage of water absorb by the concrete. The average value of three cubes is taken for the result to be more accurate. The lesser the water penetrate inside the specimens, the higher the durability of the concrete. Moreover, the water absorption rate is directly related to the relationship of the resistance of chemical diffusion into concrete.

According to the research by (Momeen, Islam, Mo, & Alengaram, 2016) water absorption test have been used to define the durability of the concrete containing POFA as partial cement replacement and OPS as partial aggregate replacement. The durability of concrete is tested for oil palm shell concrete (OPSC) between POFA-blended OPSC and OPSC without POFA. The result shows that water absorption rate for concrete with POFA-blended OPSC is higher compared to the concrete without POFA. According to the research by (Kanadasan & Razak, 2015), the irregularities of POC shape provide a poor interlocking bond to increase the presence of micro voids to give different water absorption characteristics.

2.8.2 SORPTIVITY TEST

Sorptivity test is been carried out to find the ability of the concrete to absorb water by capillarity. Sorptivity has a direct relationship to the permeability and specimen with low sorptivity that has low permeability for the dissemination of chemical solution into the concrete. Hence, the durability of the concrete can be valued through this test. Furthermore, it is a quick and simple process to check the ability of the specimen towards the penetration of water inside the concrete vertically due to the action of surface tension in the capillaries. The uptake of water into the concrete is determined by the force by the capillary. There are few factors that will influence the rate of water uptake by the materials such as liquid density, the solidity of specimens and the region of materials. The sides of the specimens except the bottom part will be sealed to ensure that water can seep only from the bottom side.

According to the ASTM C1585, the technique to measure the rate of water absorption is by determining the mass changes of the specimen after the specimen is in contact with the water for a period of time. Conferring to the (Siddique, Shrivastava, & Chaudhary, 2018) , it was found that the concrete that contain more bone china ceramic fine aggregate (BCCFA) creates more porous structure. Hence, more water is absorbed into the concrete. So the durability for concrete with higher BCCFA is lower. For the research by (Momeen et al., 2016), the higher the replacement of POFA in the OPSC, the higher the sorptivity rate due to the more numbers of porosity in the concrete.

2.8.3 WATER PENETRATION TEST

Water penetration test is important in determining the permeability of the concrete. Water penetration is used to determine the impermeability of concrete by subjected to some pressure. Impermeability is the ability of materials to resist the pressure of water or any other infiltration liquids. Permeability coefficient will reflect the rate of water flowing inside the concrete. The higher the value of permeability coefficient, the faster the flow rates of the water and the weaker the impermeability. The impermeability of specimens not only related to its own hydrophilicity and hydrophobicity but also the porosity. The smaller the porosity and the more the pore is closed, the stronger the impermeability. Hence durability of concrete is also higher.

Agreeing to the (Siddique et al., 2018), their research on BCCFA shows that, the angularity and roughness of BCCFA create a larger voids. So it result a slight high depth in the water penetration. The higher the percentage content of BCCFA, the higher the depth of the water penetrates inside the concretes. Referring to books by (Teichmann & Schmidt, 2004), they concluded that, the permeability of UHPC that is been heat cured has the lowest permeability coefficient thus have a highest durability compared to others.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The inquiry works have been performed to accomplish the objective of the research. The procedures of the lab work comprised the preparation of the material, casting and curing of specimen and laboratory test to test the durability of UHPC are presented in this chapter. Further details and information were explained in the following section. The flow chart of study is shown in Figure 3.1.

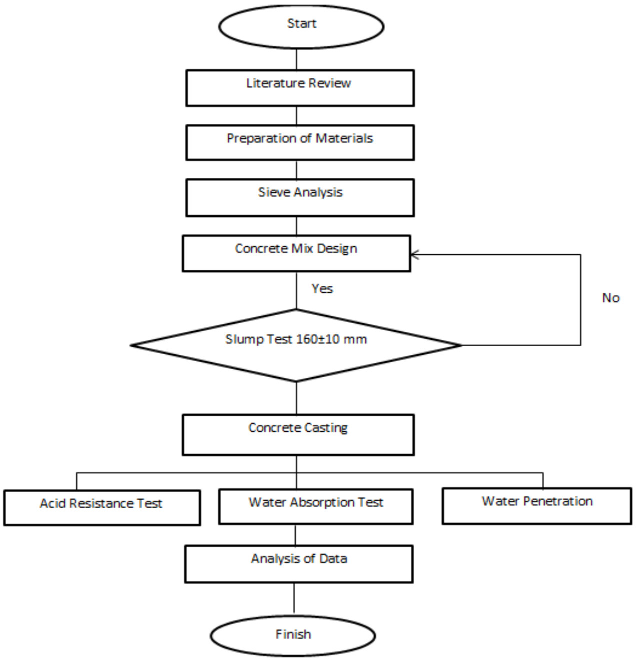


Figure 3.1 Flow chart of this research

3.2 PREPARATION OF MATERIALS

Research was conducted by using Ordinary Portland Cement, sand (fine aggregate), granite and POC (coarse aggregate), super plasticizer and water. POC will be replaced the coarse aggregate in percentage accordingly. All materials used for mixing the concrete will be prepared carefully and stored in suitable place to ensure the materials is in good condition to produce better quality of the specimens.

3.2.1 Ordinary Portland Cement

Cement used in this UHPC production is Orang Kuat Ordinary Portland Cement (OPC) from YTL cement. This cement is certified to MS 522-1:2007 (EN 197-1:2000), CEM I 42.5N/52.5N and MS 52: Part 1: 2003. This type of cement is widely used in concreting work whether in structural concrete work or general concrete work. It is certified to MS ISO 9001, MS 14001 & OHSAS 18001 which is produced under quality assurance, environmental management and health &safety systems. Cement will act as a binding agent for all others material. The cement content used is constant at 800 kg/m^3 for all series of mix proportion of plain UHPC and POC replace in UHPC. Figure 3.2 shows the ordinary Portland cement used.

Figure 3.2 Ordinary Portland Cement

3.2.2 Fine Aggregate

Fine aggregate used in this concrete mix is river sand. The sand used will be ensured free form any impurities before being added into the mix. Sand will be sieved to ensure the size of the sand is even. The sand that passed on 5 mm sieve and retained on sieve 300 µm will be used. Sieve analysis on fine aggregates has been done to determine the grading zone of the fine aggregates following BS 812: Part 1. From the results of the sieve analysis, the fine aggregates fall on grading zone 2. Fine aggregates in concrete are important in filling up the void between the coarse aggregates and can reduce concrete shrinkage.

Figure 3.3 Fine Aggregate

3.2.3 Coarse Aggregate

Type of aggregates that is used in this experiment is gravel. The shape and texture of aggregate that is rough is related to the strength of the concrete due to the bond strength between the aggregate particle and the mix. Crushed aggregate is irregular and angular in shape can provide better strength. The size of aggregate used in this mixture is sieved passing 10 mm and retained on 5mm sieve.

Figure 3.4 Coarse Aggregate

3.2.4 Water

Water is an important element in producing concrete because it will help in hydration process. Water is the main key in bonding the cement and aggregates and play important part in controlling the workability of the concrete and strength. In production of UHPC, only little amount of water is needed. Ordinary tap water was used for mixing and curing the cube specimens. Besides that, water also is use in testing for water absorption and water penetration test. Clean water used ensured to be free from any impurities.

3.2.5 Super Plasticizer

Super plasticizer help to improve workability of UHPC since low amount water is used in the mixture. Super plasticizer is a water reducer admixture which added in order to reduce the water content. Admixtures will help in modifying the properties of the concrete. The admixtures that is use in UHPC mixture is Sika ViscoCrete 2008 PC. In this experiment, the amount of the super plasticizer used for all the mixture is constant which about 4% from the total of cement for plain UHPC and 3% from the total cement for the UHPC with POC.

3.2.6 Palm Oil Clinker

Palm Oil Clinker (POC) is a waste product from palm oil industry that was supplied by Felda Factory located at Lepar Hilir in Gambang, Pahang. POC was used as a partial replacement to replace coarse aggregate in production of UHPC. About 5%, 10% and 15% of POC is used to produce a series of partial clinker UHPC. POC is the by-product form the process of incineration of palm oil shell that is hardened when left exposed in the air. POC have a flaky, porous and actually light is weight with rough and sharp broken surface. The large chunk of POC is processed to obtain the desired size needed. In this experiment, the processed POC was sieve and POC that passing 10 mm sieve and retained 5 mm sieve is used. The Figure 3.5 below show the shape of POC after it is processed.

Figure 3.5 Palm Oil Clinker

3.3 CONCRETE MIX DESIGN

Concrete mix design is used to design the specific grade of concrete by calculating the proportion of the materials like cement, aggregates, super plasticizer and water. In this research, a mix proportion of basic UHPC and three series of UHPC incorporate clinker were prepared. Plain UHPC or known as UHPC0 mix used the basic material without adding palm oil clinker (POC) into the mix. Plain UHPC play roles as control mix. In the meantime, for mix proportion of 5%, 10% and 15% of clinker UHPC, it will replace partial coarse aggregate with POC. The mix with POC will be design as UHPC5, UHPC10 and UHPC15 respectively. W/c ratio of 0.2 been applied in the concrete mix design and the concrete grade must achieve 100 N/mm^2 at 28 days.

Table 3.1 Mix proportion of UHPC and series of clinker-UHPC

Mix Designation	**Raw Materials (kg/m3)**					
	OPC	Aggregate	Sand	Super Plasticizer	Water	POC
UHPC0	880	433	800	24	160	0
UHPC5	880	411.35	800	24	160	21.65
UHPC10	880	389.60	800	24	160	43.40
UHPC15	880	368.05	800	24	160	64.95

3.4 TEST FOR FRESH CONCRETE

Test for hardened concrete was conducted after mixing of concrete was mixed in the machine.

3.4.1 Slump Test

Concrete slump test is done by following BS 1881: Part 102: 1983. Slump test is used to determine the workability of the fresh concrete form medium to high range. A hollow cone with dimension of 200 mm base diameter, 100 mm top diameter with height of 300mm is used. Before the cone being used, the inner surface of the cone is clean and wet with water. After concrete been mixed, the fresh concrete is poured into the cone. About one third height of the cone is filled with the concrete. The concrete is then is tamp by using tamping rod and about 25 strokes being released on the concrete. Another layer of concrete is added and the step above is repeated until the cone mould is fully filled. The excess concrete at the top of the cone is removed by rolling the tamping rod. The cone is then raised vertically carefully and placed beside the concrete slump. The slump is measured immediately by using a measuring tape and the height of the slump is recorded. The height of slump is measured from the top of cone and the highest point of the fresh concrete. The range of the slump for UHPC is around 170±10 mm. If the concrete is not achieving that range, the workability is failed and the mix needs to be design again.

3.5 TEST FOR HARDENED CONCRETE

The durability of concrete can be determined after the concrete is hardened.

3.5.1 Water Absorption Test

Water absorption test is conducted by following ASTM C642. The concrete size 100 mm x 100 mm x 100 mm used and 36 specimen is been used which are 9 cubes for UHPC0, UHPC5, UHPC10 and UHPC15 respectively. All the cubes were dried in the oven for 48 hour at 105±5 °C and were cured or 7, 28 and 60 days in water. After that, all the specimens ware taken out from oven and let cooled at room temperature for 24 hour. A container was filled with water until the level of water is adequate to cover the top of the specimen. The specimens were weighted and immersed inside the water immediately after. The cubes were immersed in water for 30 minutes and 72 hour interval. Each specimen was weighted and the result was recorded after 30 minutes and 72 hour immerse in water tank and the increase in cube weight per surface area was calculated.

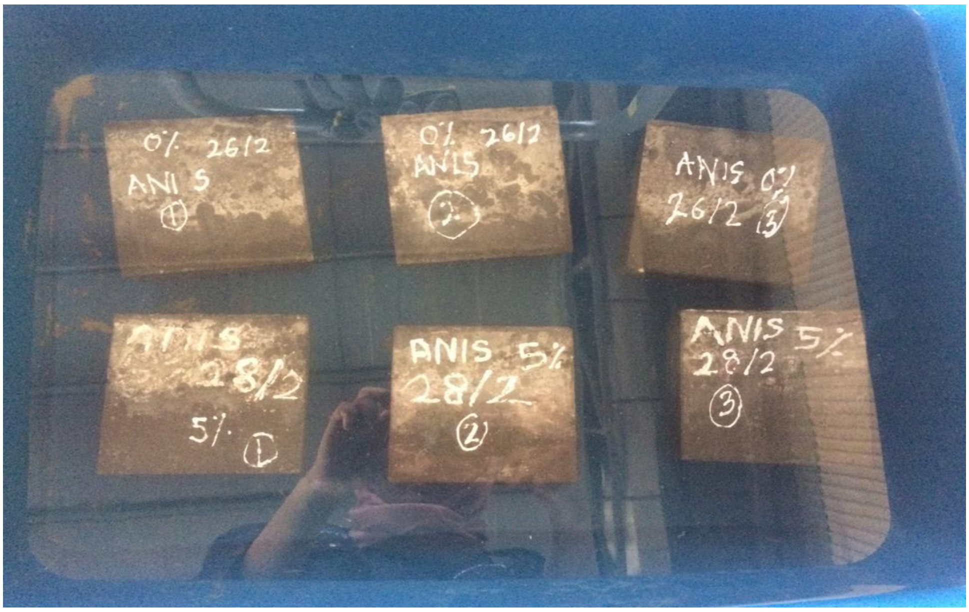


Figure 3.6 Water Absorption Test

3.5.2 Sorptivity Test

Sorptivity test is conducted by following standard ASTM C1585 and research by (Kabir et al., 2017) on study on performance evaluation and some durability characteristics of environmental friendly palm oil clinker based geopolymer concrete. 36 cubes with size 0f 100 mm x 100 mm x 100 mm is been used which is 9 cubes for UHPC0, UHPC5, UHPC 10 and UHPC15 respectively. All the cubes were dried in an oven for 48hour at the temperature of 105±5 °C. It was then being taken out from the oven and let cooled at room temperature for 24 hour. Then, the sides of the concrete cubes are coated with the epoxy resin to ensure the water can only penetrate from the bottom of the cubes. The specimens were then immersed in the water tank that was filled with water. The level of water must not exceed 5 mm beyond the base of the specimen. The weight of the specimen was recorded at intervals of 1, 4,9,16,25,36,49 and 64 minutes. The volume of the water that has being absorbed per unit area was calculated as the sorptivity coefficient in unit mm/min$^{0.5}$.

3.5.3 Water Penetration Test

Water penetration test is done to test the concrete permeability towards water under a certain pressure. Water penetration test was conducted complying to the (Siddique et al., 2018) according to BS EN 12390-8. Concrete cube with size of 100 mm x 100 mm x 100 mm was used in this test. There are total 36 cubes have been used in this test which are 9 cubes for UHPC0, UHPC5, UHPC10 and UHPC15 respectively. The specimens were dried in the oven for 5 days at 60ºC. Then, the cubes were subjected to water pressure at 0.5 N/mm^2 for 72 hour. The cubes is then were split into half and the water penetration depth was measured. The average value of three cubes is calculated.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will analyses about the result and discussion of the durability of ultra high performances concrete incorporating palm oil clinker as aggregate replacement and compare with the durability of the control concrete. The optimum percentage of the coarse aggregate replacement is 5% of POC. The result and analysis of that will be discussed in this chapter will focused on the durability of the UHPC that contains clinker and without clinker. The durability tests that will be involved are water absorption test, sorptivity test and also water penetration test. The gradation of aggregate and POC was determined by the sieve analysis. All the results and analysis will be explained and be shown through this chapter.

4.2 AGGREGATE CHARACTERISATION

The aggregate types, shape, size, angularity is very important in the concrete mix design especially in determining the properties of fresh hardened concrete. A suitable aggregate is important to design particular grade of concrete.

4.2.1 Sieve Analysis Test

Replacement of POC in the mixtures consists of 5%, 10% and 15% from the total weight of coarse aggregates in the concrete mix design. The coarse aggregates, POC and fine aggregate analysis result is shown in the Table 4.1, Table 4.2 and Table 4.3. For coarse aggregate and POC in size between 10 mm to 5 mm shows the highest percentage retained which are 80.12% and 86.24% respectively. For the fine aggregates, size between 0.6 mm to 5 mm shows the highest retained percentage which 79.75%. The grading curve of the POC, coarse aggregate and fine aggregates is shown in the Figure 4.1, Figure 4.2 and Figure 4.3

Table 4.1 Coarse aggregates sieve analysis result

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

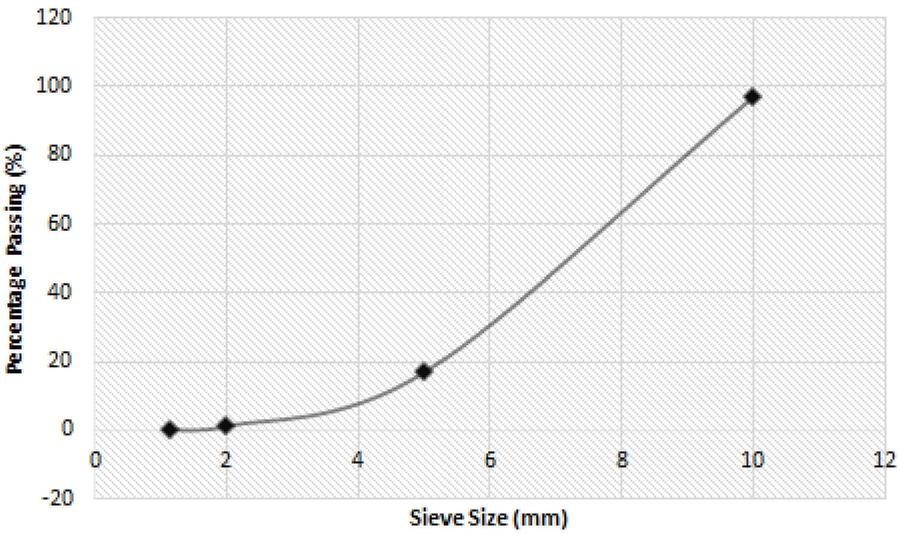


Figure 4.1 Grading curve for coarse aggregates

Table 4.2 POC sieve analysis result

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

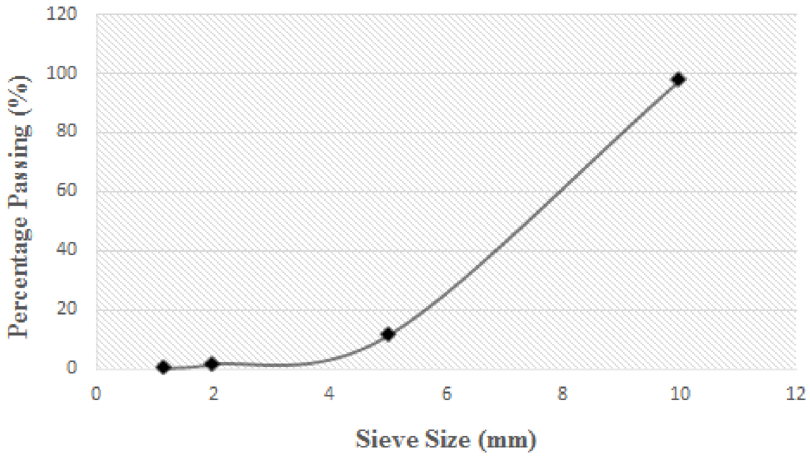


Figure 4.2 Grading curve of POC

Table 4.3 Fine aggregate sieve analysis result

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

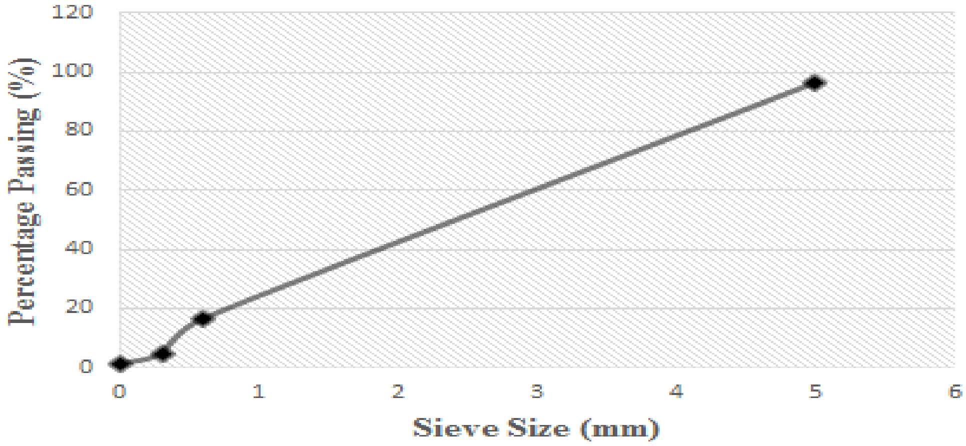


Figure 4.3 Grading curve of fine aggregates

4.3 FRESH CONCRETE PROPERTIES

Workability of concrete is important properties in determine whether the concrete is easy to be mixed and transported or not.

4.3.1 Slump Test

Slump test is conducted in order to identify the acceptability of the fresh concrete mix in terms of workability and consistency in mixing before it set. The result of the slump test is affected by the water-cement ratio. The range for the slump test must be in range of 160±10 mm. The fresh concrete is considered failed if the slump test is fall out of the range. Slump can be categorized in three categories which are true slump, shear slump and collapse slump. The only slump that is acceptable is true slump and can be applied in the work due to it desirable water content and cohesiveness. The slump test result for normal concrete and palm oil clinker concrete with water-cement ratio was shown in Table 4.4.

Table 4.4 Slump Test

Type of Mix	Slump Value (mm)	Type of Slump
UHPC0	160	True Slump
UHPC5	170	True Slump
UHPC10	170	True Slump
UHPC15	160	True Slump

4.4 DURABILITIES TEST

Durability of a concrete is the ability or tendency of concrete to resist the absorption of water. There are few durability tests have been conducted such as water absorption, sorptivity test and water penetration test.

4.4.1 Water Absorption Test

Water absorption test was conducted to determine the durability of concrete regarding to the amount of water that can be absorbed into the concrete and the porosity of the concrete that was tested in two interval period. The average result of the percentage of water absorption of UHPC0, UHPC5, UHPC10 and UHPC15 that was cured for 7, 28 and 60 days were shown in Table and Figure.

Table 4.5 Water Absorption for 7 days

Sample	Water Absorption (%)	
	30 minutes	72 hours
UHPC0	0.370	0.709
UHPC5	0.779	1.366
UHPC10	0.645	1.505
UHPC15	0.932	1.861

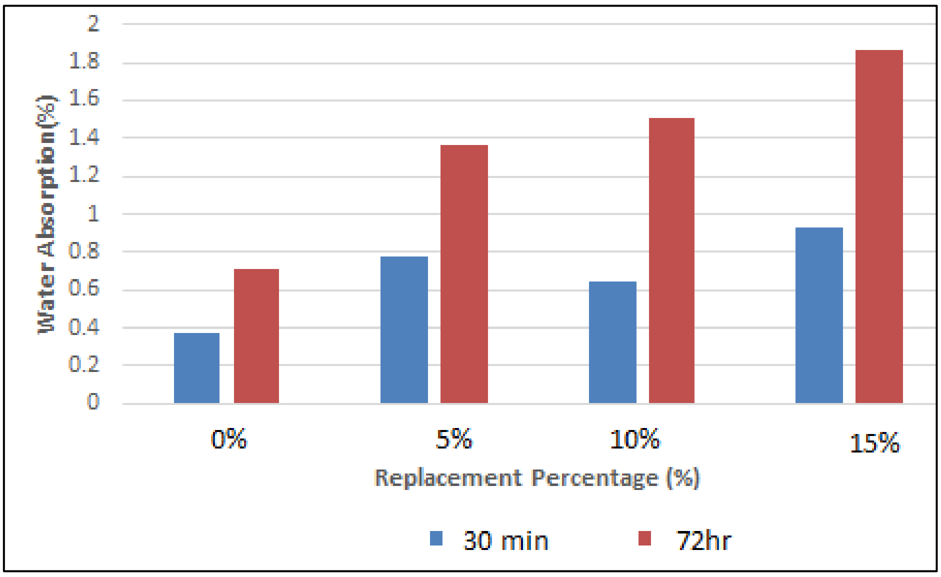


Figure 4.4 Water Absorption Percentage for 7 days

Table 4.6 Water Absorption for 28 days

Sample	Water Absorption (%)	
	30 minutes	72 hours
UHPC0	0.386	0.557
UHPC5	0.314	0.528
UHPC10	0.292	0.684
UHPC15	0.333	0.707

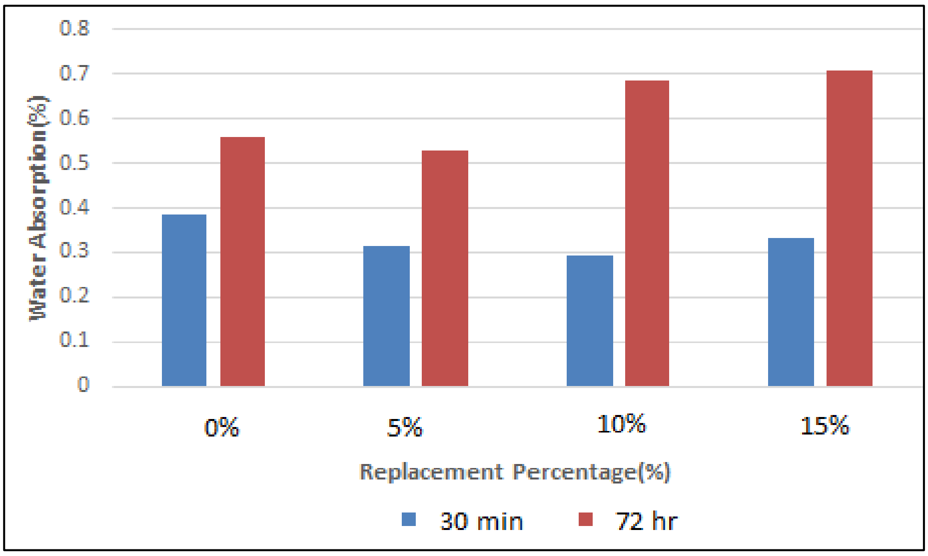


Figure 4.5 Water Absorption Percentage for 28 days

Table 4.7 Water Absorption for 60 days

Sample	Water Absorption (%)	
	30 minutes	72 hours
UHPC0	0.533	0.790
UHPC5	0.456	0.809
UHPC10	0.335	0.847
UHPC15	0.462	1.133

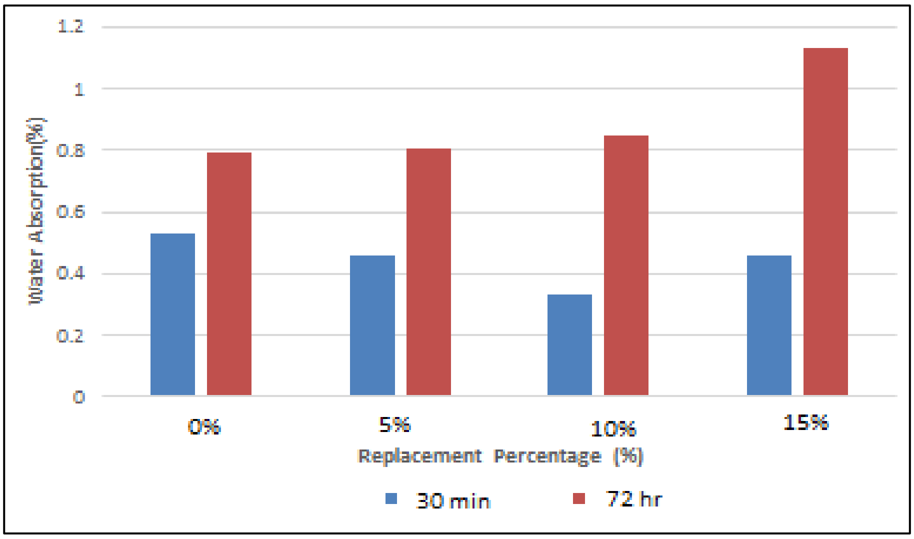


Figure 4.6 Water Absorption Percentage for 60 days

Results shows that the water absorption of UHPC containing various percentage of POC. The water absorption values were below 1.9% for all specimens. The value of water absorption is still in range as recommended by (RESPLENDINO, 2004), where the water porosity percentage for UHPC should be in range of 1.5-5%. The occurrences of chemical reaction in porous UHPC assist in absorbing the water in low quantity. The result shows that the lowest rate of absorption is for UHPC0 for 7, 28 and 60 days for 30 minutes and 72 hour interval. The water absorption pattern is increase with the increase of POC inside the mix. This is proved by (Kabir et al., 2017) in his research when the water absorption is increase as the POC aggregate size increase due to characteristics of POC that is porous and flaky which created voids in the concrete. This increase in absorption is probably due to the porous structure of POC particles. Porous structures of POC act as a storage place for water. Apart of that, the increase in percentage of water absorption proved the increase in percentage of porosity of the concrete. That shows that the concrete is having a less void inside the concrete hence the concrete is denser. According to the (Abbas, Nehdi, & Saleem, 2016), UHPC shows a very low water absorption capacity which approximately about 10 to 60 time lesser than high performances concrete (HPC) and normal-strength concrete (NSC). From the result, it can be concluded that more POC in the mixture will increase the absorption of water in the specimen.

4.4.2 Sorptivity Test

Sorptivity test was carried out to evaluate the tendency of concrete to absorb water vertically upward. The water was transmitted by capillary suction through the pores in the concrete and the rate of water transport was depending on the permeability of the concrete. For instance, the lower the value of sorptivity, the higher the resistance of concrete towards water absorption. The value of sorptivity illustrates the water mass uptake by concrete from the bottom surface, in unit of $mm^3/mm^2/mm^{1/2}$. The results of the cumulative weight for sorptivity test for 7, 28 and 60 days are shown in the Table 4.8, Table 4.9 and Table 4.10 and results of cumulative water absorption was shown in Figure 4.7, Figure 4.8 and Figure 4.9.

Table 4.8 The weight of concrete according to time for 7 days

Time (min)	**Cumulative Weight (g)**			
	0%	5%	10%	15%
0	0.000	0.000	0.000	0.000
1	1.363	1.507	2.000	2.063
4	2.067	2.460	2.670	2.863
9	2.170	2.600	3.060	3.817
16	2.310	3.140	3.227	4.453
25	2.433	3.340	3.657	5.107
36	2.753	3.697	3.723	6.097
49	2.970	3.943	3.953	6.617
64	3.707	4.220	4.157	6.743

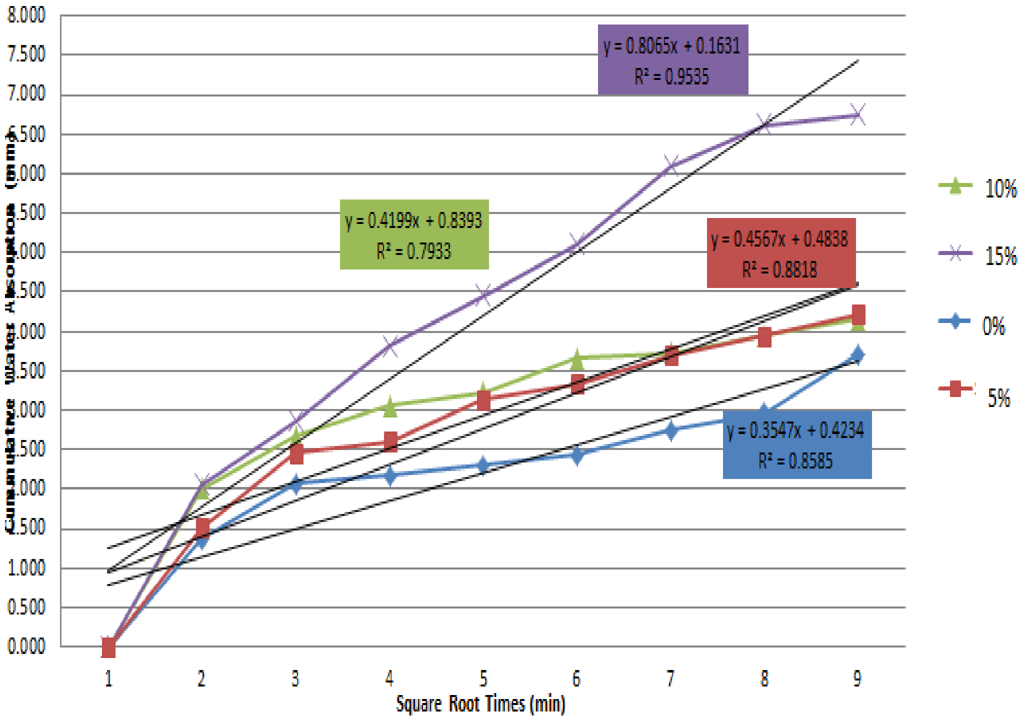


Figure 4.7 Performances of sorptivity test for 7 days

Table 4.9 The weight of concrete according to time for 28 days

Time (min)	**Cumulative Weight (g)**			
	0%	5%	10%	15%
0	0.000	0.000	0.000	0.000
1	0.540	1.067	1.330	1.253
4	0.850	1.317	1.603	1.723

9	1.370	1.813	2.140	2.187
16	1.760	2.097	2.530	2.650
25	1.920	2.450	2.840	2.920
36	2.443	2.767	3.367	3.407
49	2.700	3.180	3.783	3.827
64	2.993	3.470	4.220	4.250

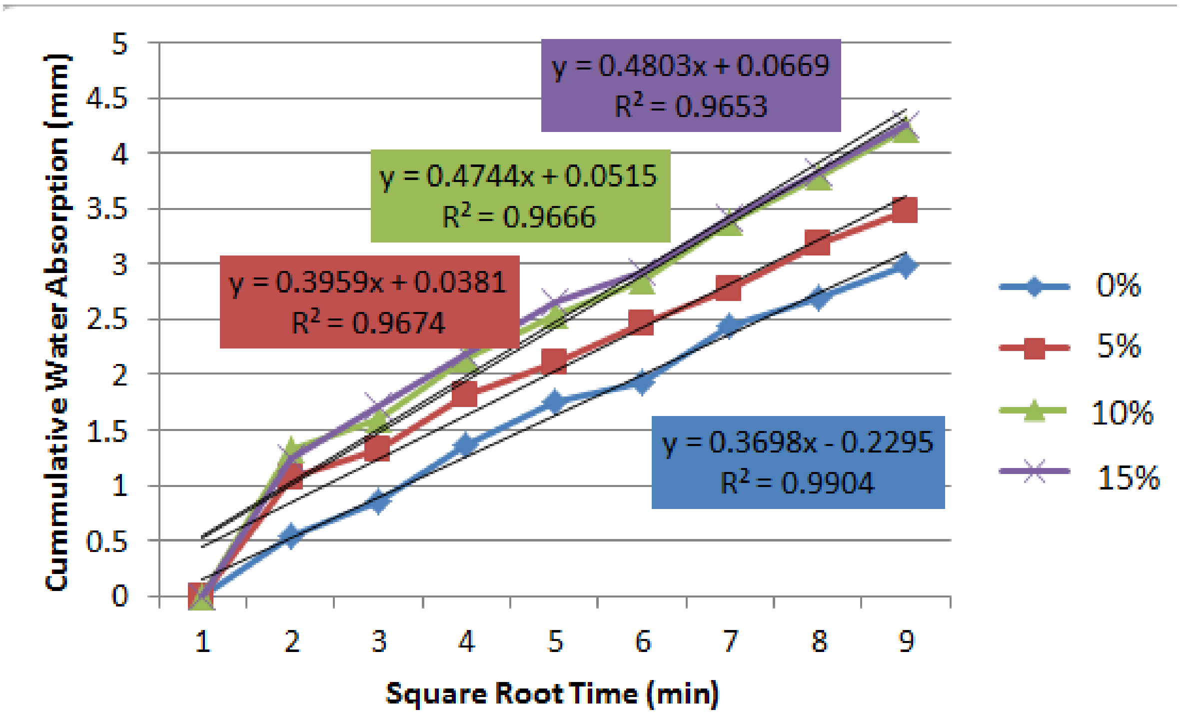


Figure 4.8 Performances of sorptivity test for 28 days

Table 4.10 The weight of concrete according to time for 60 days

Time (min)	Cumulative Weight (g)			
	0%	5%	10%	15%
0	0.000	0.000	0.000	0.000
1	0.433	0.453	0.737	1.150
4	0.987	1.300	1.587	1.637
9	1.573	1.910	2.310	2.400
16	2.297	2.310	3.053	3.463
25	3.227	3.253	3.453	4.200
36	3.830	3.967	4.247	4.740
49	4.463	4.553	4.897	5.440
64	4.913	5.183	5.730	6.040

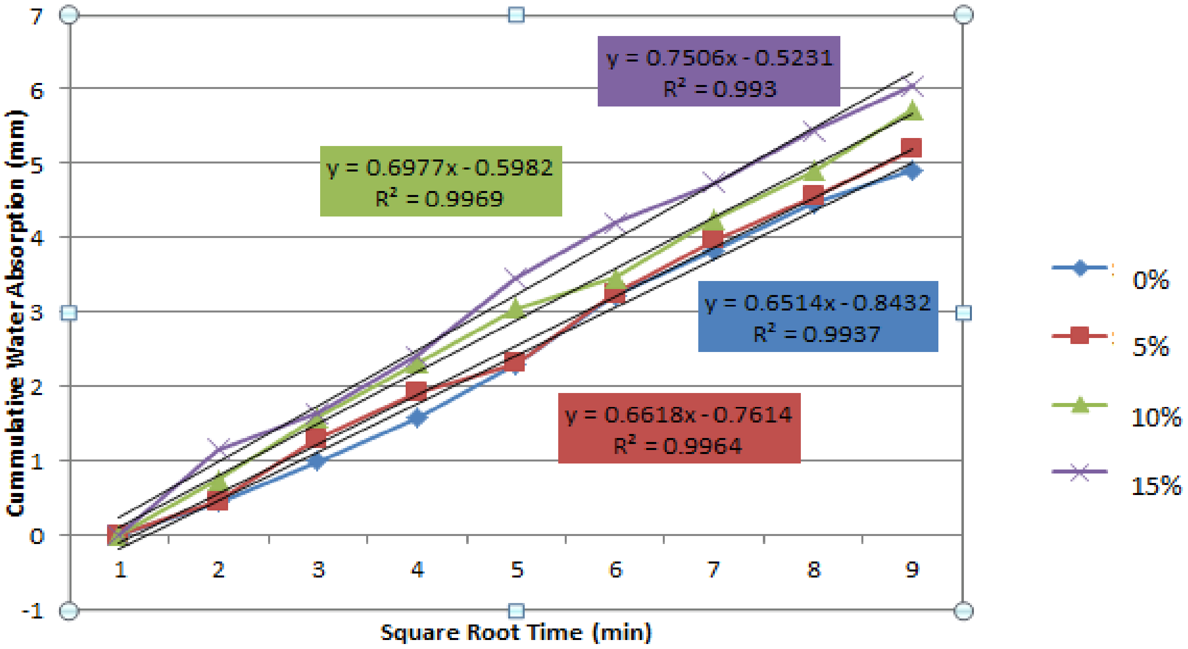


Figure 4.9 Performances of sorptivity test for 60 days

The sorptivity of all mixes are shown in table. The 7 days sorptivity value of POC with 5%, 10% and 15% were found to be 0.4567 mm/min$^{0.5}$, 0.4199 mm/min$^{0.5}$ and 0.8065 mm/min$^{0.5}$. While for 28 days, the sorptivity value for 5%, 10% and 15% are 0.3959 mm/min$^{0.5}$,0.4744 mm/min$^{0.5}$ and 0.4803 mm/min$^{0.5}$ respectively. For 60 days, it is found that the sorptivity value for 5%, 10% and 15% are 0.6618 mm/min$^{0.5}$, 0.6977 mm/min$^{0.5}$ and 0.7506 mm/min$^{0.5}$. All the sorptivity value for concrete that incorporate palm oil clinker is reported to be higher than the control concrete which contain 0% of POC which are 0.3547 mm/min$^{0.5}$, 0.3698 mm/min$^{0.5}$ and 0.6514 mm/min$^{0.5}$ for 7,28 and 60 days respectively. Following to the result, UHPC0 has the lowest sorptivity value. This shows that concrete that contains POC is less durable compared to the conventional concrete. Concrete with 5% of POC have a higher durability compared to all of concrete that contains POC in the mix. The sorptivity value is considered influenced by the present of void in the concrete. According to the (Kabir et al., 2017b), POC is porous so it will cause the increase in permeability on concrete that contains POC which will cause the water to flow easily through the pores. Findings from (Siddique et al., 2018), concrete that have higher replace of BCCFA were found to have higher sorptivity value than normal concrete.

4.4.3 Water Penetration Test

Water penetration was carried out to determine the tendency for the water to penetrate into the concrete under a certain pressure. The result shows the depth of water penetration performances at 7, 28 and 60 days in Figure 4.10 and Figure 4.11.

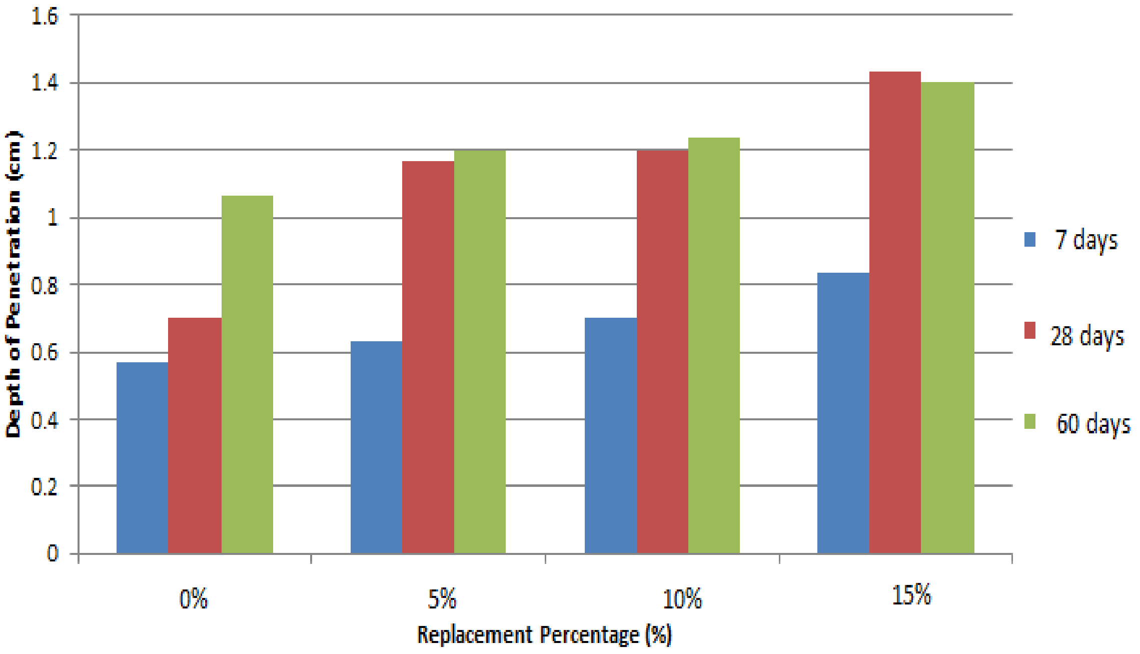


Figure 4.10 Depth of water penetrate at 7, 28 and 60 days

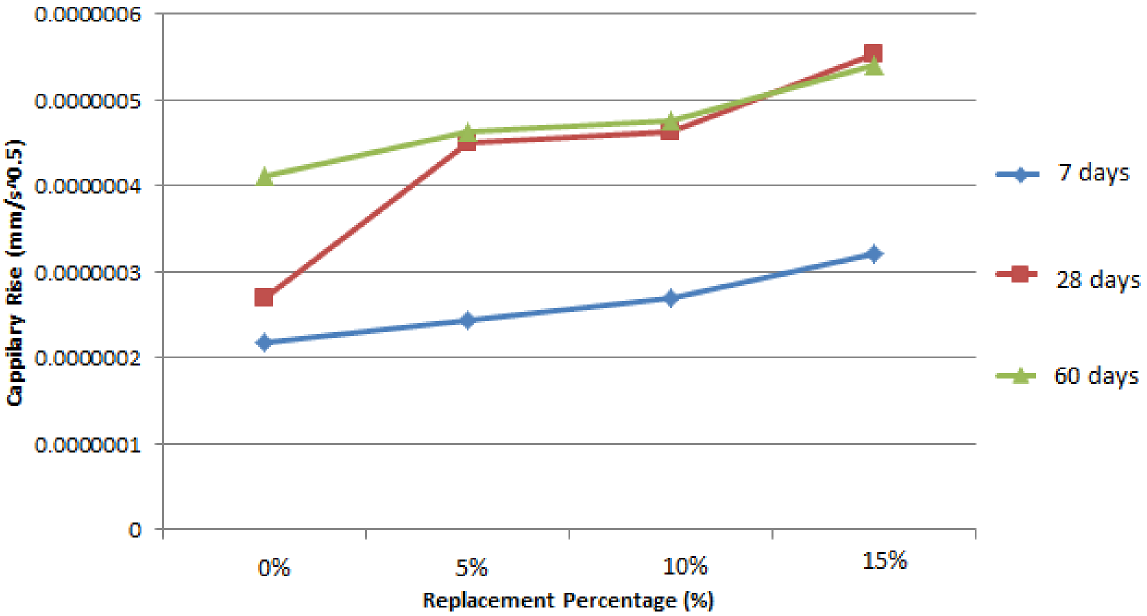


Figure 4.11 Effect of POC on sorptivity of concrete

Results shows that the replacement of POC increase in water permeability is higher in UHPC15 as compared to the other sample that contains POC. There was a general rising in water penetration depth for 7, 28 and 60 days for UHPC0, UHPC5, UHPC10 and UHPC15.UHPC0 recorded the lowest depth of penetration in the concrete. According to (Bahedh & Jaafar, 2018), the ability of the fluid to infiltrate the concrete microstructure which referred to the permeability of concrete will influence the durability of concrete. The trend also shows in increasing of the capillary rise of UHPC for 7, 28 and 60 days. The increase in permeability can be attributed to the fact that permeability is influenced by the pore structure of the cement paste and liquid transfer from the surface to its interior. The angularity and roughness of POC leads to the greater void which causes a slight penetration in depth of water penetration. The application of pressure in this study also might influence these pores by creating a channel of water filled pores which can cause the discolouration effect which was observed after splitting the samples. Since the use of POC results in denser CSH gel with greater surface, channel of water filled pores can cause a higher depth of water penetration. UHPC0, UHPC5, UHPC 10 and UHPC 15 shows a rising in permeability value leading to a conclusion that promotion should have been a result of decreasing in the dosage of POC in the concrete.

4.5 CONCLUDING REMARKS

The durability of concrete with POC as partial replacement of coarse aggregate have been identified and compared to the conventional UHPC. This study had also determined the applicable of 0%, 5%, 10% and 15% of POC as natural gravel replacement in the concrete which was optimize the percentage of replacement.

Based on the result of the research, the replacement of gravel with POC in the UHPC had reduced the durability of UHPC in term of water absorption, sorptivity and water penetration. However, the use of 5% of POC is acceptable because the result when to compare with conventional UHPC is still in range. Thus, the 5% replacement of coarse aggregate with POC is applicable and can be applied in structural application.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

The objective of this study has been identified which are compared the durability between the conventional UHPC and UHPC incorporate POC and also to reduce the dependency of the used of natural gravel in the production of concrete. All the changes in weight have been determined to analyse the concrete durability. All the concrete has been tested for 7, 28 and 60 days if water curing and the tests that have been undergone are water absorption test, sorptivity test and water penetration test.

5.2 CONCLUSION

Based on results and discussions in Chapter 4, several conclusions have been defined as follows:

i. UHPC have a high slump value because of its higher workability even though the water to cement ratio is low.
ii. The use of POC as an alternative to the natural gravel is applicable as they have similar physical properties.
iii. The POC structure which is angular and flaky increases the pore structures and void inside the concretes.
iv. Due to higher porosity and void, water permeability and sorptivity of the concrete is increase and more water can enter the concrete.
v. The higher the percentage of POC being replaced, the higher the water permeability of the concrete which resulted in higher depth of water penetrated inside the concrete.
vi. POC have the ability to store the water due to the porousness of the structure, thus the water is being kept inside the POC.
vii. The durability of UHPC is decrease when more POC is being replaced inside the mixtures.

5.3 RECOMMENDATIONS

The durability of the UHPC containing POC is mainly focus in this study. The effect of the replacement of coarse aggregate with POC has been discussed and the results have been analysed to determine the durability of UHPC incorporating POC. The influence of POC to the concrete must be stated clearly and solve the problem that has been arise in the replacement study to improve the quality of UHPC so that it can be applied in the industrial purpose in the future. The suggestion to improve the study and recommendation for the further research are as follows:

i. Use smaller size of POC so that it can fill the void in between the aggregates to reduce the porosity in the concrete which make the concrete more dense and less water can be absorbed into the concrete.
ii. The use of silica fume inside the concrete mix can help in improving the resistance of water permeability in the concrete and the partial replacement of cement with silica fume can increase the compressive strength of the concrete.

REFERENCES

Abbas, S., Nehdi, M. L., & Saleem, M. A. (2016). Ultra-High Performance Concrete : Mechanical Performance , Durability , Sustainability and Implementation Challenges. *International Journal of Concrete Structures and Materials*, *10*(3), 271–295. https://doi.org/10.1007/s40069-016-0157-4

Abutaha, F., Razak, H. A., Ibrahim, H. A., & Ghayeb, H. H. (2018). Resources , Conservation & Recycling Adopting particle-packing method to develop high strength palm oil clinker concrete. *Resources, Conservation & Recycling*, *131*(May 2017), 247–258. https://doi.org/10.1016/j.resconrec.2017.11.031

Ahmmad, R., Zamin, M., Alengaram, U. J., Bahri, S., & Abdur, M. (2016). Performance evaluation of palm oil clinker as coarse aggregate in high strength lightweight concrete. *Journal of Cleaner Production*, *112*, 566–574. https://doi.org/10.1016/j.jclepro.2015.08.043

Aprianti, E., Shafigh, P., Bahri, S., & Nodeh, J. (2015). Supplementary cementitious materials origin from agricultural wastes – A review. *Construction and Building Materials*, *74*, 176–187. https://doi.org/10.1016/j.conbuildmat.2014.10.010

Bahedh, M. A., & Jaafar, M. S. (2018). Case Studies in Construction Materials Ultra high-performance concrete utilizing fl y ash as cement replacement under autoclaving technique. *Case Studies in Construction Materials*, e00202. https://doi.org/10.1016/j.cscm.2018.e00202

Dalton, S., Mohamed, A. F., & Chikere, A. O. (2017). Status Evaluation of Palm Oil Waste Management Sustainability in Malaysia. *OIDA International Journal of Sustainable Development*, *10*(12). Retrieved from http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Dodds, W., Christodoulou, C., Goodier, C., Austin, S., & Dunne, D. (2017). Durability performance of sustainable structural concrete : Effect of coarse crushed concrete aggregate on rapid chloride migration and accelerated corrosion. *Construction and Building Materials*, *155*, 511–521. https://doi.org/10.1016/j.conbuildmat.2017.08.073

Huda, N., Zamin, M., Jumat, B., & Islam, A. B. M. S. (2016). Flexural performance of reinforced oil palm shell & palm oil clinker concrete (PSCC) beam. *Construction and Building Materials*, *127*, 18–25. https://doi.org/10.1016/j.conbuildmat.2016.09.106

Ibrahim, H. A., Razak, H. A., & Abutaha, F. (2017). Strength and abrasion resistance of palm oil clinker pervious concrete under different curing method. *Construction and Building Materials*, *147*, 576–587. https://doi.org/10.1016/j.conbuildmat.2017.04.072

Kabir, S. M. A., Alengaram, U. J., Jumaat, M. Z., Yusoff, S., Sharmin, A., & Bashar, I. I.

(2017a). Performance evaluation and some durability characteristics of environmental friendly palm oil clinker based geopolymer concrete, *161*. https://doi.org/10.1016/j.jclepro.2017.05.002

Kabir, S. M. A., Alengaram, U. J., Jumaat, M. Z., Yusoff, S., Sharmin, A., & Bashar, I. I. (2017b). Performance evaluation and some durability characteristics of environmental friendly palm oil clinker based geopolymer concrete. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2017.05.002

Kanadasan, J., & Razak, H. A. (2015). Utilization of Palm Oil Clinker as Cement Replacement Material Palm oil Type of Biomass Quantity / Annum (Mt) Mesocarp fibre, (December), 8817–8838. https://doi.org/10.3390/ma8125494

Karim, M. R., Hashim, H., Razak, H. A., & Yusoff, S. (2017). Characterization of palm oil clinker powder for utilization in cement- based applications. *Construction and Building Materials*, *135*, 21–29. https://doi.org/10.1016/j.conbuildmat.2016.12.158

Li, Y., Tan, K. H., & Yang, E. (2018). Influence of aggregate size and inclusion of polypropylene and steel fibers on the hot permeability of ultra-high performance concrete (UHPC) at elevated temperature, *169*, 629–637. https://doi.org/10.1016/j.conbuildmat.2018.01.105

Liu, Z., El-tawil, S., Hansen, W., & Wang, F. (2018). Effect of slag cement on the properties of ultra-high performance concrete. *Construction and Building Materials*, *190*, 830–837. https://doi.org/10.1016/j.conbuildmat.2018.09.173

Momeen, M., Islam, U., Mo, K. H., & Alengaram, U. J. (2016). Durability properties of sustainable concrete containing high volume palm oil waste materials. *Journal of Cleaner Production*, *137*, 167–177. https://doi.org/10.1016/j.jclepro.2016.07.061

Muthusamy, K., Mirza, J., Azzimah, N., Warid, M., Abdul, A. P. P., Kusbiantoro, A., … Budiea, A. (2019). Properties of high strength palm oil clinker lightweight concrete containing palm oil fuel ash in tropical climate. *Construction and Building Materials*, *199*, 163–177. https://doi.org/10.1016/j.conbuildmat.2018.11.211

S, G. (2016). Effect of content and fineness of slag as high volume cement replacement on strength and durability of ultra-high performance mortar, *c*, 43–54.

Siddique, S., Shrivastava, S., & Chaudhary, S. (2018). Durability properties of bone china ceramic fine aggregate concrete. *Construction and Building Materials*, *173*, 323–331. https://doi.org/10.1016/j.conbuildmat.2018.03.262

Skariah, B., Kumar, S., & Sahan, H. (2017). Sustainable concrete containing palm oil fuel ash as a supplementary cementitious material – A review. *Renewable and Sustainable Energy Reviews*, *80*(May), 550–561. https://doi.org/10.1016/j.rser.2017.05.128

Zhou, Z., & Qiao, P. (2018). Durability of ultra-high performance concrete in tension under cold weather conditions. *Cement and Concrete Composites*, *94*(January), 94–106. https://doi.org/10.1016/j.cemconcomp.2018.08.019

APPENDIX A

Water absorption result for 7 days

0%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.365	2.292	2.348	2.335
30 min	2.373	2.303	2.355	2.344
72 hr	2.380	2.309	2.366	2.352

5%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.340	2.297	2.369	2.335
30 min	2.365	2.320	2.376	2.354
72 hr	2.373	2.330	2.400	2.368

10%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.345	2.270	2.320	2.312
30 min	2.354	2.278	2.348	2.327
72 hr	2.365	2.287	2.389	2.347

15%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.338	2.253	2.316	2.302
30 min	2.360	2.272	2.340	2.324
72 hr	2.390	2.295	2.353	2.346

APPENDIX B

Water absorption result for 28 days

0%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.322	2.313	2.330	2.322
30 min	2.331	2.323	2.338	2.331
72 hr	2.336	2.325	2.343	2.335

5%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.303	2.339	2.335	2.326
30 min	2.308	2.346	2.345	2.333
72 hr	2.314	2.352	2.348	2.338

10%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.283	2.269	2.272	2.275
30 min	2.289	2.275	2.380	2.315
72 hr	2.298	2.285	2.288	2.290

15%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.290	2.327	2.266	2.294
30 min	2.297	2.334	2.275	2.302
72 hr	2.306	2.343	2.283	2.311

APPENDIX C

Water absorption result for 60 days

0%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.271	2.312	2.322	2.302
30 min	2.289	2.322	2.331	2.314
72 hr	2.295	2.34	2.325	2.32

5%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.354	2.304	2.329	2.329
30 min	2.363	2.313	2.343	2.340
72 hr	2.365	2.328	2.351	2.348

10%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.362	2.419	2.359	2.380
30 min	2.371	2.428	2.365	2.388
72 hr	2.385	2.445	2.371	2.400

15%				
	Mass of the specimens (kg)			Average
	1	2	3	
0 min	2.306	2.303	2.285	2.298
30 min	2.318	2.312	2.296	2.309
72 hr	2.326	2.325	2.322	2.324

APPENDIX D

Sorptivity result for 7 days

0%

Minutes	1	2	3	Average	Cummulative Average
0	2349.00	2311.14	2343.47	2334.54	0.00
1	2350.53	2312.48	2344.69	2335.90	1.36
4	2350.70	2313.56	2345.55	2336.60	2.07
9	2350.81	2313.63	2345.68	2336.71	2.17
16	2350.95	2313.75	2345.84	2336.85	2.31
25	2351.12	2313.81	2345.98	2336.97	2.43
36	2351.36	2314.27	2346.24	2337.29	2.75
49	2351.49	2314.46	2346.57	2337.51	2.97
64	2352.25	2315.25	2347.23	2338.24	3.71

5%

Minutes	1	2	3	Average	Cummulative Average
0	2322.12	2332.13	2282.32	2312.19	0.00
1	2323.76	2333.59	2283.74	2313.70	1.51
4	2324.97	2334.15	2284.83	2314.65	2.46

9	2325.53	2334.79	2284.05	2314.79	2.60
16	2325.82	2335.02	2285.15	2315.33	3.14
25	2325.78	2335.24	2285.57	2315.53	3.34
36	2326.11	2335.52	2286.03	2315.89	3.70
49	2326.55	2335.64	2286.21	2316.13	3.94
64	2326.63	2336.07	2286.53	2316.41	4.22

10%

Minutes	1	2	3	Average	Cummulative Average
0	2317.53	2298.31	2295.67	2303.84	0.00
1	2320.12	2299.65	2297.74	2305.84	2.00
4	2320.46	2300.13	2298.93	2306.51	2.67
9	2320.70	2300.54	2299.45	2306.90	3.06
16	2320.69	2300.82	2299.68	2307.06	3.23
25	2320.84	2301.25	2300.39	2307.49	3.66
36	2321.36	2301.31	2300.01	2307.56	3.72
49	2321.48	2301.46	2300.43	2307.79	3.95
64	2321.65	2301.68	2300.65	2307.99	4.16

15%					
Minutes	1	2	3	Average	Cummulative Average
0	2313.32	2329.43	2247.25	2296.67	0.00
1	2315.65	2330.55	2249.99	2298.73	2.06
4	2317.65	2330.74	2250.20	2299.53	2.86
9	2318.10	2332.59	2250.76	2300.48	3.82
16	2318.80	2333.21	2251.35	2301.12	4.45
25	2319.25	2333.42	2252.65	2301.77	5.11
36	2320.22	2333.95	2254.12	2302.76	6.10
49	2321.15	2334.32	2254.38	2303.28	6.62
64	2321.31	2334.46	2254.46	2303.41	6.74

APPENDIX E

Sorptivity result for 28 days

0%					
Minutes	1	2	3	Average	Cummulative Average
0	2263.75	2353.55	2290.75	2302.68	0.00
1	2263.82	2353.73	2292.12	2303.22	0.54
4	2264.12	2353.96	2292.52	2303.53	0.85
9	2264.34	2354.12	2293.70	2304.05	1.37
16	2264.57	2354.38	2294.38	2304.44	1.76
25	2264.71	2354.42	2294.68	2304.60	1.92
36	2265.23	2354.89	2295.26	2305.13	2.44
49	2265.31	2355.21	2295.63	2305.38	2.70
64	2265.49	2355.52	2296.02	2305.68	2.99

5%					
Minutes	1	2	3	Average	Cummulative Average
0	2292.72	2271.35	2298.82	2287.63	0.00
1	2293.23	2273.68	2299.18	2288.70	1.07

4	2293.51	2273.90	2299.43	2288.95	1.32
9	2293.89	2274.48	2299.96	2289.44	1.81
16	2294.15	2274.92	2300.11	2289.73	2.10
25	2294.36	2275.30	2300.58	2290.08	2.45
36	2294.65	2275.83	2300.71	2290.40	2.77
49	2294.98	2276.22	2301.23	2290.81	3.18
64	2295.33	2276.53	2301.44	2291.10	3.47

10%

Minutes	1	2	3	Average	Cummulative Average
0	2288.82	2285.68	2260.73	2278.41	0.00
1	2290.59	2287.13	2261.50	2279.74	1.33
4	2290.90	2287.40	2261.74	2280.01	1.60

9	2291.24	2287.99	2262.42	2280.55	2.14
16	2291.47	2288.42	2262.93	2280.94	2.53
25	2291.60	2288.70	2263.45	2281.25	2.84
36	2292.31	2289.28	2263.74	2281.78	3.37
49	2292.59	2289.53	2264.46	2282.19	3.78
64	2292.81	2289.71	2265.37	2282.63	4.22

15%

Minutes	1	2	3	Average	Cummulative Average
0	2310.69	2283.54	2300.42	2298.22	0.00
1	2312.58	2284.25	2301.58	2299.47	1.25
4	2312.94	2284.95	2301.93	2299.94	1.72
9	2313.48	2285.46	2302.27	2300.40	2.19

16	2313.96	2285.97	2302.67	2300.87	2.65
25	2314.42	2286.10	2302.89	2301.14	2.92
36	2315.30	2286.63	2302.94	2301.62	3.41
49	2316.10	2286.72	2303.31	2302.04	3.83
64	2316.77	2286.85	2303.78	2302.47	4.25

APPENDIX F

Sorptivity result for 60 days

0%					
Minutes	1	2	3	Average	Cummulative Average
0	2295.30	2284.48	2370.32	2316.70	0.00
1	2295.82	2284.91	2370.67	2317.13	0.43
4	2296.47	2285.30	2371.29	2317.69	0.99
9	2297.25	2285.96	2371.61	2318.27	1.57
16	2298.24	2286.33	2372.42	2319.00	2.30
25	2299.53	2286.91	2373.34	2319.93	3.23
36	2300.04	2287.69	2373.86	2320.53	3.83
49	2301.16	2288.30	2374.03	2321.16	4.46
64	2301.63	2288.79	2374.42	2321.61	4.91

5%					
Minutes	1	2	3	Average	Cummulative Average
0	2297.01	2302.28	2294.39	2297.89	0.00
1	2297.40	2302.61	2295.03	2298.35	0.45
4	2298.53	2303.47	2295.58	2299.19	1.30
9	2298.78	2304.68	2295.95	2299.80	1.91
16	2299.01	2305.29	2296.31	2300.20	2.31
25	2299.79	2306.08	2297.57	2301.15	3.25
36	2300.65	2306.63	2298.30	2301.86	3.97
49	2301.32	2307.21	2298.81	2302.45	4.55
64	2301.98	2307.79	2299.46	2303.08	5.18

10%					
Minutes	1	2	3	Average	Cummulative Average
0	2350.72	2402.71	2359.52	2370.98	0.00
1	2351.53	2403.16	2360.47	2371.72	0.74
4	2352.37	2404.20	2361.14	2372.57	1.59
9	2352.78	2405.37	2361.73	2373.29	2.31
16	2353.59	2406.03	2362.49	2374.04	3.05
25	2354.28	2406.29	2362.74	2374.44	3.45
36	2355.47	2406.69	2363.53	2375.23	4.25
49	2355.84	2407.52	2364.28	2375.88	4.90
64	2356.49	2408.43	2365.22	2376.71	5.73

APPENDIX G

Water Absorption for 7 days

0%				
	1	2	3	Average
Depth	0.8	0.5	0.4	0.566667

5%				
	1	2	3	Average
Depth	0.7	0.5	0.8	0.666667

10%				
	1	2	3	Average
Depth	0.9	0.7	0.5	0.7

15%				
	1	2	3	Average
Depth	0.9	0.7	0.5	0.7

APPENDIX H

Water penetration result for 28 days

0%				
	1	2	3	Average
Depth	0.7	0.7	0.7	0.7

5%				
	1	2	3	Average
Depth	1	1.3	1.2	1.166667

10%				
	1	2	3	Average
Depth	1	1	1	1

15%				
	1	2	3	Average
Depth	1.3	1.5	1.5	1.433333

APPENDIX I

Water penetration result for 60 days

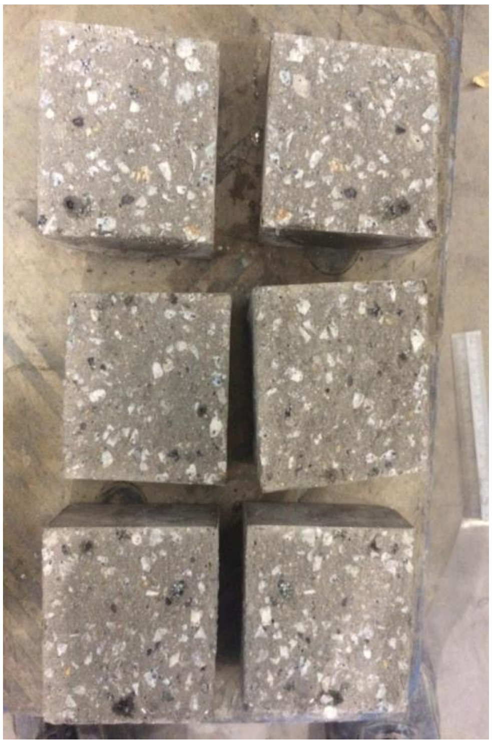
0%				
	1	2	3	Average
Depth	1	1.1	1.1	1.067

5%				
	1	2	3	Average
Depth	1.1	1.2	1.3	1.2

10%				
	1	2	3	Average
Depth	1.2	1.1	1.4	1.233333

15%				
	1	2	3	Average
Depth	1.3	1.4	1.5	1.4

APPENDIX J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