APPLICATION OF USED ENGINE OIL (UEO) IN CONCRETE

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UNIVERSITI TUNKU ABDUL RAHMAN

APPLICATION OF USED ENGINE OIL (UEO) IN CONCRETE

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) Construction Management

Faculty of Engineering and Green Technology
Universiti Tunku Abdul Rahman

May 2016

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **“APPLICATION OF USED ENGINE OIL (UEO) IN CONCRETE”** was prepared by **NON KEE SAM** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) Construction Management at Universiti Tunku Abdul Rahman.

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Signature : _________________________

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Date : 06 May 2016

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APPLICATION OF USED ENGINE OIL (UEO) IN CONCRETE

ABSTRACT

Nowadays, many industrial by-products or wastes are increasing and some of the wastes have reported in the literature or reference book that it used as a supplementary material or ingredient in concrete as well as construction industry. This is a very good solution to reduce the pollution in the earth. Therefore, this research was carried out to determine the viability of application of Used Engine Oil (UEO) in concrete while the objectives are to evaluate the workability properties of UEO in concrete and examine the performance of the concrete between UEO concrete. Next, three sources of UEO were collected to test the integrity and standardization of the UEO in concrete. Besides that, UEO is one of the toxic wastes which bring negative impact to the environment, human being as well as other living organisms. This toxic waste required proper management because one quart (0.95 litre) of the UEO can pollute about 40,730 square feet of soil which make it non-productive to plant any vegetables up to 100 years. Not only have that, about 1 litre of UEO can contaminated 250,000 gallons of drinking water. This is a very serious issue. Moreover, chemical admixtures are environment unfriendly products. In addition, experimental programs were conducted to determine the performance of UEO in concrete such as slump test, compressive strength, rebound hammer, ultrasonic pulse velocity and porosity test. The results shows that, when UEO was utilize in concrete, workability of concrete increased while the quality of the concrete has maintained as well as the strength of concrete doesn't affected. Application of UEO in concrete can enhanced the durability of concrete due to the lower porosity was obtained.

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LIST OF ABBREVIATIONS

cm	Centimetre
mm	Millimetre
µs	Microsecond
N/mm^2	Newton per millimetre square
kg/cm^2	Kilogram per centimetre square
kg/m^3	Kilogram per cubic meter
kN	Kilo newton
km/s	Kilometre per second
Pb	Lead
Cu	Copper
Mg	Magnesium
Zn	Zinc
CaO	Calcium oxide
SiO_2	Silicon dioxide
$CaCO_3$	Calcium Carbonate
PCB	Polychlorinated byphenyls
PCT	Polychlorinated terphenyls
$CaSO_4.2H_2O$	Calcium Sulfate Dehydrate
FM	Fineness Modulus
PCC	Portland Composite Cement
NEO	New Engine Oil
UEO	Used Engine Oil
ASTM	American Society for Testing and Materials
BS	British Standard

UPV	Ultrasonic Pulse Velocity
US	United State
RILEM	International Union of Laboratories and Experts in Construction Materials

V	Pulse Velocity
L	Path Length
T	Transit Time
W_1	Weight of Specimen in Air
W_2	Weight of Specimen in Water
W_3	Weight of Dry Specimen

LIST OF SYMBOL

%	Percentage
°C	Degree Celcius
$\sum$	Sum

CHAPTER 1

INTRODUCTION

1.1 Research Background

In the era of the globalization, according to the Population Pyramids of the World, the population of the world is approximate 7.32 billion people while Malaysia consists of 30 million people. Everyone needs building to protect them and create a satisfactory internal environment like provide sufficient of air, heat and light as well as weather or noise exclusion to survive the life. The Malaysia economy's Gross Domestic Product (GDP) is significantly contributed by the construction industry because it plays the main role to generate the wealth as well as improve the quality of life for the Malaysian by constructing schools, bridges, hospitals, roads and many more (Hussin, Rahman & Memon, 2013). This means that the prime mover of the Malaysian's economy is the construction industry (The Star, 2014). Thus, the construction industries are growing due to the number of the construction projects are increasing from day to day.

Furthermore, construction materials that basically required for a project are concrete, steel, wood, glass and others. The primary element of the concrete is cement which can forms the building's foundations as well as the structures that we stay and work in and the roads that we always drive on. The second most common construction material that used on Earth is concrete after water (Low, 2005). Concrete is strong, fire-resistance, durable and inexpensive so it is widely used in all countries. It is normally used to construct the dams, tunnels, runways, sewerage systems as well as apartments. Next, there are approximately 3 tons of the concrete consumed by each of the person in the planet each year (Rubenstein, 2012). The usage of the concrete is typically 2 times more than the plastics, steel and glass (Sharma, 2012). Therefore, concrete is one of the construction materials that play a vital part in a functioning society as well as in our daily lives and there are only few structures that don't required concrete to construct the building.

Other than Portland cement, water, aggregates, the ingredients that added to the concrete mix immediately during the mixing is known as chemical admixtures. The substance that added at the cement manufacturing stage is called additive. By using the chemical admixture, the properties of the hardened concrete can be modified, quality of the concrete during mixing or curing can be ensured, the cost of the construction project also can be reduced. Chemical admixture are classified into 5 different classes which are the water-reducing, retarding, accelerating, air-entraining as well as the plasticizers or superplasticizers.

Used engine oil (UEOs) are among the toxic wastes where required proper management to reduce the impact on the environment as well as the human health. According to the research, there are around 55 % of UEOs are being thrown by the end user in the environment and another 45 % by the municipalities (El-Fadel & Khoury, 2002). The UEOs will become a serious problems if they discharge everywhere without proper management. For an instance, one oil change contains of four quarts of the foils, if improperly disposed in the environment on marine, human and underwater lives and agriculture production will be affected. Thus, minimize the potential environmental impacts is very important by having proper management of the used engine oils (Abdelaziz, 2009).

Moreover, the recycled concrete aggregate, fly ash, silica fume, rice husk ash, organic fiber materials and blast furnace slag are the waste or by-product that have been reported in the literature to be used in the construction industry and in the concrete (Samarin, 1999). Next, the leakage of the oil into the older grinding units has result in greater resistance to freezing and thawing which has stated in the concrete technology reference book. In this study, different sources and percentage of the engine oil is added to the concrete mix respectively. The comparison between different percentages of used engine oil in concrete, commercial plasticizer, air-entraining agent and conventional concrete will conduct by the lab test.

1.2 Problem Statement

Nowadays, the industrial wastes as well as the by-products either liquid based chemical or solid based chemical are increasing all over the world. Although the environment agencies in all country have their own rules, regulations and the laws about the proper handling and disposal the waste, but there still have a part of people who illegally throw or dispose the waste (Salmia et al., 2013). This will pollute the environments and the reputation of the country will be affected as well. If the environment polluted, human life and other living organisms also will be affected.

According to the Tendering District Council (2011), they stated that one of the sources that cause water pollution is oil which has causes nearly a quarter of all pollution incidents. Disposal of used engine oil will become a serious problem if without proper management. One of the reasons is the used oil will affects the human life as well as the marine. Improper disposed of engine oil will also pollute the groundwater with the contaminants which consist of lead (Pb), copper (Cu), magnesium (Mg), zinc (Zn), polychlorinated biphenyls, arsenic, chromium, chlorides and cadmium (El-Fadel & Khoury, 2001; Hamad, Rteil & El-Fadel, 2003).

According to the Road Transport Department (2013), there are a total of 17.9 million motor vehicles in the year of 2008 in Malaysia while in 2013, the total motor vehicles is approximate 23.8 million which means that the number of vehicles are increasing from year 2008 to year 2013 as show in Table 1.1 and Figure 1.1. When the number of the registered vehicles is increasing, consequently the productions of the lubricating oil will increase and the amount of UEO will also rise. Due to lack of the proper disposal and treatment, UEO poses a serious threat to the health of the human and the environment (Hewstone, 1994).

Table 1.1: Total Motor Vehicles in Malaysia from 2008 to 2013

Years	Number of Motor Vehicles
2008	17,971,901
2009	19,016,782
2010	20,188,565
2011	21,401,269
2012	22,702,221
2013	23,819,256

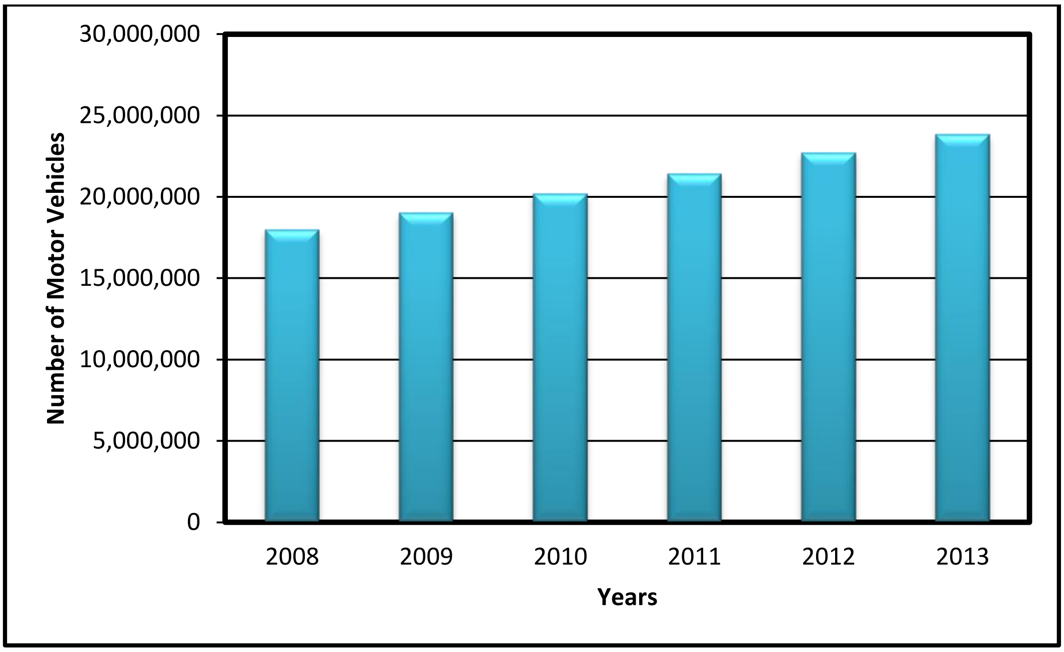

Figure 1.1: The Relationship between the Year of 2008 to 2013 and Number of Motor Vehicles (Road Transport Department, 2013)

Besides the motor vehicles, the UEO will also generate from the machinery industry, for instance, after a certain period, the machines need to change the engine oil due to the engine oil from a fresh oil (Amber or gold colour) turns into dirty oil (Black colour) which the ability to coat has lost and the ability to protect the engine components will be affected. Machineries need the engine oil to lubricate engine's moving parts, maximise its performance, reduce the friction and maximise the lifespan such as lawn mower, excavator, generator and many more. After changed the engine oil, the mechanic may discharges into storm drains which can reduce the cost of the disposal oil. These are the examples where UEO are produced and it will become a serious issue when the amount of UEO is getting a lot.

Moreover, UEO will also contain some toxic materials which it can reach to the human through the food chain and it will affect our health (Hamad, Rteil & El-Fadel, 2003). According to the research, one quart of UEOs can pollute roughly 40,730 square feet of soil which will make it non-productive for farmers to plant the vegetables and fruits almost up to one hundred year. Next, approximate 250,000 gallons of drinking water also can be polluted by one quart of the UEOs. A million gallons of the fresh water can ruin by a single change of the used engine oil which is adequate for 50 people in a year (Chin, Shafiq & Nuruddin, 2012). Many campaign are organized all over the world regarding the safe disposal of used engine oil but the reality is there are 40% of the UEOs is illegally disposed to the rivers and the seas (Shafiq, Nuruddin & Beddu, 2011).

In addition, UEO is one of the liquid wastes which can affect the ecosystem. According the US Environmental Protection Agency (2014), UEO can remain in the environment for years due to the extensive concentrated cocktail of toxic compounds in the UEO and it is sticky and heavy (US Environment Protection Agency, 2014). Water and soil pollution will occur when the environment accumulated by the UEO. A good example is in the form of runoff, when engine oil escapes from the engine, it will create a direction into the waterway. With the toxic substances in the UEO, it is harmful to the living things in the water and cause them die. The reason is the UEO less dense than the water so it appears on top of the water and blocks the oxygen and photosynthesis that needed for the animals and plants in the sea (Elvidge, 2015). Next, UEO will also cause cancer due to the many toxic substances involving polycyclic aromatic hydrocarbons (King, nd). UEO is a dirty and foul material and it can affect the people who are living nearby it when without good management and the reputation of the country will influenced.

Besides that, plasticizers are also known as water-reducers. The purpose of using plasticizers is higher strength can be achieved when the water-cement ratio is reducing at the same workability as an admixture-free-mix. Next, when decreasing the cement content, the same workability also can be achieved so the heat of the hydration in concrete can be reduced is another purpose of using these admixtures. Plasticizers are an environmental unfriendly product which also will bring negative impact to the environment. On the other hand, used engine oil can acted as plasticizers which the slump of the concrete mix can be improved and the workability (Shafiq, Nuruddin & Kamaruddin, 2006). Thus, the plasticizers can replaced by the used engine oil and this can reduce the amount of using plasticizers. Used engine oil is one of the waste disposal product so when it act as an admixture in concrete, it can reduce the cost of the project. The problem of the disposal of the used engine oil will be solved by act as green chemical admixture in the concrete.

From the previous studies, the researchers only collected the UEO from one source which means that it has the probability that can lead to change in the results when the UEO collected from another area. To have a standardization result, the gap of my study is to collect UEO from different sources and mix in the concrete mix respectively. Three different sources of the UEO are collected from car service workshops such as Cameron Highlands, Pahang, Sabak Bernam, Selangor and Kampar, Perak. This experiment will carry out by lab test.

1.3 Aim and Objectives of study

The aim of this study is to determine the viability of the application of Used Engine Oil (UEO) in concrete. In this study, the following objectives have been formulated in order to achieve the aim of this study.

Objective 1: To evaluate the workability properties of Used Engine Oil (UEO) in concrete.

Objective 2: To examine the performance of the concrete between UEOs concrete, water reducing concrete and air-entraining concrete.

1.4 Scope of Study

The scope of this research was conducted by the laboratory test. This is to evaluate the workability properties of Used Engine Oils (UEOs), air entrained in UEOs concrete, and the performance of the concrete after the mixing of the different percentages of the used engine oil in the concrete, water reducing and air-entraining concrete. UEOs are collected from three different sources which are from Cameron Highlands, Pahang, Sabak Bernam, Selangor and Kampar, Perak. The grade for the concrete that used in this experiment is Grade 40 and the size of the concrete cubes is 100 mm x 100 mm x 100 mm.

Besides that, slump test was carried out to determine the workability of the concrete during fresh state according to the British Standard. Next, compressive strength, Rebound Hammer test, Ultrasonic Pulse Velocity (UPV) test and Porosity test were conducted to investigate the performance of the used engine oil concrete compared to the plasticizer and air entraining concrete at the same grade. For the compressive strength test, the concrete cubes was tested at the age of 3, 7 and 28 days while for the ultrasonic pulse velocity and rebound hammer test carried out at the age of 7, 28 days. Lastly, porosity test conduct at the age of 28 days. The codes for the UEO collected from different sources are show in Table 1.2 respectively while Table 1.3 shows the details for the concrete mix proportion. Table 1.4 depicts the code for the test and the size as well as the type of the concrete.

Table 1.2: UEO from Different Sources

Code	**Source**
O (A)	Cameron Highlands, Pahang
O (B)	Sabak Bernam, Selangor
O (C)	Kampar, Perak

Table 1.3: Details of the Concrete Mix Proportion

	Materials (kg/m^3)				**Chemical Admixtures (%)**				
Mix Code	**OPC**	**Sand**	**Gravel**	**w/c ratio**	**Plasti-cizers**	**Air Entraining**	**O (A)**	**O (B)**	**O (C)**
C	434	631	1170	0.43	-	-	-	-	-
P 0.5	434	631	1170	0.43	0.5	-	-	-	-
P 1.0	434	631	1170	0.43	1.0	-	-	-	-
A 0.5	434	631	1170	0.43	-	0.5	-	-	-
A 1.0	434	631	1170	0.43	-	1.0	-	-	-

O(A) 0.5	434	631	1170	0.43	-	-	0.5	-	-
O(A) 1.0	434	631	1170	0.43	-	-	1.0	-	-
O(B) 0.5	434	631	1170	0.43	-	-	-	0.5	-
O(B) 1.0	434	631	1170	0.43	-	-	-	1.0	-
O(C) 0.5	434	631	1170	0.43	-	-	-	-	0.5
O(C) 1.0	434	631	1170	0.43	-	-	-	-	1.0

Table 1.4: The Code for the Test and Concrete's Size and Type

Test Types	Code	Type	Size
Slump	BS EN 12350.2009	-	-
Compressive Strength	BS EN 12390-3: 2002	Cube	100mm x 100mm x 100mm
Rebound Hammer	BS EN 12504-2: 2001	Cube	100mm x 100mm x 100mm
Ultrasonic Pulse Velocity	BS EN 12504-4: 2004	Cube	100mm x 100mm x 100mm
Porosity test	RILEM CP11.3	Cylinder	45mm (Diameter) x 40mm (Height)

1.5 Significant of Study

The production of engine oil is increasing every year due to the number of transportation increase. Used engine oil can considered as the liquid waste. This waste is normally from the car factory service centre. It is very important to manage the used oil properly because it will affect the environment and the living things when illegally dispose everywhere in the earth.

Other than that, application of used engine oil in the concrete can help to reduce the cost of the management disposal used engine oil. The reason is the used engine oil added in the concrete can act as an admixture in the concrete. This is one of the recommendations to reduce the impact of the environment and health of human due to the inappropriate dispose used the oil waste. The UEO can behaves as the chemical plasticizer admixture in the concrete because it can improve the fluidity and increase the slump of the concrete mix. Thus, this can also reduce the cost of the construction project by using UEO to replace the plasticizers in the concrete mix. Not only that, cost of the waste disposal, transportation of the waste to the manufacturing site also can be reduced.

As a result, it is very important to study the usage of the liquid waste because it can reduce or minimize the problems of the environment and human life.

1.6 Research Outline

Chapter 1: Introduction

Used Engine Oil (UEO) is one of the toxic wastes and the effects of the UEO was discussed in this chapter. Aim and objectives, scope of study and significant of this study were also discussed so that it can be achieved.

Chapter 2: Literature Review

In this chapter will discussed the materials, chemical admixtures and the previous researches that related to the Used Engine Oil (UEO) in concrete. This is to provide better understanding and knowledges can be gained from the previous researches.

Chapter 3: Research Methodology

Materials and laboratory test will be discussed so that the objectives will be achieved. All the laboratory tests are conducted according to their standard to investigate whether the UEO has the potential benefit to acts as an ingredient in the concrete.

Chapter 4: Results and Discussions

In this chapter, laboratory test such as slump test, compressive strength test, rebound hammer test, ultrasonic pulse velocity test as well as the porosity test will be conducted to collect the data and it will be analysed.

Chapter 5: Conclusion and Recommendations

Conclusion and recommendations will be concluded in this chapter so that further study can be done before the Used Engine Oil (UEO) recommend to the concrete industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Concrete

Concrete is an artificial stone which is formed after the hardening homogenous mixtures. The homogenous mixtures normally consist of water, cement, aggregates but it will also consist of the additive or the admixture. The chemical reaction for the cement and water hardened is called hydration. When newly mixed, the concrete is plastic and malleable, then it give strong and durable when set and harden over the duration. With these qualities, large quantities amount of concrete are widely used by mankind everywhere for making the highways, architectural structures, pavements, foundations, footings and many other infrastructures.

There are some desired properties of concrete. One of the desired properties is when the concrete is newly mixed or fresh, it has a good workability. The reason is the concrete can be easily be transported, handled and poured into the formwork by workmen. Concrete also has high strength; adequate durability and the hardness are the desired properties of the concrete. Due to these reasons, there is 80 % of the constructions required concrete to construct buildings all over the world (Civil Engineering Terms, 2010).

Furthermore, an important factor that may influence the concrete properties is the water/cement ratio. The ratio of the water to cement will affects strength which means that as the ratio of the water to cement increased, strength and durability will decrease. To achieve a higher durability as well as the strength of the concrete, the water-cement ratio should be decreased as shown in Figure 2.1.

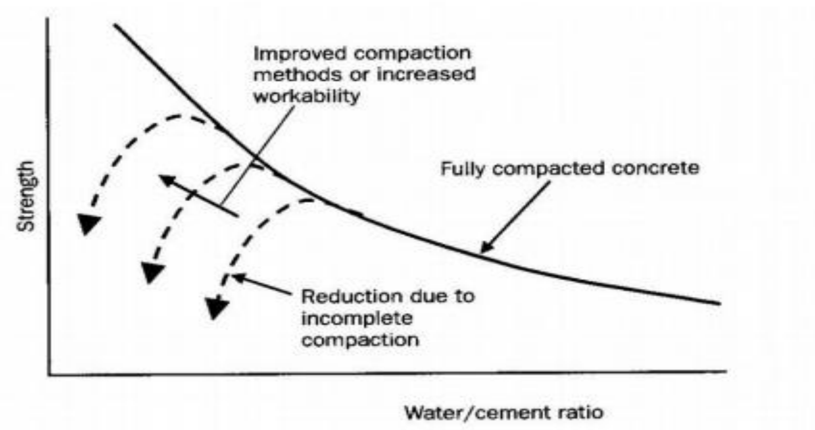

Figure 2.1: The General Relationship between Strength and Water/Cement Ratio of Concrete

A normal conventional concrete consists of 10 % - 15 % of cement; aggregate (fine and coarse aggregates) is about 60 % - 75 % and 15 % - 20 % is for the water. Next, for the entrained air in concrete mixes, it will also take up to 5 % to 8 % as shown in Figure 2.2.

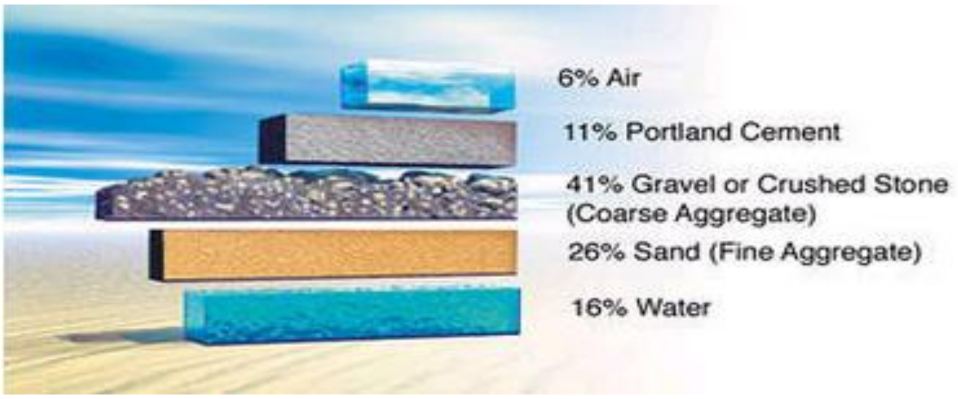

Figure 2.2: Proportion of the Concrete Mix

Moreover, steel reinforced bars are used because the hardened concrete is a brittle material which has a low tensile strength. The reinforced bars are added, it can increase the toughness of the material and provide tensile load bearing capacity (Nawy, 2008). When concrete and reinforcement bars are combined together, the strength will become stronger and it suitable used for built heavy infrastructure such as bridges, tunnels, dams and many more (Lorraine et al., 2008).

2.1.1 Portland Cement

Based on the Joseph Aspdin, the first patent for the Portland cement was taken out in England in the year of 1824 (Nawy, 2008). Portland cement is one of the ingredients in the concrete. Cement creates a paste with water and binds with the rock or sand, concrete is formed. Next, calcium oxide (CaO) and silica or silicon dioxide (SiO_2) are the important ingredients in the manufacture of the cement. Chalk and limestone are the examples which can found the CaO and it is occurs in different form of the calcareous calcium carbonate ($CaCO_3$). For the silica or the SiO_2, it can be found in clay or shale (Neville, 2008). Limestone, chalk or marl and shells combined together with the shale, slate, clay, silica sand, iron ore and the blast furnace slag are the common materials used to manufacture the cement.

Other than that, cement manufacturing process contains of grinding the raw materials into fine powder, mixing in fixed proportion and burning in rotary kiln at the temperature of 1400 °C to 1500 °C (Anosike, 2011). After the clinker cooled, a small amount of the gypsum (calcium sulfate dehydrate, $CaSO_4.2H_2O$) is added before ground into fine powder, and the commercial Portland cement is produced which is used all around the world. The aim of add gypsum to the clinker is to retard the curing process. The immediate stiffening of the cement paste can be avoided during the process of hydration.

Furthermore, there are two types of process to manufacture cement. Dry method is the basic method to manufacture the Portland cement. Although the dry process is the most common and popular method to manufacture the cement but some kilns in the United states (US) use wet process. These two methods are almost the same except the raw materials are ground with the water before being fed into kiln for the wet process.

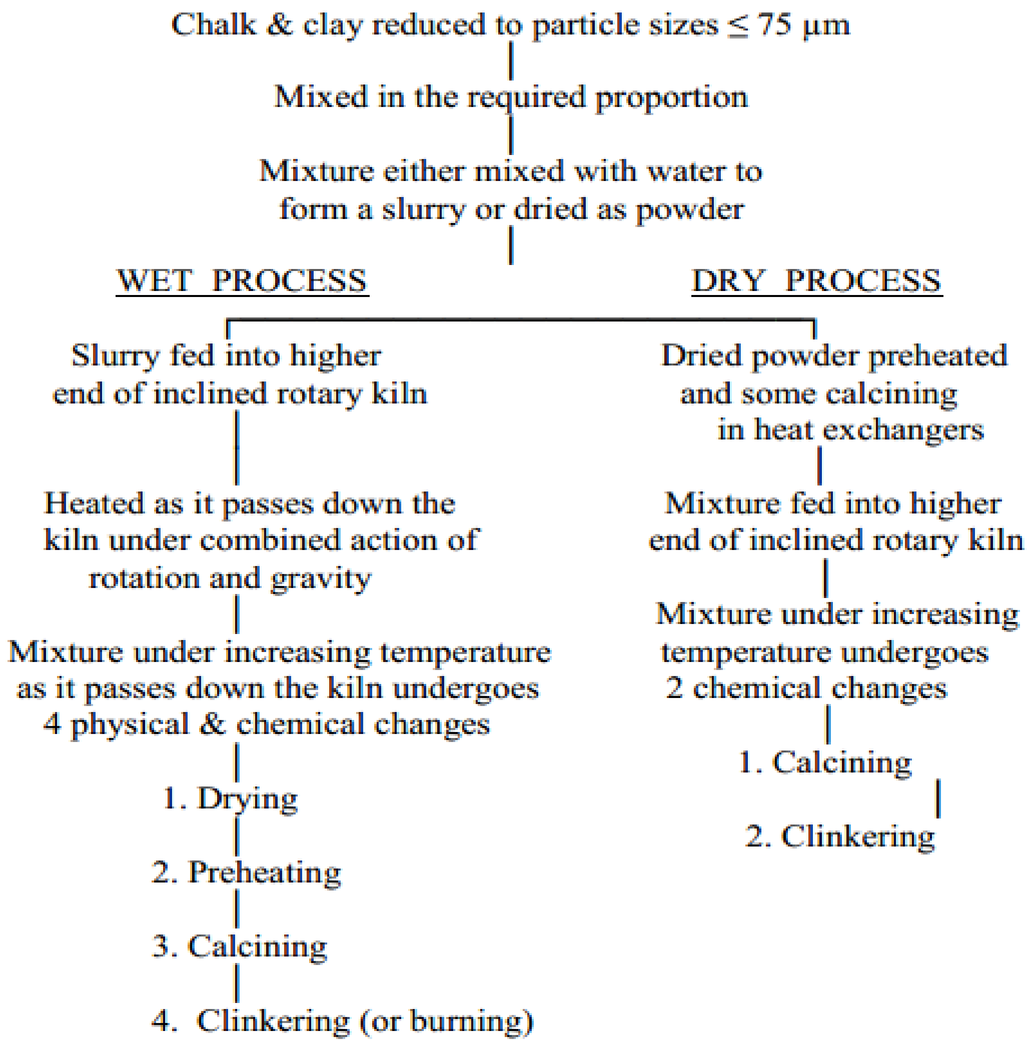

Figure 2.3: Cement Production Process

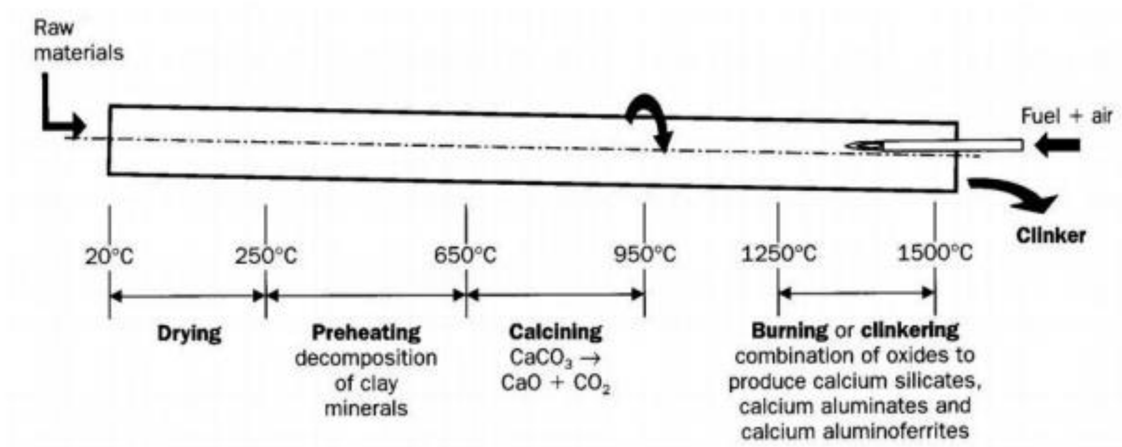

Figure 2.4: The Process Taking Place in Portland Cement Kiln in the Wet Process

2.1.2 Aggregates

In the volume of the concrete, there are approximately 70% are aggregates so they have a large influence on the properties of the concrete (Alexander & Mindess, 2005). The specific gravities for most of the aggregates are in the range of 2.6-2.7, although both lightweight and the heavyweight are sometimes used for the special concrete. To provide the much better dimensional stability and wear the resistance is the role of the aggregates (Nawy, 2008).

Although cement and water mix together will harden in any shape that has set but they are of no practical use. The reasons are they will shrink unacceptably during hydration and the costs are too expensive. One of the ways to solve this problem is to mix with the insoluble non-comentitious particles which is the aggregate as well as is defined as "granular mineral material suitable for use in concrete" in BS EN 206-1:2000. When using the aggregates in concrete, the cost can be greatly reduced, shrinkage of the concrete also can be reduced and they can help to produce a fresh concrete with satisfactory plastic properties. Last but not least, aggregates can reduce the heat output so the thermal stress also will reduce. These are the reason why aggregates are used in the concrete.

Aggregates are classified into two types which are the fine and coarse aggregates. British Standard of the specification for aggregates from natural sources for concrete (BS 882: 1992) depicts the grading limits for the various particles sizes (Table 2.1) and Figure 2.5 portrays the various particle sizes' grading limits for fine and coarse aggregates.

Table 2.1: British Standard Grading Requirements for Aggregates for Concrete (BS 882: 1992)

Sieve size (mm)	Coarse aggregate							Fine aggregate			
	Single size				Graded			Overall limits	Additional limits		
	40 mm	20 mm	14 mm	10 mm	40–5 mm	20–5 mm	14–5 mm		Coarse	Medium	Fine
	Per cent by weight passing										
37.5	85–100	100	–	–	90–100	100	–				
20	0–25	85–100	100	–	35–70	90–100	100				
14	–	0–70	85–100	100	25–55	40–80	90–100				
10	0–5	0–25	0–50	85–100	10–40	30–60	50–85	100			
5	–	0–5	0–10	0–25	0–5	0–10	0–10	89–100			
2.36		–	–	0–5	–	–	–	60–100	60–100	65–100	80–100
1.18				–				30–100	30–90	45–100	70–100
0.6								15–100	15–54	25–80	55–100
0.3								5–70	5–40	5–48	5–70
0.15								0–15			

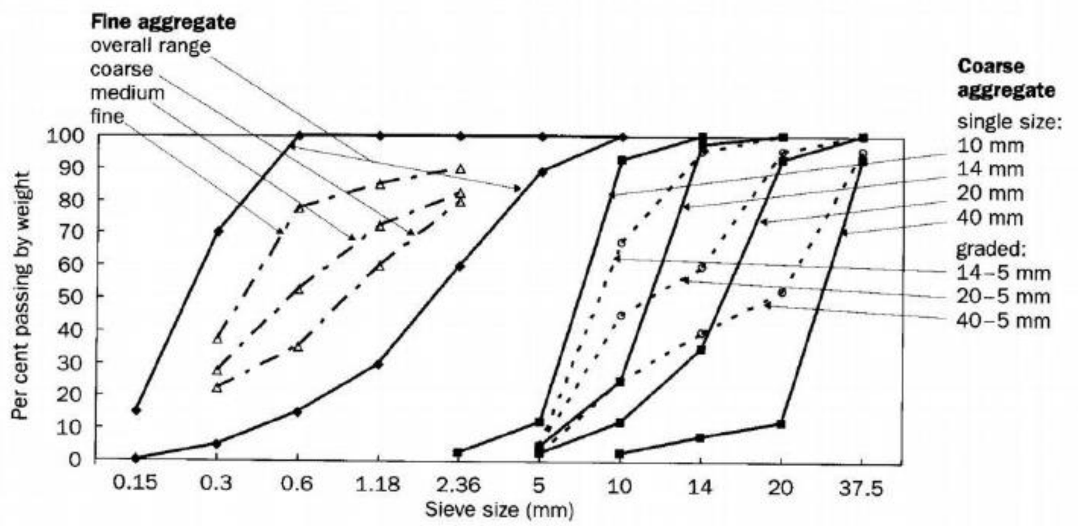

Figure 2.5: Grading Curves of Aggregates at Mid-range of BS 882 limits

Coarse aggregate is the aggregate that retained on a 5.0 mm BS test sieve. The practice greater than 0.19 inch is called as coarse aggregate and it is generally between the 3/8 and 1.5 inches in diameter. The shape of three dimensional irregular bodies as coarse aggregates is difficult to describe but it is the vital property affecting the workability of the fresh concrete and its strength and durability. On the other hand, the aggregate that pass 5.0 mm BS test sieve is known as the fine aggregate. Fine aggregates consist of the natural sand or crushed stone with most particles passing through a 3/8-inch sieve. The range for the fine aggregate is very wide. It subdivided into 3 divisions which are fine, medium and the course. As a guide, the ratio for 1 fine aggregate is equal to 1 ½ to 3 coarse aggregate satisfactory.

2.2 Chemical Admixture

Admixtures are the natural or manufactured chemicals which added to the concrete during mixing. Admixture can be used to modify the properties of the concrete by affecting its workability, set time, compensating for the effects of the temperature during curing, ensuring the quality of the concrete during mixing, transport, placing and many more. There are 4 types of chemical admixture which are the set retarders, set accelerators, plasticizers or superplasticizers or water reducers and the air entraining. Every types of the admixture have its own function. Next, admixture are used to overcome difficult construction situations such as hot or cold weather placements, pumping requirements, early strength requirements, or very low-cement ratio specifications.

2.2.1 Plasticizers

Plasticizer is same as the water reducing admixture. Plasticizers are added to the concrete to improve the workability while using significantly lower amount of the mix water. Therefore, better strength and durability can be achieved. According to the ASTM C494, water reducing admixtures are classified as the Type A and must allow at least 5 % reduction in water without changing the consistency.

Concrete requires different degree of workability in different situations. Examples of the situation which required higher degree of the workability are column and beam junctions, deep beams, thin walls of water retaining structures and many more. Thus, by using plasticizers, higher workability in difficult conditions can be achieved without adding excessive of water. Next, Plasticizers or water reducing admixtures are primarily used in the hot weather concrete placing, pumping, and tremie. By using the plasticizers, it will give a higher initial concrete compressive strength up to 28 days by 10 % compared to the control mixture. Other than that, by using the water reducing admixture is that higher concrete density can achieve which makes the concrete less permeable and have higher durability.

Furthermore, plasticizers are polymers so they will get absorbed on the cement particles with an ionic group pointing outwards. The mutual repulsion of the cement particles occur due to the negative charged surfaces. Then, the particles dispersed and entrapped air released to give a greater fluidity. The action of the plasticizers is shown in Figure 2.6.

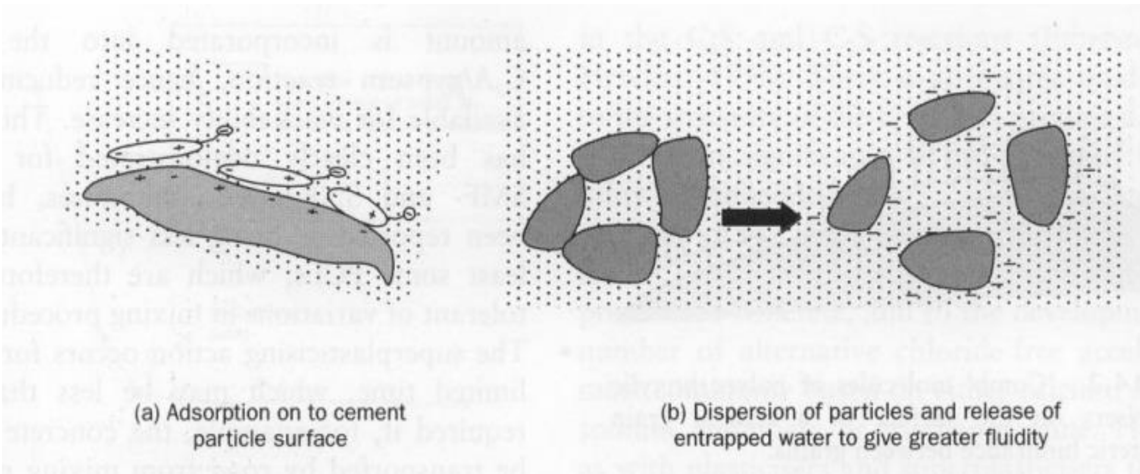

Figure 2.6: Mode of Action of the Plasticizers

2.3 Used Engine Oil (UEO)

Used engine oil is one of the liquid wastes and it can consider as toxic waste that can affect the human lives, marine and environment via soil, air or water contamination (Ssempebwa & Carpenter, 2009; Romera et al., 2006). The main sources of UEO generated are from the factories that with heavy machinery and the vehicle workshops. In general, engine oil can referred to the oil cylinder, oil lubricants as well as the motor oil. The function of the motor oil is to lubricate the engine parts in the motor vehicle engines. After the motor oil reaches the limit that set, it requires changing new engine oil and the oil engine oil is called UEO.

In addition, there have a huge different between the colour between the fresh engine oil and UEO which shows in Figure 2.7 while Figure 2.8 portrays the chemical and physical properties of UEO. The colour for the fresh engine oil is amber colour or gold and translucent colours while the UEO is black in colour, dirty and opaque. The reason why the engine oil will change from a clean and translucent state to dirty and opaque state is there is a heating process in the vehicle engine after the car started. Next, millions gallons of the fresh water can be polluted by a little of dirty and black UEO (Moghaddam, 2011). For example, if a drop of black water colour drops into a glass of clean and clear water, the clear water will be affected. This show that the harmful and toxic of the UEO.

Figure 2.7: The Different Colour of Fresh Engine Oil and Used Engine Oil

Oil	
Physical State	Liquid
Colour	Black
Odour	Oily/Oxidised
Density at 20°C ASTM D 4052 kg/L	Varies, usually around 0.9
Flash Point (PMCC) ASTM D 93 °C	>60.5 (lower if contaminated with fuel or solvent)
Solubility in Water Mass @ 20C	Varies, usually <0.1%
Viscosity at 40°C ASTM D 445 mm2/s	+/-80
Water ASTM D95 %	+/- 10
Ash ASTM D482 %	1.0
Fuel Solvents ASTM D322 %	>3.5
Elemental Analysis Atomic Absorption ppm (mg/l)	
Sulphur (S)	8000
Calcium (Ca)	1200
Zinc (Zn)	650
Lead (Pb)	40
Phosphorous (P)	600
Iron (Fe)	100
Magnesium (Mg)	65
Sodium (Na)	55
Silicon (Si)	40
Boron (B)	40
Manganese (Mn)	10
Copper (Cu)	40
Molybdenum (Mo)	15
Aluminum (Al)	15
Tin, Chromium, Barium, Nickel, Vanadium	<5

Figure 2.8: The Chemical and Physical Properties of UEO

Furthermore, there are some recommendations suggested by the El-Fadel and Khoury to reduce the amount of UEO which can affects the environment and the human health. Firstly, UEO are collected to undergo the process of re-refining to the lube oil. The purpose of UEO undergoes refining process is to remove the impurities and contaminants, distil the oil and reform the oil molecules to produce a premium grade base oil with similar characteristics or performance as virgin oil. The process of re-refining of the UEO is shows in the Figure 2.9. The pros of re-refining the UEO are the amount of the imported lubricator oil can be reduced create a market for the re-refined motor oil products and consequently the pollution of UEO in environment can be minimized.

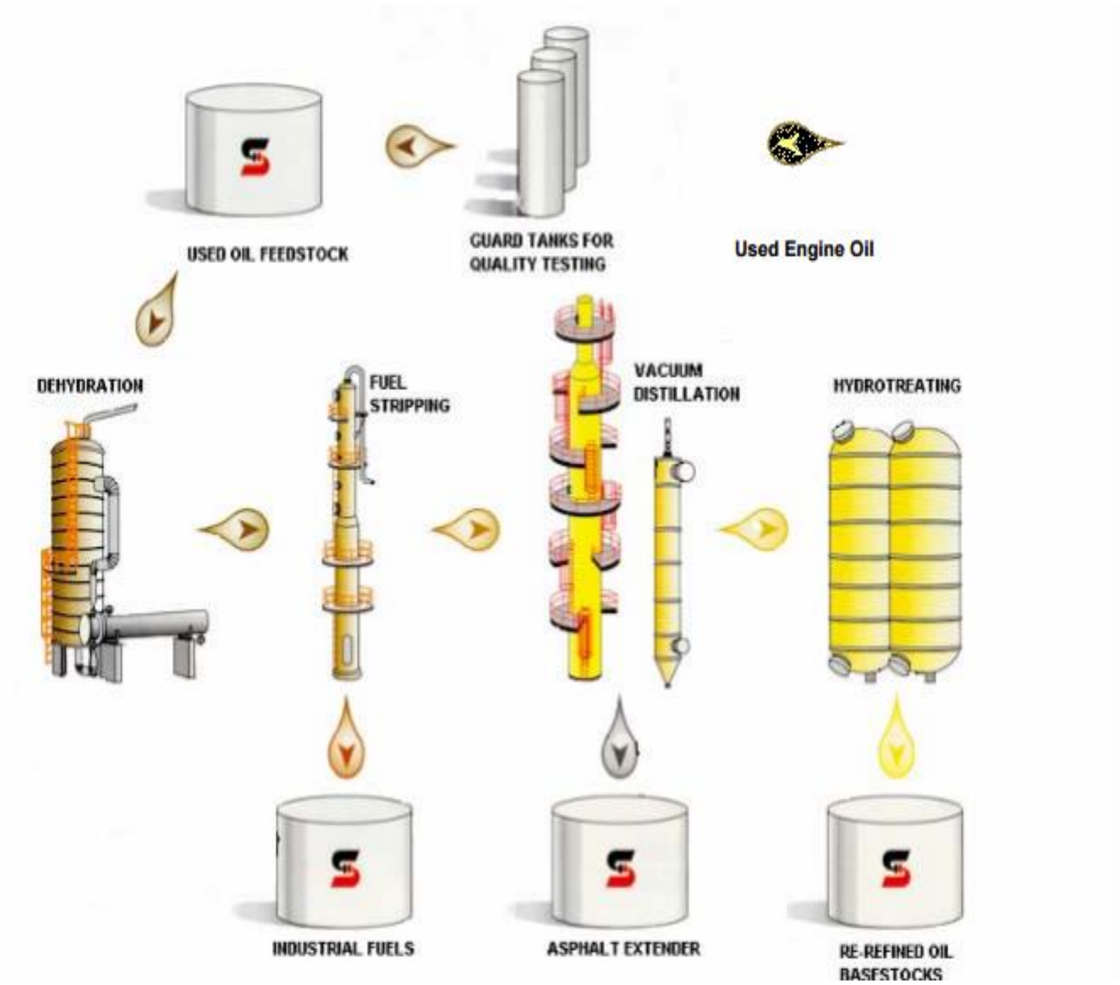

Figure 2.9: Re-refining Process

On the other hand, polychlorinated byphenyls (PCB) and polychlorinated terphenyls (PCT) are the highly contaminated substances which can found in the UEO. With these of highly contaminated substances, re-refining method is not a suitable solution so the better solution for this situation is the conduct destruction of the oil waste at a high temperature. With the 2000 °C and 2400 °C, it is a good way because organics can be destroy as well as acid compounds can be neutralised. Although there are 45 % of UEO are collected to re-refining, destruction and other method but there are still remaining of 55 % of UEO without proper management.

2.4 Previous Research of UEO in Concrete

As discussed in previous chapter, it is estimated that more than half of the UEOs are improper dispose and manage by the end user in the environment while less than half of the UEOs are collected by the municipalities (El-Fadel et al., 2011). Although there has a few portion of the waste oil has collected to re-processing it into fuel oil, re-fining the used oil into lube oil or conduct controlled destruction of the used oil at high temperature but the remaining uncollected UEO can affect the ecosystems around the world.

According to the researchers, they found that the result of the concrete has greater resistance to freezing and thawing when the leakage of oil into the cement in older grinding. This shows that when UEO add into the fresh concrete mix, it has similar function with the air-entraining chemical admixture (Shafiq, Nuruddin & Kamaruddin, 2006). Therefore, this is one of the recommendations that UEO can act as a green chemical admixture in concrete which can reduce the cost of the improper disposal of UEO and minimize the oil waste around the world which can cause the negative impacts to the environment.

2.4.1 Effect of UEO on Properties of Fresh and Hardened Concrete

According to the Hamad, Rteil and El-Fadel's (2003) research, two group of the concrete mixes were conducted which are Group 1 and group 2 with water/cement ratio 0.62 and 0.59 respectively. The test results were obtained as shown in Table 2.2.

Table 2.2: Test Variables and Test Results (Hamad, Rteil & El-Fedel, 2003)

Group	Mix no.	Mix properties				Fresh concrete properties		Hardened concrete properties						
		Air entraining agent	Dosage (%)	W/C[a] ratio	Mixing time (min)	Slump (cm)	Air content (%)	f_r[b] @ 28 days (MPa) (%)	f_{sp}[c] @ 28 days (MPa)	E[d] @ 28 days (MPa)	Compression strength @ 3 days (MPa)	@ 7 days (MPa)	@ 28 days (MPa)	@ 90 days (MPa)
Group 1	1	None	–	0.62	2	10.5	2.3	6.9	2.6	32 678	11.5	17.1	24.9	28.5
	2	None	–	0.62	5	13.0	2.8	6.4	2.1	32 631	11.1	17.3	26.9	34.6
	3	Sika	0.075	0.62	2	19.5	10.5	4.9	1.7	21 386	6.5	8.6	11.8	17.1
	4	Sika	0.075	0.62	5	18.0	9.5	4.3	1.2	21 276	7.5	9.4	14.5	19.3
	5	Sika	0.15	0.62	2	19.5	11.0	4.6	1.3	22 832	5.5	7.4	12.5	15.0
	6	Sika	0.15	0.62	5	17.0	12.5	4.1	1.5	20 238	5.6	7.5	11.6	15.3
	7	Used oil	0.075	0.62	2	19.0	4.4	5.0	1.7	30 365	11.0	15.5	21.0	27.8
	8	Used oil	0.075	0.62	5	21.0	3.3	4.9	2.6	28 788	12.5	18.1	25.8	29.1
	9	Used oil	0.15	0.62	2	18.0	4.4	5.2	1.7	28 262	11.3	15.6	23.5	28.6
	10	Used oil	0.15	0.62	5	19.5	3.6	5.9	2.2	32 889	14.3	18.4	25.9	32.7
	11	Used oil	0.30	0.62	2	16.0	4.6	5.7	1.7	32 866	13.3	19.1	25.8	29.4
	12	New oil	0.075	0.62	2	20.5	2.5	5.6	2.2	26 840	10.8	14.3	20.8	30.1
	13	New oil	0.075	0.62	5	15.5	3.4	5.3	1.7	29 451	13.5	18.4	25.0	31.0
	14	New oil	0.15	0.62	2	22.0	3.5	5.9	2.0	28 694	11.6	17.6	23.8	30.6
	15	New oil	0.15	0.62	5	18.0	4.3	4.9	1.5	29 795	11.3	14.4	22.8	22.1
	16	New oil	0.30	0.62	2	16.0	5.7	6.1	1.7	32 011	13.5	17.1	26.3	29.1
Group 2	17	Used oil	0.15	0.59	2	9.0	4.4	7.0	2.6	34 298	15.3	19.4	30.2	34.5
	18	Used oil	0.30	0.59	2	9.0	4.8	6.9	2.6	32 885	12.8	19.7	26.5	30.1
	19	New oil	0.15	0.59	2	9.0	4.6	6.4	2.8	33 745	15.6	22.0	28.9	34.6
	20	New oil	0.30	0.59	2	9.5	4.5	7.1	2.5	32 211	13.1	20.8	26.2	27.5

[a] W/C = water/cement ratio.
[b] f_r = modulus of rupture or flexural strength.
[c] f_{sp} = splitting tensile strength.
[d] E = modulus of elasticity.

For the fresh concrete properties, the slump for the concrete mix with different admixture of dosage 0.15 % and 2 minutes for the mixing time is shown in Figure 2.10. When the concrete mixes with the 0.62 water/cement ratio, the UEO can improve the workability and the slump almost double. This means that UEO has the same performance as the chemical plasticizers. On the other hand, the fluidity of the control mix with the 0.59 water/cement ratio is similar with the UEO mix by using the slump test to measure.

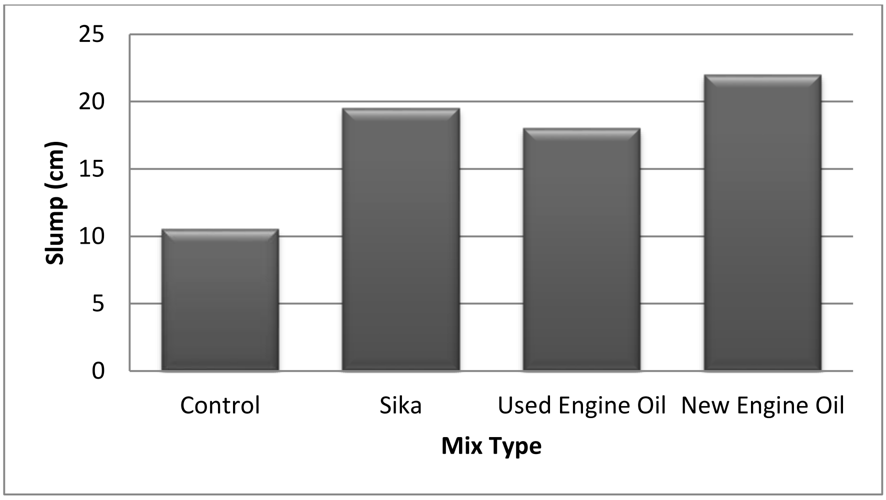

Figure 2.10: Variation of Slump for the Different Air-entraining Agents in Concrete Mixes (Hamad, Rteil & El-Fedel, 2003)

From the Table 2.2 above, for the hardened concrete, the average losses for the flexural strength, splitting tensile strength and modulus of elasticity were 33, 42 and 35 % with the adding of the air-entraining agent while the average losses for the UEO in concrete were 21, 17 and 6 %. Next, for the concrete with 0.62 water/ cement ratio, the compressive strength was maintained by using the UEO while there are roughly 50 % losses in the compressive strength when air entraining admixture was used. The UEO mixes with 0.59 water cement ratio, the fluidity, flexural strength, spitting tensile strength, modulus elasticity were maintained except the concrete compressive strength improved about 20 % in the age of 28 and 90 days.

Last but not least, UEO is one of the liquid wastes which can be used in the concrete as admixture to replace the air entraining agent as well as the plasticizers due to the results that obtained.

2.4.2 Effectiveness of Used Engine Oil (UEO) on Improvement of Properties of Fresh and Hardened Concrete.

Based on the Shafiq's (2006) research, for the fresh concrete, the slump value obtained for the control mix is 130 mm. When the used engine oil added to the concrete, the slump value for the 0.15 used oil concrete mix obtained as 150mm which shows in Figure 2.11. This means that the UEO can act as chemical plasticizer which can increase the slump as well as improve the fluidity of the concrete mix. Therefore, UEO can act as an admixture to replace the plasticizer so the amount of the UEOs can be reduced.

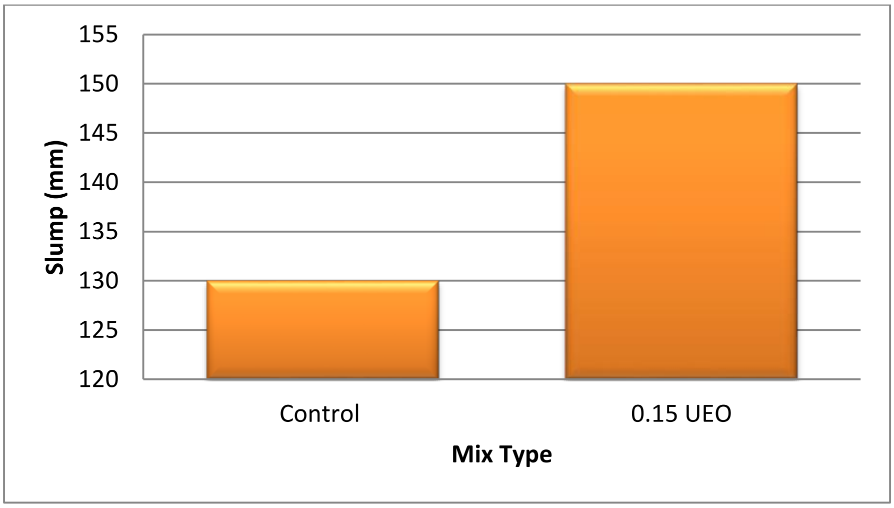

Figure 2.11: Variation of Slumps, mm of Concrete Mixes (Shafiq, Nuruddin & Kamaruddin, 2006)

Besides that, the control mix without any air-entraining agent, the percentage of air content obtained is about 4 % while the air content increased to 5.3 % when the 0.15 UEO added to the concrete mix. For the concrete mix that added air-entraining chemical admixture, the amount of the entrained air is approximate 7.3 %. This depicts that the air content for the fresh concrete mix with adding of UEO increased 32 % while for the concrete mix with commercial chemical air-entrained admixture; the air entrained is almost double as shown in Figure 2.12.

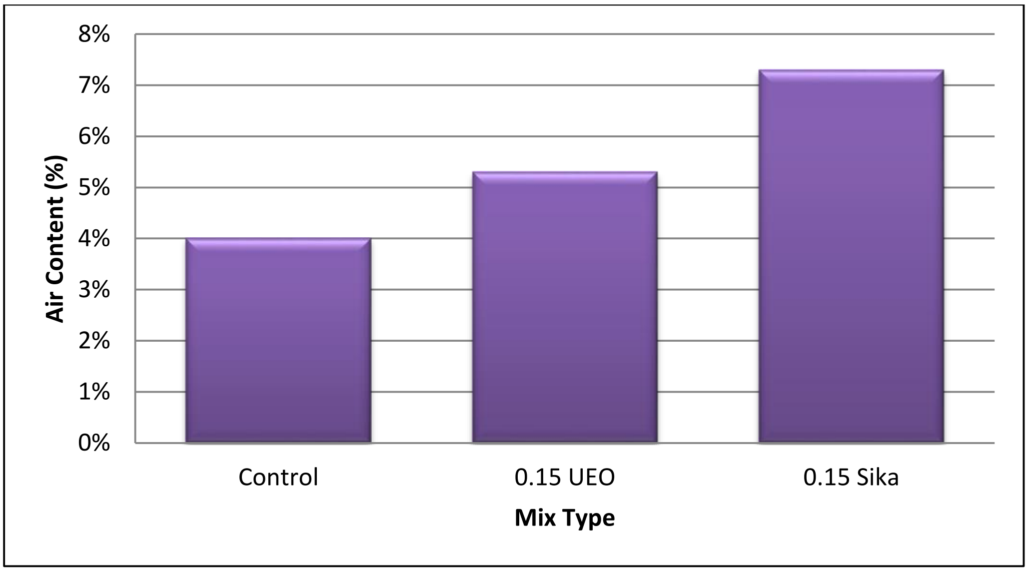

Figure 2.12: Air Content, % in Concrete Mixes (Shafiq, Nuruddin & Kamaruddin, 2006)

The Figure 2.13 shows the days of 3, 7, 28, and 90 of the porosity of concrete mixes with different admixtures. The total porosity of the concrete mix without any chemical admixture is 16.8 % which is the highest value obtained compared to the others at the age of 3 days. At the age of 7 days, the control mix dropped due to 70 % of the cement hydration takes place. The porosity of all concrete mixes is lower than the control mix except the concrete mix with 0.3 Sika air entraining admixture. From this line graph, it portrays that concrete mix with the UEO admixture can reduce the porosity of the concrete. As a result, concrete mix with UEO has low porosity so it can enhance the durability of the concrete. On the other hand, the compressive strength for the 4 different stages (3, 7, 28 and 90 days) of the concrete mixes was measured as shown in Figure 2.14. The usage of the air entraining chemical admixture in the concrete mixes has decreased the compressive strength at all the ages while the compressive strength of the concrete mixes with added of UEO was maintained. This means that UEO are suitable to add into the concrete instead of the air entraining agent.

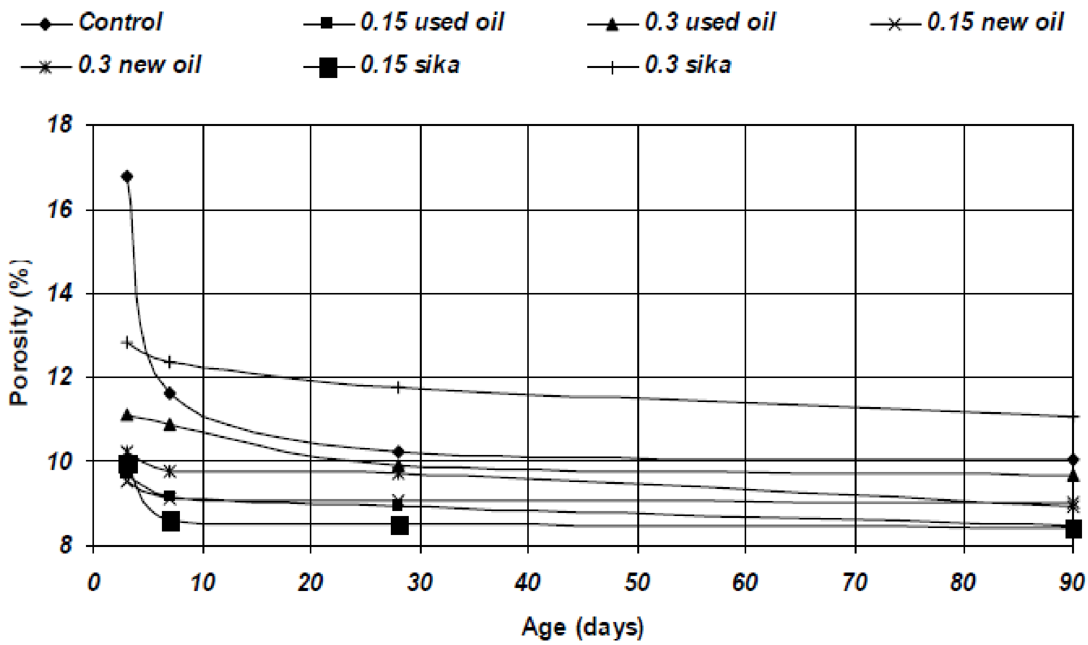

Figure 2.13: Porosity of the Concrete Mixes (Shafiq, Nuruddin & Kamaruddin, 2006)

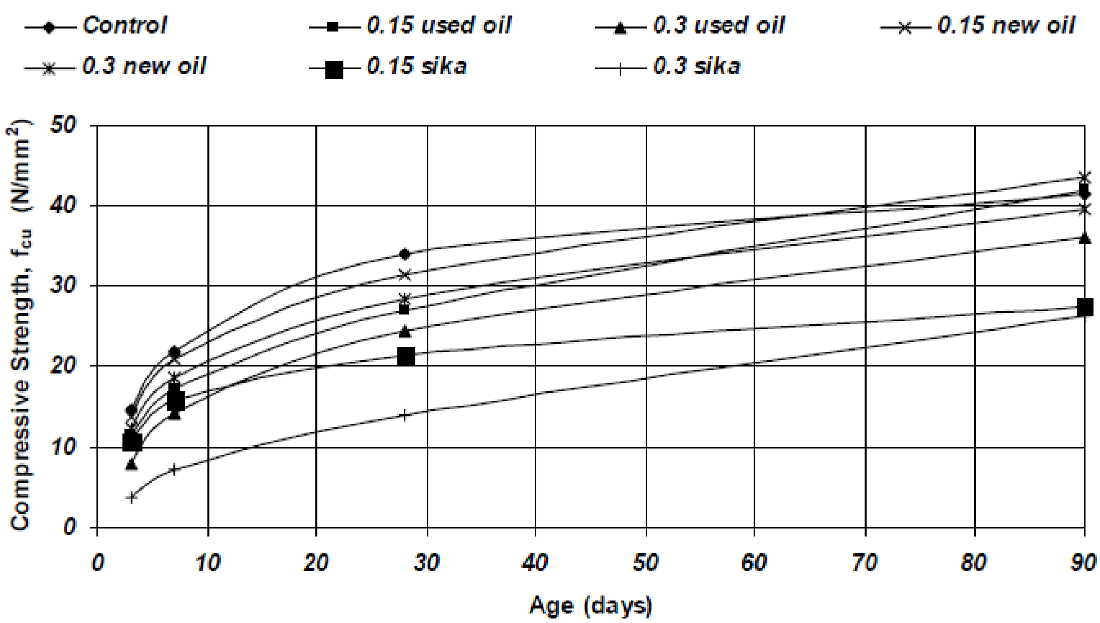

Figure 2.14: The Compressive Strength, f_{cu} (N/mm^2) of the Concrete Mixes (Shafiq, Nuruddin & Kamaruddin, 2006)

2.4.3 Utilization of UEO in Concrete as a Chemical Admixture

This research is conducted by the Abdelaziz (2009) to compare the effect of concrete made with the UEO, air entraining as well as the plasticizers during the fresh and hardened state. From the Figure 2.15, it depicts that when the percentage dosage of the UEO and the water reducer increase, the initial slump also increase. The result that obtained for the initial slump between UEO and water reducers are nearly close.

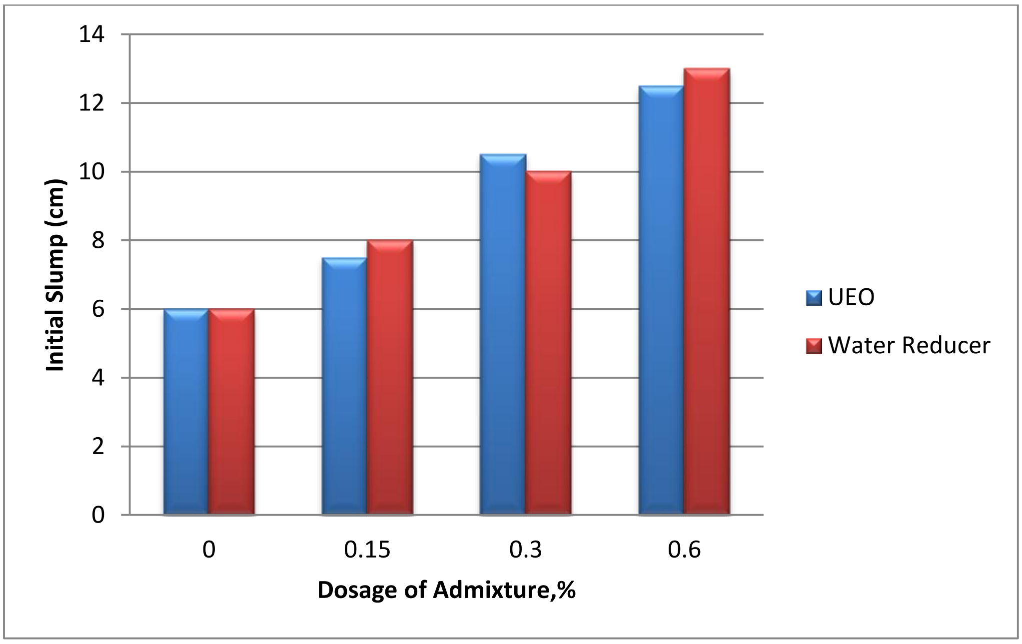

Figure 2.15: The Initial Slump of the Concrete Mixes Made with Either UEO or Water Reducer (Abdelaziz, 2009)

Besides the initial slump, there has an increase of 5, 10 and 25 % of air content in the dosage of 0.15, 0.3 and 0.6 % of UEO respectively when compared with the concrete mix without any admixture added. However, there has a significant increase in the air content when the air entraining agent is added in the OPC mix which shown in the Figure 2.16.

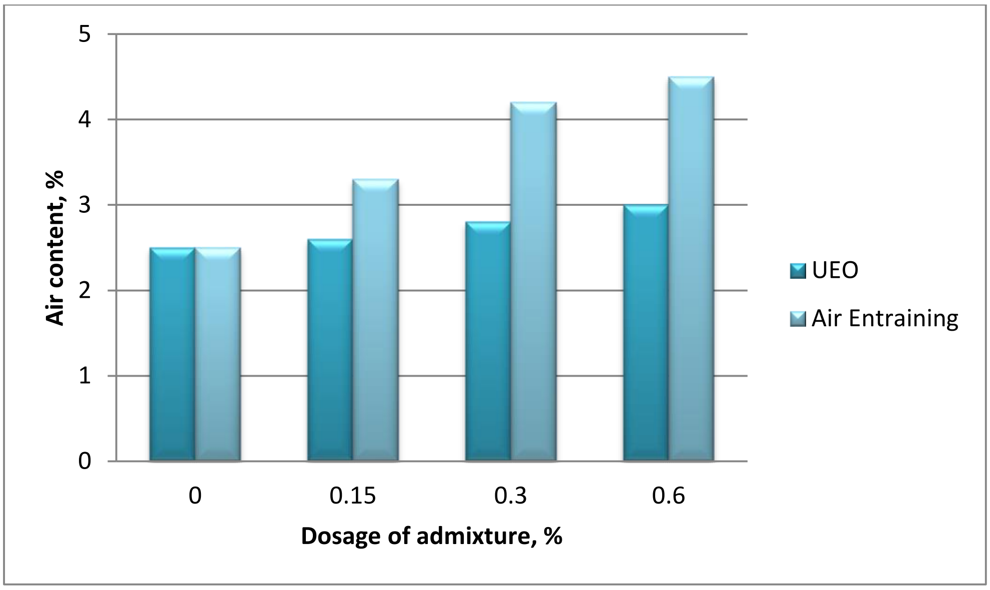

Figure 2.16: Air Content of OPC Mixes Made with Either UEO or AE (Abdelaziz, 2009)

In this study, not only the initial slump and air content were conducted. The initial setting time and rate of slump loss of OPC mixes made with different various admixtures were also carry out and the results were shown in Figure 2.17 and 2.18.

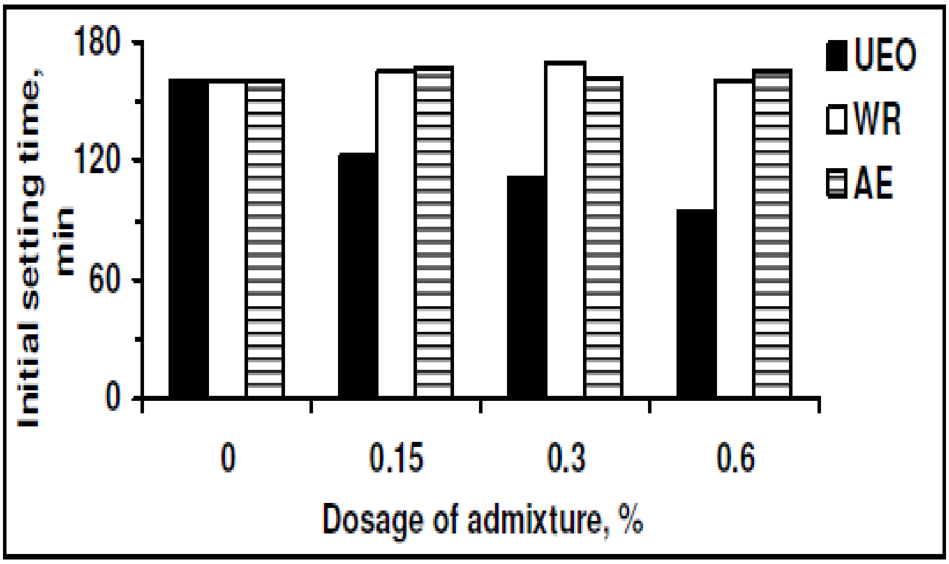

Figure 2.17: Initial Setting Time of OPC Mixes Made with Different Types of Admixture (Abdelaziz, 2009)

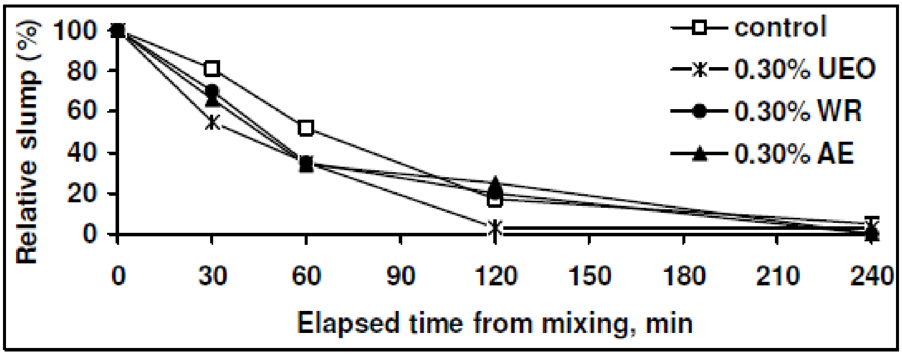

Figure 2.18: Rate of slump loss of OPC mixes made with various admixtures (Abdelaziz, 2009)

From the results that obtained for the fresh concrete state, consistency, air content and rate of fluidity loss are increased in the OPC concrete when UEO is used while the initial setting time has decreased. This situation occurs when the amount of the UEO is increasing. In conclusion, UEO can act as a green chemical admixture and it can provide dual action for the air entraining and the water reducer admixtures.

Furthermore, for the hardened concrete state, the result shows that there are more or less similar for the characteristic of air entraining and the UEO in the OPC concrete. In this research, Abdelaziz disagree the statement made by the Hamad et al (2003) and Shafiq et al (2006) who stated that the compressive strength was maintained when UEO was used whereas there are about 50% loss in the compressive strength when air entraining admixture used. The result that obtained by Abdelaziz is shows in the Figure 2.19.

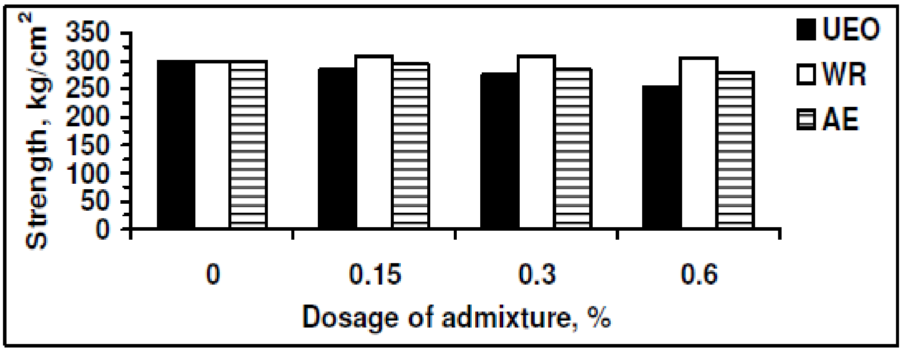

Figure 2.19: Compressive strength of OPC concrete made with various admixtures in 28 days (Abdelaziz, 2009)

2.4.4 Performance of Fresh State Properties of Normal and Blended Cement Concrete Containing Used Engine Oil

This research was conducted by the Chin, Shafiq and Nuruddin in the year of 2010. The objective of this research was to investigate the slump and air content of fresh concrete which containing the UEO in 100 % OPC, 20 % rice hush ash and 40 % fly ash blended cement concrete respectively. Water / cement ratio for this study is 0.55. The details of the concrete mix proportion is Table 2.3.

Table 2.3: Details of Concrete Mix (Chin, Shafiq & Nuruddin, 2010)

No.	Type of mix	Control mix	Superplasticizer, (SP)		Used Engine Oil, (UEO)		New Engine Oil, (NEO)	
			Dosage, %					
		CM	SP-1	SP-2	UEO-1	UEO-2	NEO-1	NEO-2
1.	100% Ordinary Portland Cement (OPC)	-	0.15	0.30	0.15	0.30	0.15	0.30

<u>Effect on the Slump</u>

The slump that obtained for the 100 % OPC without any admixture was 15mm while with the 0.15 % and 0.30 % of the Superplasticizer in the concrete, the slump were 35 mm and 65 mm respectively. Next, the concrete with the 0.15 % as well as the 0.30 % UEO, the slump that achieved was 33 mm and 145mm respectively. For the concrete with 0.15 % NEO was 60 mm while the concrete with the 0.30 % NEO added, the slump value was approximate 83 mm. This showed that with the 0.15 % dosage, the slump increase almost double when compared with the control mix. On the other hand, the slump had increased about four (4) times when added 0.30 % dosage. The Figure 2.19 shows the slump of the OPC and OPC with various admixture.

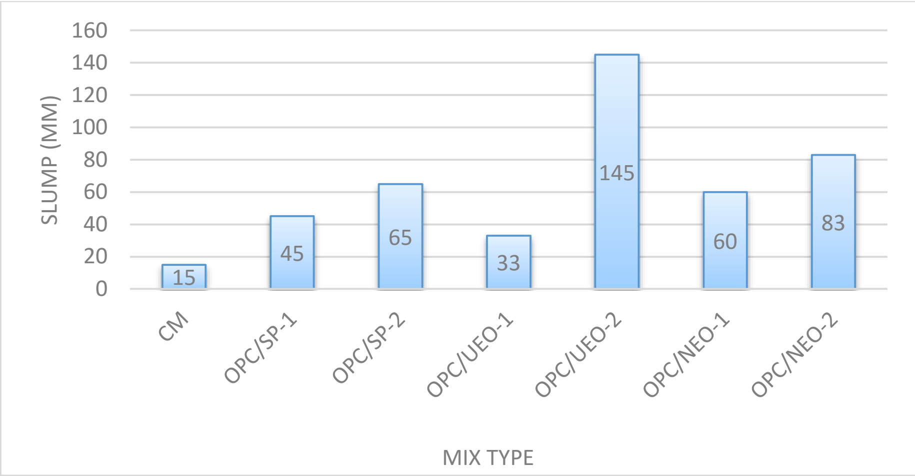

Figure 2.20: The Slump of the OPC and OPC with Various Admixture (Chin, Shafiq & Nuruddin, 2010)

Effect on the Air Content

From the Figure 2.20 showed that the amount of air content in OPC/UEO-1 and OPC/UEO-2 was 3 % and 4 % respectively while the 4.8 % and 5 % of the air content obtained was the OPC/NEO-1 and OPC/NEO-2. Next, the amount of air content for the concrete with 0.15 % of superplasticizer was 1.8 % and the amount of air content for the concrete with 0.30 % of superplasticizer was 2 %.

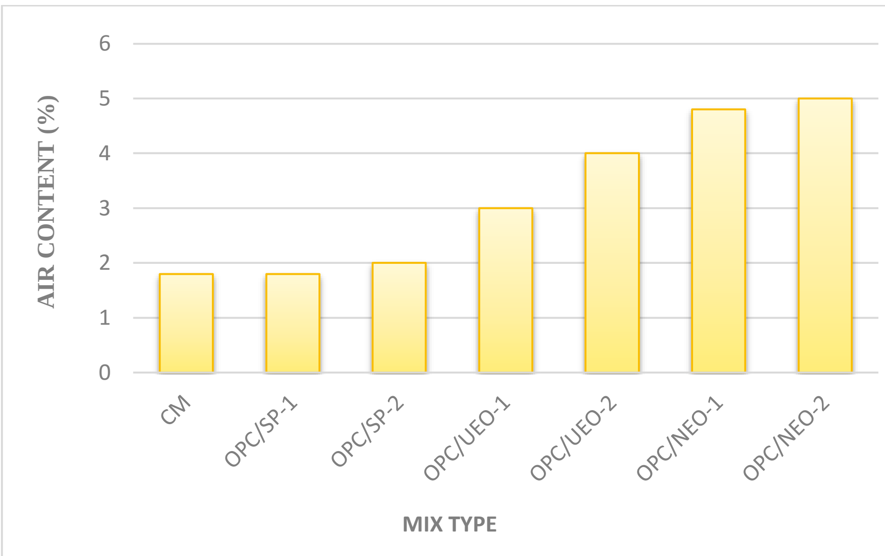

Figure 2.21: The Air Content of the OPC and OPC with Various Admixture (Chin, Shafiq & Nuruddin, 2010)

As a result, there are approximately 50 % of the slump increased when UEO added into the OPC concrete. This support the hypothesis that the performance of the UEO is almost similar and comparable with the performance of the superplasticizer. The slump also can be improved as well as increase the fluidity of the concrete mixes. There are also showed that almost double of the air content when UEO used in the concrete mix compared to the control mix and the superplasticizer in the OPC concrete. Therefore, with the 0.30 % dosage of the admixture has higher slump and air content compared with the concrete mixes with the 0.15 % of admixture.

2.5 Concluding Remark

In a nutshell, there are some researches that had been carried out to determine the liquid waste - UEO as a chemical admixture in the concrete. It showed that UEO can acts as chemical plasticizers which improve the slump and fluidity of the concrete mix. It also portrays that the air content will increase when UEO is added. Furthermore, one of the researcher disagrees the statement stated by others researchers which are the UEO can maintain the compressive strength whereas there are 50 % of the compressive strength loss when air-entraining admixture is added. Therefore, in this research, different sources of UEO will be collected and use it to conduct the experiment. This can shows that the result that obtained will be more consistent and accurate rather than only one source is used. The results that obtained can also determine whether which statement are true and false.

CHAPTER 3

RESEARCH METHODLOGY

3.1 Introduction

In this chapter will discuss about the method that conducted to achieve the objectives of this research. Lab tests were involved in this research to determine the performance of Used Engine Oil (UEO) in concrete with different percentages. The properties of the fresh and hardened concrete will be evaluated. Other than that, the materials that used in concrete such as Portland Composite Cement, aggregates, water, chemical admixtures will also be discussed.

3.2 Materials

In this research, the performances of the UEO in concrete Grade 40 were evaluated and compared with the conventional concrete, plasticizers and air entraining. The materials that required to conduct this research were Portland composite cement, mining sand as a fine aggregates, granite as coarse aggregates, water, plasticizer as well as air entraining. UEO were collected from three (3) sources to test the integrity of the UEO in concrete and to test the standardization of the application of UEO in the concrete.

3.2.1 Portland Cement

Panda Portland Composite Cement (PCC) is the brand of cement that used in this research as shown in Figure 3.1. This type of cement is generally produced by the Hume Cement Sdn. Bhd. According to Hume Cement (2015), high quality portland cement clinker was grinded with carefully selected cementitious materials to produce Panda PCC to ensure the consistent performance. It is very useful binding material in construction industry such as plastering, concreting, bricklaying and other works. Cement need to store at a suitable room condition because if not stored properly it can react with moisture chemically after absorbed it from the atmospheric air. Next, Hume PCC also used to produce Grade 40 concrete in this study.

Figure 3.1: Portland Composite Cement

3.2.2 Mining Sand

Mining sand is categorized as fine aggregate which the particle retained on No. 100 (0.15 mm) sieve but can pass through the (4.75 mm) No.4 sieve (Nawy, 2008). According to the Gambhir (2008), the lower size limit for the sand is about 0.07 mm. The sand needs to be cleaned before used because the bond of the cement paste will be affected if the aggregates contain impurities on it. Figure 3.2 shows the mining sand that use to mix in the concrete in this research.

Figure 3.2: Mining Sand

3.2.3 Granite

According to the Portland Cement Association (2015), the particle that greater than 0.19 inch is known as the coarse aggregate. Normally, it is in the range of 3/8 and 1.5 inches in diameter. The size of the coarse aggregates required for concrete need to carry out by using the sieve analysis test in accordance to the British Standard (BS EN 933-2: 1996). The coarse aggregate also need to be free from impurities which same as the fine aggregates because it will affect the strength or bond of the paste. The coarse aggregate that use in the concrete for Grade 40 was shown in Figure 3.3.

Figure 3.3: Granite

3.2.4 Water

The most abundant compound in the earth's surface is the water which about 70 % of the planet. Water is the important ingredients for the concrete. The potable water used in producing the concrete should be free from the organic impurities, clean, and the pH value should in between 6 – 8 (Neville, 2002). According to the BS EN 1008, potable water are suitable used for the concrete mixing. Therefore, the potable water that use for the concrete mixing was supplied by the Lembaga Air Perak as shown in Figure 3.4.

Figure 3.4: Water

3.2.5 Used Engine Oil (UEO)

UEO is generally generated from the factories that with heavy machinery and the vehicle workshops. It was collected from different source like Cameron Highlands (Pahang), Kampar (Perak) and Sabak Bernam (Selangor). Differences percentages of UEO were added into the concrete mixes respectively which acts as chemical admixture to determine, evaluate and investigate the performance of the UEO in concrete respectively. Figure 3.5 shows the UEO use in the concrete mixes while Table 3.1 shows the UEO collected from difference sources.

Figure 3.5: Used Engine Oil (UEO)

Table 3.1: Difference Sources of UEO

Code	**Source**
O (A)	Cameron Highlands, Pahang
O (B)	Sabak Bernam, Selangor
O (C)	Kampar, Perak

3.2.6 Plasticizer

Plasticizer is one of the chemical admixtures that used in the concrete during the mixing stage. According to the Nawy (2008), plasticizers are used to improve the workability of the fresh mixed concrete when amount of the mix water is low so that the durability and the strength can be achieved. This admixture is categorized as Type A according to the ASTM C494. Figure 3.6 shows the plasticizer that use in this research.

Figure 3.6: Plasticizer

3.2.7 Air Entraining

Air entraining agent (AEAs) is to entrain a controlled quantity of air in the form of microscopic, discontinuous and uniformly distributed bubbles in the cement paste. The workability of the fresh concrete will also improve and it can reduce or eliminate the segregation and bleeding. Provide the resistance to frost is the primarily effect of the air entrained which will lead to progressive deterioration of the concrete. Furthermore, air entrainment has 2 important secondary effects which are to increase the workability of the concrete and increase the porosity result in drop in strength.

3.3 Mix Proportion of Concrete

In this research, the mix proportion that used in Concrete Grade 40 to compare the performance of the UEO in the concrete with plasticizer and air-entraining admixture. Laboratory test will be conducted in order to determine the performance of UEO in concrete and compare with the plasticizers and air entraining in concrete. Slump test was conduct to determine the workability of the fresh concrete. On the other hand, for the hardened concrete, compressive test, rebound hammer, ultrasonic pulse velocity test and porosity test were carried out to investigate the strength as well as durability of the concrete. The mix proportion of the concrete was shown in Table 3.2.

Table 3.2: Mix Proportion of the Concrete

Mix Code	Materials (kg/m^3)			w/c ratio	Chemical Admixtures (%)				
	OPC	Sand	Gravel		Plasti-cizers	Air Entraining	O (A)	O (B)	O (C)
C	434	631	1170	0.43	-	-	-	-	-
P 0.5	434	631	1170	0.43	0.5	-	-	-	-
P 1.0	434	631	1170	0.43	1.0	-	-	-	-
A 0.5	434	631	1170	0.43	-	0.5	-	-	-
A 1.0	434	631	1170	0.43	-	1.0	-	-	-
O(A) 0.5	434	631	1170	0.43	-	-	0.5	-	-
O(A) 1.0	434	631	1170	0.43	-	-	1.0	-	-
O(B) 0.5	434	631	1170	0.43	-	-	-	0.5	-
O(B) 1.0	434	631	1170	0.43	-	-	-	1.0	-

O(C) 0.5	434	631	1170	0.43	-	-	-	-	0.5
O(C) 1.0	434	631	1170	0.43	-	-	-	-	1.0

3.4 Moulding and Demoulding

In this study, 100 mm x 100 mm x 100 mm of the concrete specimens were prepared and the casting procedure is based on the BS EN 12390-1. All the concrete specimens with this size were cast to undergo the compressive strength test, rebound hammer, ultrasonic pulse velocity as well as the porosity test.

Before start casting the concrete cube specimen, all the moulds should be cleaned and a layer of the grease must be applied on it. This is to ensure that the concrete cube can demould easily after hardened. When demoulding the concrete cube, it is very important that to take care not to damage the cube. The compressive strength will reduce when present of crack on the concrete cube specimen. A waterproof ink should to use to mark with a legible identification on top of the concrete cube. This is to avoid the concrete cubes with other concrete specimens. The error will also increase.

Figure 3.7: Concrete Cube Moulds

3.5 Curing of Concrete Specimen

According to the Portland Cement Association (2015), the curing process for the concrete is to keep it within a resoanable temperature range and protect the loss of moisture. Next, Neville (2010) stated that curing is the process that developing the hydration of the cement as well as the temperature and movement of the moisture from and into the concrete can be controled. It is very important that to make sure the concrete to have an adequate curing process because it will cause the failure of concrete to gain strength when inadequate curing.

Besides that, the concrete cubes were placed into a black tank with water after demoulded which shown in Figure 3.8. The curing process will according to the British Standard (BS EN 12390-2: 2000). The age of the testing determines the duration of the curing process for the concrete specimens. For the compressive strength test, the concrete cubes will be tested at the age of the 3, 7 and 28 days while for the ultrasonic pulse velocity test will be carried out at the age of 7 and 28 days which stated in Table 3.4. Next, for the porosity test was tested on 28 days.

Figure 3.8: Water Curing of Concrete Specimens

3.6 Determination of Concrete Performance

There are some laboratory tests were carried out to determine the performance of the concrete in fresh and hardened states. For the fresh concrete state, slump test were carried out. On the other hand, compressive strength test, rebound hammer, UPV test and porosity test were conducted to identify the hardened concrete. The experimental details and the age of testing are shown in Table 3.2 and 3.3.

Table 3.3: Experimental Details

No.	Testing	Standard	Specimens
1.	Slump	BS EN 12350.2009	Fresh
2.	Compressive Strength	BS EN 12390-3: 2002	Cube
3.	Rebound Hammer	BS EN 12504-2: 2001	Cube
4.	Ultrasonic Pulse Velocity (UPV)	BS EN 12504-4: 2004	Cube
5.	Porosity	RILEM CP11.3	Cylinder

Table 3.4: Age of Testing

			Age of Testing (days)		
No.	**Testing**	**Standard**	**3**	**7**	**28**
1.	Compressive Strength	BS EN 12390-3: 2002	√	√	√
2.	Rebound Hammer	BS EN 12504-2: 2001		√	√
3.	Ultrasonic Pulse Velocity	BS EN 12504-4: 2004		√	√
4.	Porosity	RILEM			√

3.6.1 Slump Test

Slump test is conducted to determine the workability of the fresh concrete. The definition of the slump is the decrease in the height of the free-standing concrete from that of its constrained height in the cone. The apparatus that used to conduct the slump test is shown in Figure 3.9.

The procedure of slump test is according to the British Standard (BS EN 12350: 2009). Before conducting the test, the equipment should be clean and damped. After that, the fresh concrete fills in three layers, each layer approximately one-third of the fresh concrete. Then, use a round, straight steel rod of 16 mm diameter x 600 mm long having a hemispherical tip rod it with 25 strokes to compact each layer. The excess concrete from top of the cone needs to strike off with the steel rod to make it levelled. The slump cone will be lift up slowly without any sideways movement after the cone has been filled. The steel rod places horizontally across the inverted cone and over the concrete lump. Lastly, the difference in heights of the cone and the concrete lump at its centre is measured by using measuring tape or ruler. Besides that, Table 3.5 shows the description of workability and magnitude of the slump.

Figure 3.9: Slump Test Equipment

Table 3.5: Description of Workability and Magnitude of Slump

Description of workability	Slump Value (mm)
No slump	0
Very low	5-10
Low	15-30
Medium	35-75
High	80-155
Very high	160 to collapse

3.6.2 Compressive Strength Test

In this study, compressive strength test is to determine the strength of the concrete. The concrete cube specimen with the size of 100 mm x 100 mm x 100 mm was determined by using the compressive strength test which described in the British Standard (BS EN 12390-3: 2002).

The Figure 3.10 shows the Kenco compressive strength testing machine which located at the Block J Construction Management's workshop. The specification of this machine as shown in figure 3.11. This machine produced by the Kensains Sdn. Bhd and the capacity of this machine is about 2000 kN. Lastly, three concrete specimens were tested in the age of 3 days, 7 days and 28 days respectively and get an average among them according to the day stated so that it can obtain an accurate result rather than only one concrete specimen being tested.

Figure 3.10: Kenco Compressive Strength Testing Machine

Figure 3.11: Specification of Kenco Compressive Strength Testing Machine

3.6.3 Rebound Hammer Test

Rebound hammer test is Non-Destructive Test (NDT) which use to determine the strength of the concrete as shown in Figure 3.12. The benefit of NDT is when the test is done, the concrete still can be used because this test will not destroy the serviceability of the concrete. In the year of 1948, Ernst Schmidt designed the rebound hammer and it also known as Schmidt hammer or sclerometer test. Based on the BS EN 12504-2 (2012), the rebound number (R) indicates the strength of the concrete. The rebound hammer must be used against a smooth surface and it must perpendicular with the concrete's surface to obtain an accurate reading. Therefore, the value of the R-number is higher which means that the strength of the concrete is stronger.

Figure 3.12: Rebound Hammer

3.6.4 Ultrasonic Pulse Velocity (UPV) Test

Ultrasonic Pulse Velocity (UPV) is a non-destructive evaluation test. The UPV method is a stress wave propagation method based on measuring the travel time, over a known path length, of a pulse of ultrasonic compressional waves (stress waves associated with normal stress) (Nawy, 2008). Next, the elastic constants and the density are referring to the speed of the compressive waves in a solid. This test also used to determine or predict the internal flaws in the concrete such as cracks, void, decay and others defect. The ultrasonic pulse velocity test in this research was conducted according the British Standard (BS EN 12504-4: 2004) as shown in Figure 3.13.

Figure 3.13: Ultrasonic Pulse Velocity (UPV) test equipment

3.6.5 Porosity Test

Porosity test is conduct to test the voids in the concrete. This is one of the tests to determine the durability of the concrete. High porosity value indicates that more voids in the concrete. In this research, porosity test was conducted according to the RILEM CP11.3 and the samples with the size of 45 mm diameter x 40 mm thick cylinders were tested at the age of 28 days. The samples were dried in a ventilated oven for 24 hours at 105 ºC. After 24 hours, the samples were weighted as dry specimen and place into the vacuum desiccator after cooled as shown in Figure 3.14. While the samples in the vacuum, water filled into the desiccator above the samples about one centimetre to cover the top of the samples. The vacuum machine will start for 15 minutes to suck the air in the desiccator and left for 3 hours. This process is repeated twice. After that, the samples will left in the desiccator for 1 day to achieve the full saturation. Then, the weight of the sample in the air and water will be weighed.

Figure 3.14: Porosity Test

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter was examined and discussed the results that collected by conducting various laboratory test. The performance of the concrete with different sources of Used Engine Oil (UEO) was analysed and compare with the concrete that added with plasticizers and air entraining admixture respectively. There are different type of laboratory test that carried out to determine the performance of the concrete, for an example, slump test, air entrainment, compressive strength, rebound hammer, ultrasonic pulse velocity (UPV) as well as porosity test.

4.1 Determination of the Concrete Performance

In order to achieve the aim of this research, there are two objectives needed to be fulfilled. The objectives are to evaluate the workability properties of Used Engine Oil (UEO) as well as examine the performance of the concrete between UEO concrete, water reducing concrete and air-entraining concrete. Several laboratory tests were required to examine the performance of the concrete.

Firstly, slump test was conducted to evaluate the workability or fluidity of the concrete during the fresh state. Besides that, compressive strength, rebound hammer, ultrasonic pulse velocity (UPV) and porosity test were to examine the performance of the UEO concrete with the comparison between conventional concrete, plasticizer and air entraining concrete. Figure 4.1 depicted the diagram of the determination of concrete performance.

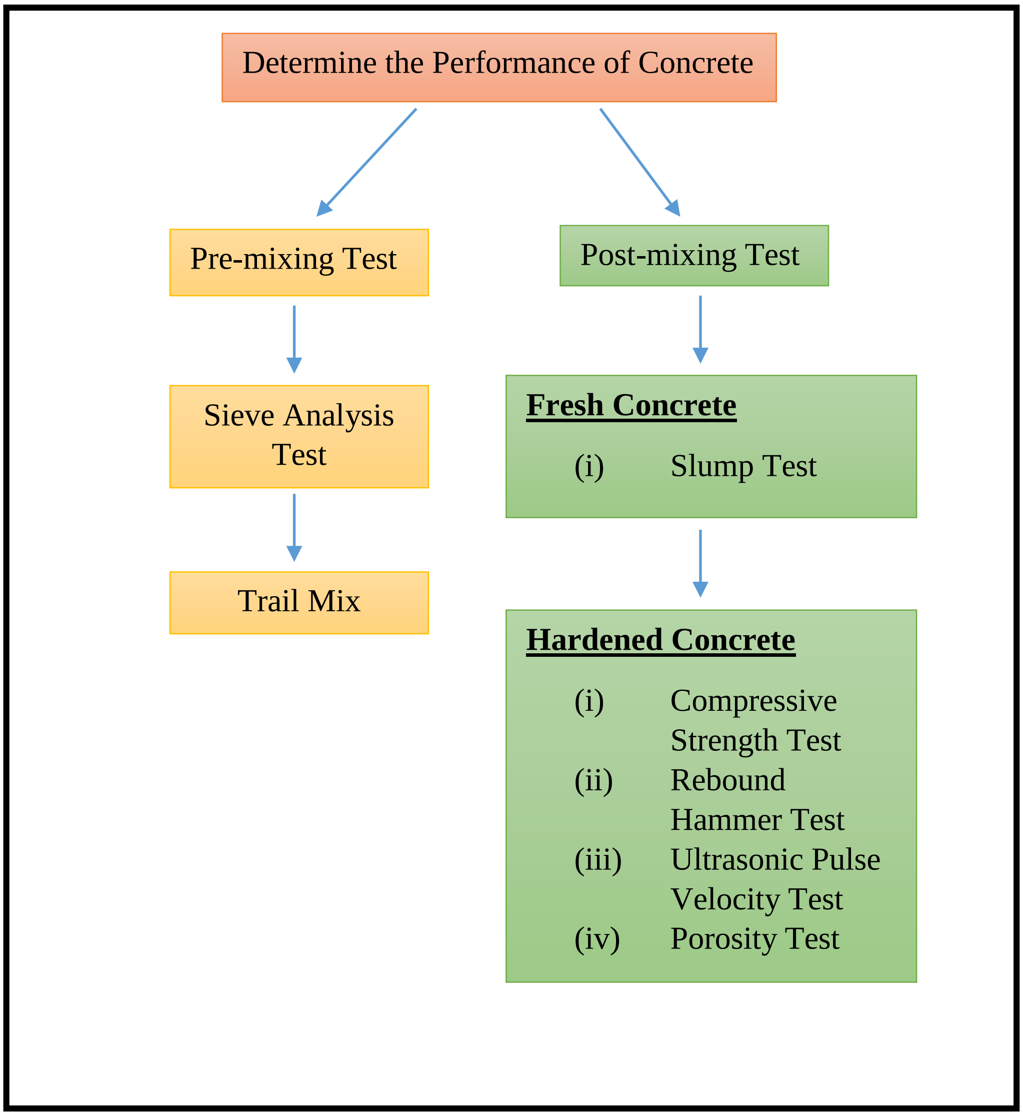

Figure 4.1: Diagram of Determination of Concrete Performance

4.2 Pre-Mixing

4.2.1 Sieve Analysis Test

In this research, sieve analysis was used to evaluate the particle size distribution of the coarse aggregate and fine aggregate. Based on the Design and Control of Concrete Mixtures, the workability of the concrete will be affected if present of wide variation in the course aggregates grading or fine aggregate. In order to have sufficient fluidity of the fresh concrete, the aggregate particles must be roughly equidimensional and smooth surfaces (Nawy, 2008). When the consideration of the type and grading of the aggregates are taken, an optimum condition for minimum voids can be achieved.

Besides that, the fineness modulus (FM) for the coarse and fine aggregates can be calculated by sum up the cumulative percentages by mass retained on each specific series of sieve divided by 100. This formula was used to determine the fineness of the aggregates. Generally, lower value of the FM shows the finer aggregates while higher value indicates the coarser aggregates.

Moreover, Table 4.1, 4.2 and 4.3 portray the result for the sieve analysis test on coarse aggregate respectively. From the data obtained, it can be seen that most of the aggregates retained on the 10 mm and 14 mm sieve size. The highest amount of aggregates that retained on the sieve is 14 mm while the lowest amount of aggregates that retained on sieve size of 4.75 mm. By using the formula, the average fineness modulus for the coarse aggregate is 7.09. Form the graph plotted in Figure 4.2, the gradation curve was well graded from 4.75 mm to 20 mm. This shows that greater amount of gravel was used in this research.

Table 4.1: Coarse Aggregate Sieve Test 1

B. S. Sieve Size	Wt. of material retained on each sieve (kg)	Cumulative wt. of materials retained on each sieve (kg)	Cumulative wt. of materials passing each sieve (kg)	% Cumulative wt. of materials retained on each sieve	% Cumulative wt. of materials passing each sieve
25mm	0.000	0.000	2.000	0.00	100.00
20mm	0.063	0.063	3.937	3.15	96.85
14mm	0.802	0.865	5.072	43.25	56.75
10mm	0.559	1.424	5.648	71.20	28.80
5mm	0.496	1.920	5.728	96.00	4.00
4.75mm	0.024	1.944	5.784	97.20	2.80
Pan	0.056	2.000	5.784	100.00	0.00
Total:	2.000				

$$\boldsymbol{Fineness\ Modulus, FM} = \frac{\sum(\%\ Cumulative\ Retained)}{100}$$

$$= \frac{0.00 + 3.15 + 43.25 + 71.20 + 96.00 + (100.00)5}{100}$$

= 7.14

Table 4.2: Coarse Aggregate Sieve Test 2

B. S. Sieve Size	Wt. of material retained on each sieve (kg)	Cumulative wt. of materials retained on each sieve (kg)	Cumulative wt. of materials passing each sieve (kg)	% Cumulative wt. of materials retained on each sieve	% Cumulative wt. of materials passing each sieve
25mm	0.000	0.000	2.000	0.00	100.00
20mm	0.058	0.058	3.942	2.90	97.10
14mm	0.709	0.767	5.175	38.35	61.15
10mm	0.624	1.391	5.784	69.55	30.45
5mm	0.550	1.941	5.843	97.05	2.95
4.75mm	0.016	1.957	5.886	97.85	2.15
Pan	0.043	2.000	5.886	100.00	0.00
Total:	2.000				

$$\boldsymbol{Fineness\ Modulus, FM} = \frac{\sum(\%\ Cumulative\ Retained)}{100}$$

$$= \frac{0.00 + 2.90 + 38.35 + 69.55 + 97.05 + (100.00)5}{100}$$

= 7.08

Table 4.3: Coarse Aggregate Sieve Test 3

B. S. Sieve Size	Wt. of material retained on each sieve (kg)	Cumulative wt. of materials retained on each sieve (kg)	Cumulative wt. of materials passing each sieve (kg)	% Cumulative wt. of materials retained on each sieve	% Cumulative wt. of materials passing each sieve
25mm	0.000	0.000	2.000	0.00	100.00
20mm	0.036	0.036	3.964	1.80	98.20
14mm	0.719	0.775	5.189	38.75	61.25
10mm	0.629	1.384	5.805	69.20	30.80
5mm	0.537	1.921	5.884	96.05	3.95
4.75mm	0.020	1.941	5.943	97.05	2.95
Pan	0.059	2.000	5.943	100.00	0.00
Total:	2.000				

$$\boldsymbol{Fineness\ Modulus, FM} = \frac{\sum(\%\ Cumulative\ Retained)}{100}$$

$$= \frac{0.00 + 1.80 + 38.75 + 69.20 + 96.05 + (100.00)5}{100}$$

= 7.06

$$\boldsymbol{Mean\ of\ Fineness\ Modulus} = \frac{7.14 + 7.08 + 7.06}{3}$$

= 7.09

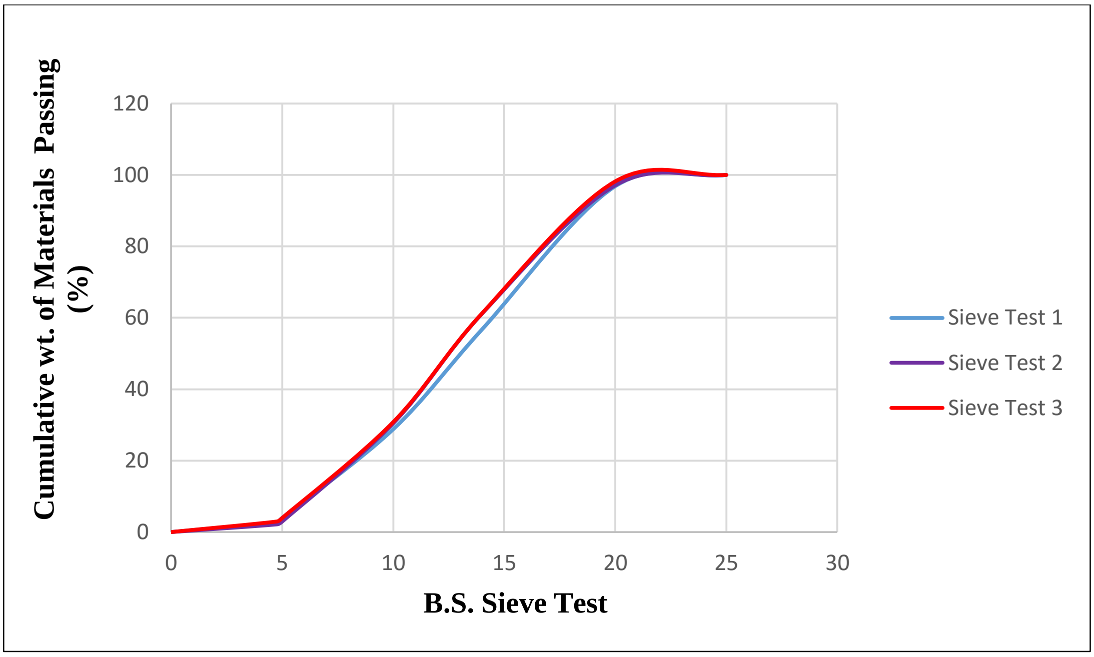

Figure 4.2: Graph of the Sieve Test for Coarse Aggregates

Table 4.5, 4.6 and 4.7 depict the data obtained for the sieve analysis test on fine aggregate respectively while the results were interpreted in Figure 4.3. The average fineness modulus for fine aggregate is 2.11 and this type of sand can be used for making good concrete due to the fineness modulus not more than 3.2 (Suryakanta, 2014). From the Table 4.4, fine aggregates that used were in Zone 2 which is medium fine sand.

Table 4.4: Upper and Lower Limits for Sand Passing Each sieve in Different Zones

B. S. Sieve Size	Percentage Passing by Weight			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
4.76mm	90-100	90-100	90-100	90-100
2.40mm	60-95	75-100	85-100	95-100
1.20mm	30-70	55-90	75-100	95-100
600µm	15-34	35-59	60-79	80-100
300µm	5-20	8-30	12-40	15-50
150µm	0-10	0-10	0-10	0-15

Table 4.5: Fine Aggregate Sieve Test 1

B. S. Sieve Size (mm)	Wt. of material retained on each sieve (kg)	Cumulative wt. of materials retained on each sieve (kg)	Cumulative wt. of materials passing each sieve (kg)	% Cumulative wt. of materials retained on each sieve	% Cumulative wt. of materials passing each sieve
1.18	0.000	0.000	0.500	0.00	100.00
0.50	0.219	0.219	0.781	43.80	56.20
0.30	0.128	0.347	0.934	69.40	30.60
0.18	0.090	0.437	0.997	87.40	12.60
0.09	0.049	0.486	1.011	97.20	2.80
Pan	0.014	0.500	1.011	100.00	0.00
Total:	0.500				

$$\boldsymbol{Fineness\ Modulus, FM} = \frac{\sum(\%\ Cumulative\ Retained)}{100}$$

$$= \frac{0.00 + 43.80 + 69.40 + 87.40}{100}$$

$$= 2.01$$

Table 4.6: Fine Aggregate Sieve Test 2

B. S. Sieve Size (mm)	Wt. of material retained on each sieve (kg)	Cumulative wt. of materials retained on each sieve (kg)	Cumulative wt. of materials passing each sieve (kg)	% Cumulative wt. of materials retained on each sieve	% Cumulative wt. of materials passing each sieve
1.18	0.000	0.000	0.500	0.00	100.00
0.50	0.267	0.267	0.733	53.40	46.60
0.30	0.119	0.386	0.847	77.20	22.80
0.18	0.072	0.458	0.889	91.60	8.40
0.09	0.033	0.491	0.898	98.20	1.80
Pan	0.09	0.500	0.898	100.00	0.00
Total:	0.500				

$$\boldsymbol{Fineness\ Modulus, FM} = \frac{\sum(\%\ Cumulative\ Retained)}{100}$$

$$= \frac{0.00 + 53.40 + 77.20 + 91.60}{100}$$

$$= 2.22$$

Table 4.7: Fine Aggregate Sieve Test 3

B. S. Sieve Size	Wt. of material retained on each sieve (kg)	Cumulative wt. of materials retained on each sieve (kg)	Cumulative wt. of materials passing each sieve (kg)	% Cumulative wt. of materials retained on each sieve	% Cumulative wt. of materials passing each sieve
1.18 mm	0.000	0.000	0.500	0.00	100.00
500 µm	0.234	0.234	0.734	46.80	53.20
300 µm	0.128	0.362	0.872	72.40	27.60
180 µm	0.085	0.447	0.925	89.40	10.60
90 µm	0.042	0.489	0.936	97.80	2.20
Pan	0.011	0.500	0.936	100.00	0.00
Total:	0.500				

$$\boldsymbol{Fineness\ Modulus, FM} = \frac{\sum(\%\ Cumulative\ Retained)}{100}$$

$$= \frac{0.00 + 46.80 + 72.40 + 89.40}{100}$$

= 2.09

$$\boldsymbol{Average\ Fineness\ Modulus, FM} = \frac{2.01 + 2.22 + 2.09}{3}$$

= 2.11

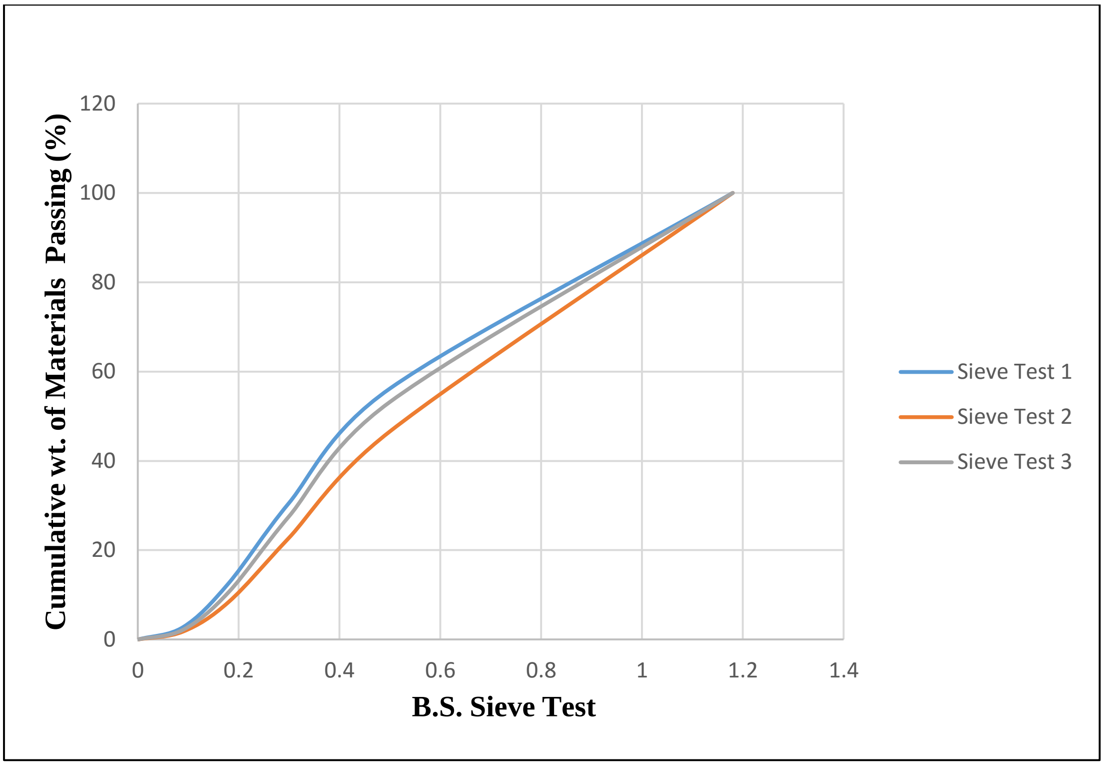

Figure 4.3: Graph of the Sieve Test for Fine Aggregates

4.3 Fresh Concrete

4.3.1 Slump Test

Slump test is one of the measurements of workability and consistency of fresh concrete. Based on the Neville (2002), this type of test is greatly used at the site all over the world. The concrete known as workable when it can be easily mixed, transported, placed, compacted and finished. If the concrete is in dry or stiff condition, it has the difficulty to handle, place, compact and finish. It also doesn't be as strong or durable when hardened (Concrete Basic, 2010). For a workable concrete, segregation or bleeding shouldn't occur. Segregation happen will cause the concrete reduce its strength, less durability as well as large voids formed because of the coarse aggregates are tend to separate from the finer aggregates. This result in the coarse aggregates concentrate in one place. On the other hand, excessive water form at the surface of the concrete is defined as bleeding.

In this research, slump test was conducted according to the British Standard (BS EN 12350: 2009). This is to investigate the workability or fluidity of the conventional concrete, concrete with 0.5 % and 1.0 % of plasticizer, air entraining, and used engine oil respectively. Table 4.8 shows the description of workability and magnitude of the slump while the result of slump test with the height of slump as well as degree of workability shown in Table 4.9.

Table 4.8: Description of Workability and Magnitude of Slump

Description of Workability	Slump	
	mm	in.
No slump	0	0
Very Low	5 – 10	¼ - ½
Low	15 – 30	¾ - 1 ¼
Medium	35 – 75	1 ½ - 3
High	80 – 155	3 ¼ - 6
Very High	160 to collapse	6 ¼ to collapse

Table 4.9: Result of the Slump Test

Sample	Water/Cement Ratio	Slump (mm)	Degree of Workability
Control	0.43	37	Medium
P 0.5	0.43	143	High
P 1.0	0.43	157	High
AE 0.5	0.43	140	High
AE 1.0	0.43	180	Very High
O (A) 0.5	0.43	128	High
O (A) 1.0	0.43	150	High
O (B) 0.5	0.43	118	High
O (B) 1.0	0.43	139	High
O (C) 0.5	0.43	125	High
O (C) 1.0	0.43	140	High

Furthermore, slump test result of 11 different concrete mixes was tabulated in bar chart as shown in Figure 4.4. From the data obtained, it can be seen that with the admixture in the concrete, the slump height is higher than the control mix (37 mm). When plasticizer was added to the concrete, the slump value for 0.5 % and 1.0 % concrete mixes was obtained 143 mm and 157 mm respectively and 140mm slump was measured for 0.5 % air entraining and 180 mm for 1.0 % air entraining concrete mixes. In addition, when the used engine oil added in concrete mix, the slump height also increase with the 10 % of the dosage of UEO which means that it can increase the workability of the concrete. The application of UEO in concrete improved 305 % compared to the control mix. The reason is UEO is greasy fluid so it can acted as a lubricant and reduce the friction between the aggregates and the base. This cause the workability of the concrete increased.

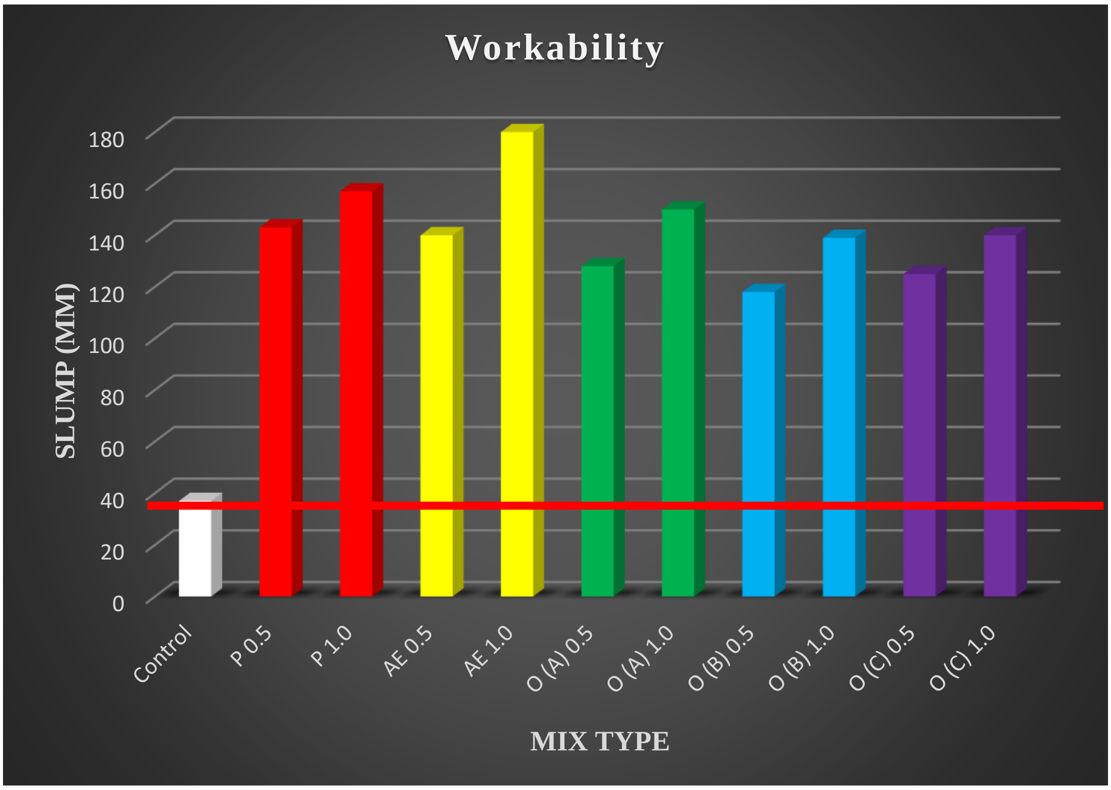

Figure 4.4: Slump Test Result

4.4 Hardened Concrete

4.4.1 Compressive Strength Test

Compressive strength test is the most common test on hardened concrete and it use to determine the compressive strength of concrete cubes. The reasons are this test is easily to be performed and most of the desirable characteristics of the concrete are qualitatively related to its strength (Neville, 2005).

In this study, 100 mm x 100 mm x 100 mm concrete cubes were casted to undergo the test in accordance with the procedure in BS EN 12390-3: 2002. Three samples for each eleven (11) concrete mixes were tested at different ages which are 3, 7 and 28 days. The result of the compressive strength test at different age was shown in Table 4.10.

Table 4.10: Result of the Compressive Strength Test at Different Age

Sample / Age	Average Compressive Strength (N/mm^2)		
	3 Day	**7 Day**	**28 Day**
Control	16.82	24.27	31.21
P 0.5	18.50	24.80	31.22
P 1.0	19.00	28.19	33.17
AE 0.5	16.36	20.25	30.93
AE 1.0	12.75	17.02	24.89
O (A) 0.5	19.78	26.17	33.31
O (A) 1.0	14.64	21.90	35.43
O (B) 0.5	15.85	21.35	32.73
O (B) 1.0	17.57	23.76	33.98
O (C) 0.5	13.86	21.80	32.36
O (C) 1.0	14.90	24.40	33.10

The compressive strength of all the concrete mixes at different ages: 3, 7, 28, 90 days was plotted in Figure 4.5 while Figure 4.6 shows the compressive strength at 28 days. The compressive strength of the concrete mix with plasticizer admixture was 31.22 N/mm^2 and 33.17 N/mm^2 respectively at the age of 28 days. Next, when the air entraining admixture increase to 1.0 %, the compressive strength was decrease and the value obtained was lower than the control mix. The compressive strength of the UEO in concrete slightly higher compared to the others, it improved about 13.5 % in comparison between the compressive strength of control mix and the best UEO concrete.

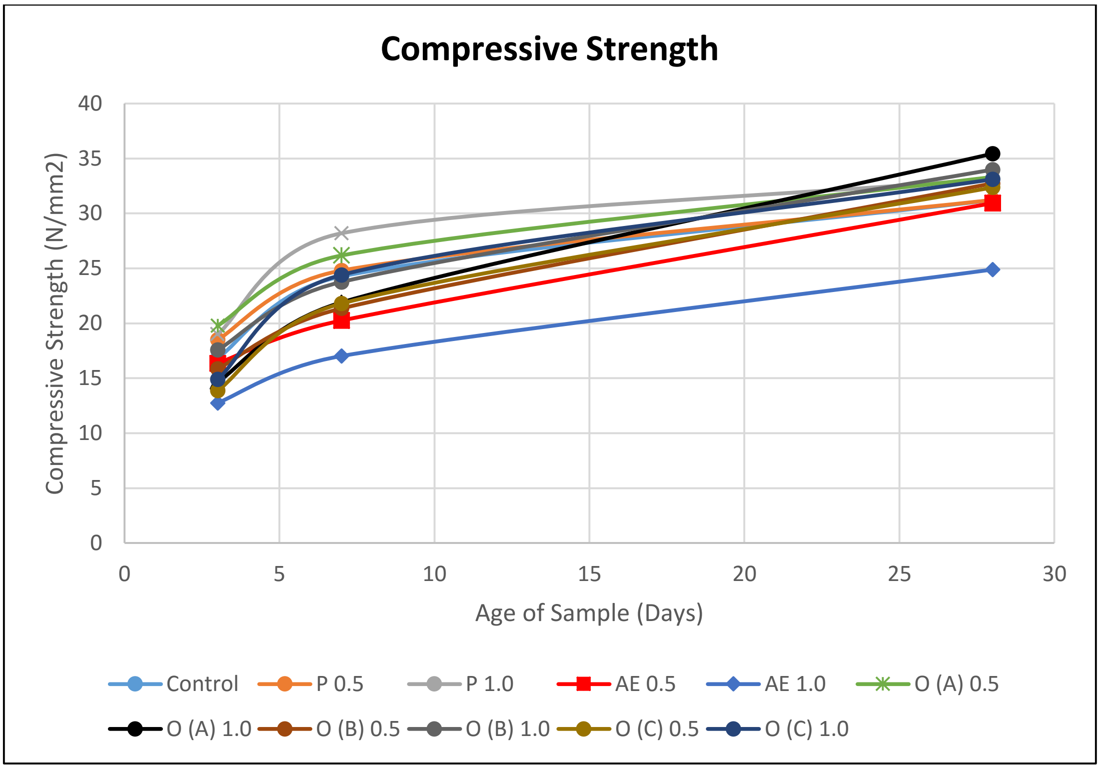

Figure 4.5: Compressive Strength of Various Mixes at Different Age

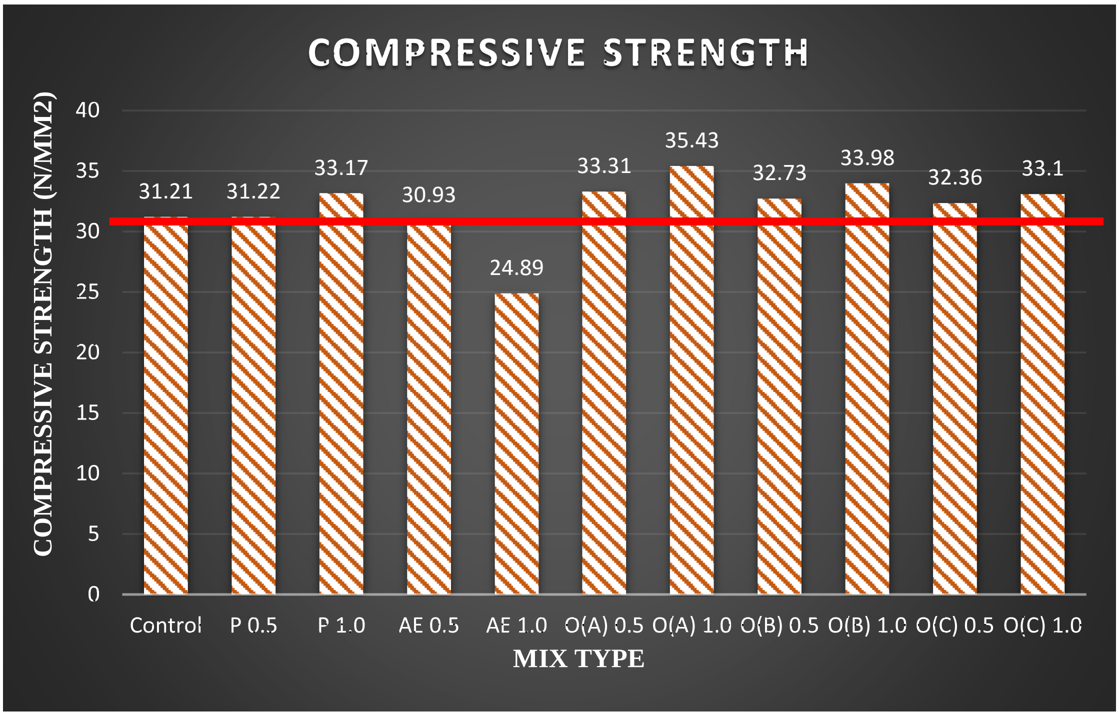

Figure 4.6: Compressive Strength Result at 28 Days

4.4.2 Rebound Hammer

Rebound hammer is one of the non-destructive test (NDT) which is most frequently used for NDT. Based on the Gambhir (2008), rebound hammer is used to test the hardness of the concrete. Not only that, the damaged zones can be detected as well as the uniformity of the concrete and structural element also can be checked by using this Schmidt Rebound Hammer. This test was conducted based on the BS EN 12504-2: 2001 with the size of concrete cube (100 mm x 100 mm x 100 mm) at the age of 7 and 28 day. 10 different point on the front and back surface of each of the concrete cube were recorded. The results for the rebound hammer at the age of 7 days and 28 days was shown in Table 4.11.

Table 4.11: Result for Rebound Hammer at 7 Days and 28 Days

Sample / Age	Average Rebound Normal	
	7 Days	**28 Days**
Control	15.9	20.9
P 0.5	14.2	19.5
P 1.0	17.0	21.7
AE 0.5	14.8	20.0
AE 1.0	14.1	17.0
O (A) 0.5	15.1	21.2
O (A) 1.0	14.5	20.5
O (B) 0.5	14.6	21.6
O (B) 1.0	16.1	20.3
O (C) 0.5	15.4	22.0
O (C) 1.0	15.9	23.4

The result of the rebound hammer test was tabulated in Figure 4.7. The value of rebound hammer were increasing with the age of the concrete. At the age of 7 days, the rebound number for the concrete containing 0.5 % of admixture and UEO were lower than the control mix but the rebound number was increased when the dosage increase to 1.0 % except the concrete contains air entraining decreased. At 28 days, the concrete with 1.0 % of UEO showed the highest rebound hammer compared to the control mix and other concrete with different admixture. Therefore, the application of UEO in concrete doesn't affect the surface hardness of the concrete.

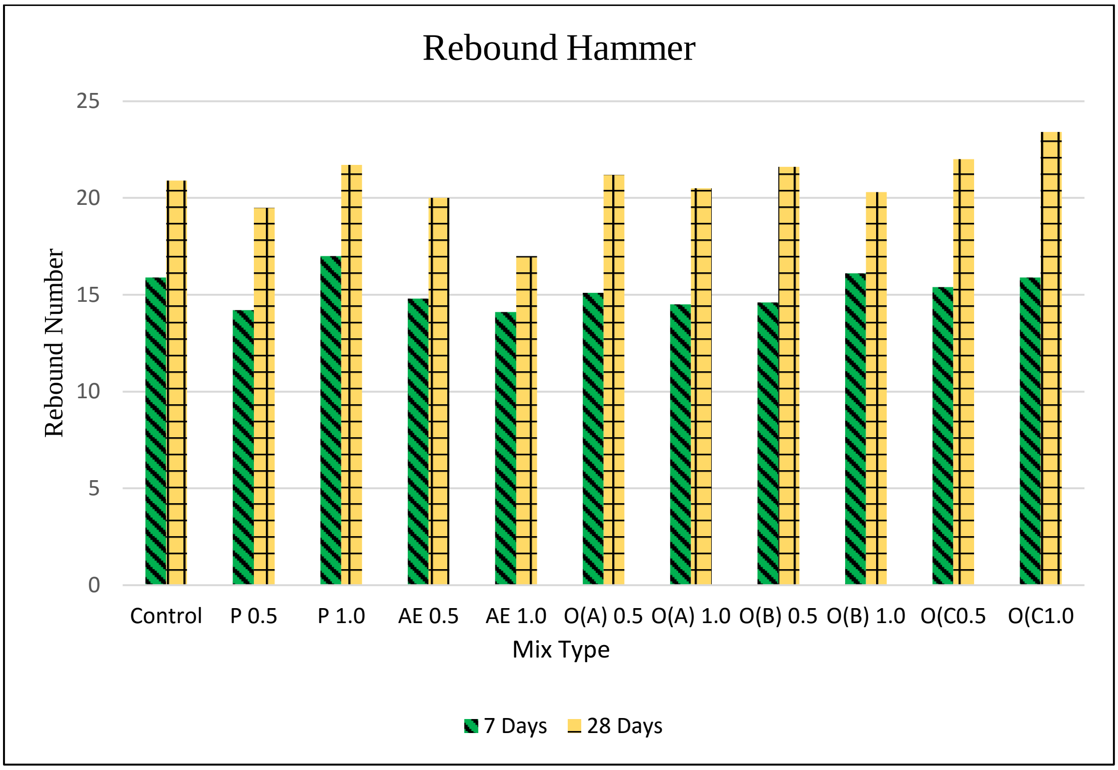

Figure 4.7: Result of Rebound Hammer

4.4.3 Ultrasonic Pulse Velocity Test

Ultrasonic Pulse Velocity (UPV) test is another non-destructive test method. The velocity of longitudinal waves can be determined by using this test. Based on the Civil Engineering Portal (2011), UPV test contains of measuring of the time taken by a pulse passing through the concrete. High Velocity indicates that the quality of the concrete is good in term of the density, homogeneity, uniformity and many more.

In addition, the concrete quality such as absence of cracks, segregation, uniformity and internal flaws can be assessed based on the Table 4.12. Pulse velocity can be obtained by using the equation as shown in Equation 4.1.

$$V = L / T \tag{4.1}$$

Where,

V = Pulse Velocity, km/s

L = Path Length, cm

T = Transit Time, µs

Besides that, British Standard (BS EN 12504-4: 2004) was used to conduct this test in this research. Concrete cube with size 100 mm x 100 mm x 100 mm was tested at the age of 7 and 28 days as the results showed in Table 4.13 and Table 4.14. Table 4.15 shows the summary of the results for the UPV.

Table 4.12: Quality of Concrete in Terms of UPV

Pulse Velocity (km/second)	**Concrete Quality (Grading)**
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Table 4.13: Result of the Samples for Ultrasonic Pulse Velocity at Age 7

Sample		**Average of Transit Time (µs)**	**Pulse Velocity (km/s)**	**Mean of Pulse Velocity (km/s)**	**Concrete Quality (Grading)**
Control	**1**	25.13	3.98	**4.05**	**Good**
	2	24.27	4.12		
	3	24.69	4.05		
P 0.5	**1**	23.40	4.27	**4.29**	**Good**
	2	22.80	4.39		
	3	23.75	4.21		
P 1.0	**1**	23.00	4.35	**4.29**	**Good**
	2	23.35	4.28		
	3	23.60	4.24		

AE 0.5	**1**	22.75	4.40	**4.26**	**Good**
	2	24.25	4.12		
	3	23.40	4.27		
AE 1.0	**1**	24.45	4.09	**3.97**	**Good**
	2	25.15	3.98		
	3	26.00	3.85		
O (A) 0.5	**1**	23.30	4.29	**4.30**	**Good**
	2	24.00	4.17		
	3	22.50	4.44		
O (A) 1.0	**1**	23.45	4.26	**4.25**	**Good**
	2	23.60	4.24		
	3	23.50	4.26		
O (B) 0.5	**1**	22.80	4.39	**4.35**	**Good**
	2	22.95	4.36		
	3	23.20	4.31		
O (B) 1.0	**1**	24.25	4.12	**4.23**	**Good**
	2	23.55	4.25		
	3	23.20	4.31		
O (C) 0.5	**1**	24.10	4.15	**4.20**	**Good**
	2	23.26	4.30		
	3	24.10	4.15		
O (C) 1.0	**1**	24.39	4.10	**4.10**	**Good**
	2	23.53	4.25		
	3	25.32	3.95		

Table 4.14: Result of the Samples for Ultrasonic Pulse Velocity at Age 28

Sample		Average of Transit Time (μs)	Pulse Velocity (km/s)	Mean of Pulse Velocity (km/s)	Concrete Quality (Grading)
Control	1	25.38	3.94	3.93	Good
	2	24.45	4.09		
	3	26.60	3.76		
P 0.5	1	25.32	3.95	3.94	Good
	2	25.65	3.90		
	3	25.20	3.97		
P 1.0	1	23.85	4.19	4.19	Good
	2	23.81	4.20		
	3	23.85	4.19		
AE 0.5	1	27.62	3.62	3.61	Good
	2	27.85	3.59		
	3	27.65	3.62		
AE 1.0	1	46.30	2.16	2.15	Doubtful
	2	45.90	2.18		
	3	47.30	2.11		
O (A) 0.5	1	25.91	3.86	4.00	Good
	2	24.15	4.14		
	3	25.00	4.00		
O (A) 1.0	1	21.19	4.72	4.25	Good
	2	23.95	4.18		
	3	25.95	3.85		
O (B) 0.5	1	30.77	3.25	3.64	Good
	2	25.10	3.98		
	3	27.10	3.69		
O (B) 1.0	1	24.81	4.03	3.85	Good
	2	26.32	3.80		
	3	26.88	3.72		
O (C) 0.5	1	25.84	3.87	3.86	Good
	2	25.60	3.91		

	3	26.35	3.80		
O (C) 1.0	**1**	23.92	4.18	**4.05**	**Good**
	2	24.39	4.10		
	3	25.85	3.87		

Table 4.15: Summary of Ultrasonic Pulse Velocity

Sample	**Pulse Velocity (km/s)**		**Concrete Quality (Grading)**
	7 Day	**28 Day**	**7Day / 28 Day**
Control	**3.80**	3.93	Good
P 0.5	3.88	3.94	Good / Good
P 1.0	4.10	4.19	Good / Good
AE 0.5	3.50	3.61	Good /Good
AE 1.0	2.10	2.15	Doubtful / Doubtful
O(A) 0.5	3.80	4.00	Good / Good
O(A) 1.0	4.05	4.25	Good / Good
O(B) 0.5	3.58	3.64	Good / Good
O(B) 1.0	3.65	3.85	Good / Good
O(C) 0.5	**3.62**	3.86	Good / Good
O(C) 1.0	**3.85**	4.05	Good / Good

From Figure 4.8, it can be seen that when UEO was used, the ultrasonic pulse velocity that obtained were more or less similar to the control mix and the grading show good based on the table provided by Civil Engineering Portal (2016). Thus, it can concluded that the concrete mixes maintained their quality of the concrete except the concrete containing 1.0 % of the air entraining admixture which cause the concrete degraded.

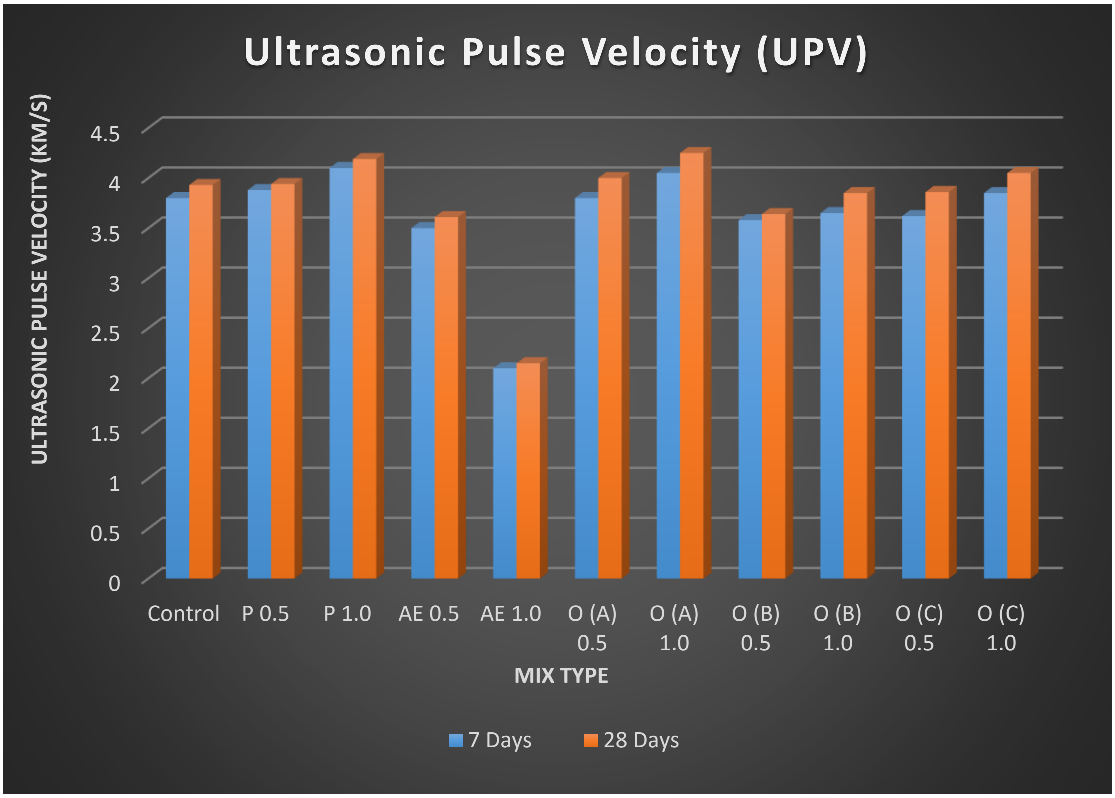

Figure 4.8: Result for Ultrasonic Pulse Velocity of Concrete Mixes

4.4.4 Porosity Test

Based on the Siddique et al., (2015) stated that the porosity (P, %) is inversely related to the strength which means that higher value of porosity has lower strength or vice versa. In this research, porosity test was conducted according to the RILEM CP113 and the samples with the size of 45 mm diameter x 40 mm thick cylinders were tested at the age of 28 days.

The porosity, % of the samples can be calculated by using the Equation 4.2. The weight measurements for all the samples are in grams, g. The dry specimens need to be dried in a ventilated oven at 105 °C for 24 hours before weigh it. The result for the porosity test at 28 days was shown in Table 4.16.

$$P\ (\%) = \frac{W_1 - W_3}{W_1 - W_2}\ x\ 100 \qquad (4.2)$$

Where,

W_1 = Weight of Specimen in Air,

W_2 = Weight of Specimen in Water,

W_3 = Weight of Dry Specimen.

Table 4.16: Result of the Samples for Porosity at Age 28 Days

Sample		Weight of Specimen in Air, W_2 (g)	Weight of Specimen in Water, W_3 (g)	Weight of Dry Specimen, W_4 (g)	Porosity (%)	Average Porosity (%)
Control	**1**	169	90	160	11.39	
	2	161	87	152	12.16	**12.12**
	3	166	88	156	12.82	
P 0.5	**1**	163	87	153	13.16	
	2	158	85	149	12.33	**12.72**
	3	154	83	145	12.68	
P 1.0	**1**	165	88	155	12.99	
	2	165	88	156	11.69	**12.17**
	3	162	86	153	11.84	
AE 0.5	**1**	152	80	140	16.67	
	2	156	81	144	16.00	**15.91**
	3	153	80	142	15.07	
AE 1.0	**1**	156	82	143	17.57	
	2	153	80	140	17.81	**17.81**
	3	150	78	137	18.06	
O (A) 0.5	**1**	161	86	151	13.33	
	2	164	88	154	13.16	**12.88**
	3	161	87	152	12.16	
O (A) 1.0	**1**	165	87	155	12.82	
	2	163	87	155	10.53	**11.78**
	3	163	88	154	12.00	
O (B) 0.5	**1**	162	86	153	11.84	**12.49**

	2	168	90	158	12.82	
	3	166	88	156	12.82	
O (B) 1.0	**1**	163	86	153	11.84	**11.89**
	2	161	86	152	12.00	
	3	162	86	153	11.84	
O (C) 0.5	**1**	156	82	146	13.51	**13.39**
	2	158	82	148	13.16	
	3	162	88	152	13.51	
O (C) 1.0	**1**	161	85	152	11.84	**11.11**
	2	160	86	152	10.81	
	3	158	83	150	10.67	

One of the important characteristics of hardened concrete is the total porosity because it is a measurement of the durability, strength and quality of concrete (Shafiq, Nuruddin and Beddu, 2011). From the Figure 4.9, the total porosity of the control mix achieved 12.12 % at 28 days. When 0.5 % of admixtures (plasticizers and air entraining) and UEO were added, the total porosity was higher than the control mix. On the other hand, when admixture increase to 1.0 %, the porosity for the concrete with UEO was reduced expect the concrete with air entraining admixture increased. This had shown that 1.0 % of used engine oil reduced the total porosity of concrete between 2.8 to 8.3 % whilst 1.0 % of air entraining increased the porosity of the concrete. Thus, low porosity of used engine oil can improve the durability of concrete.

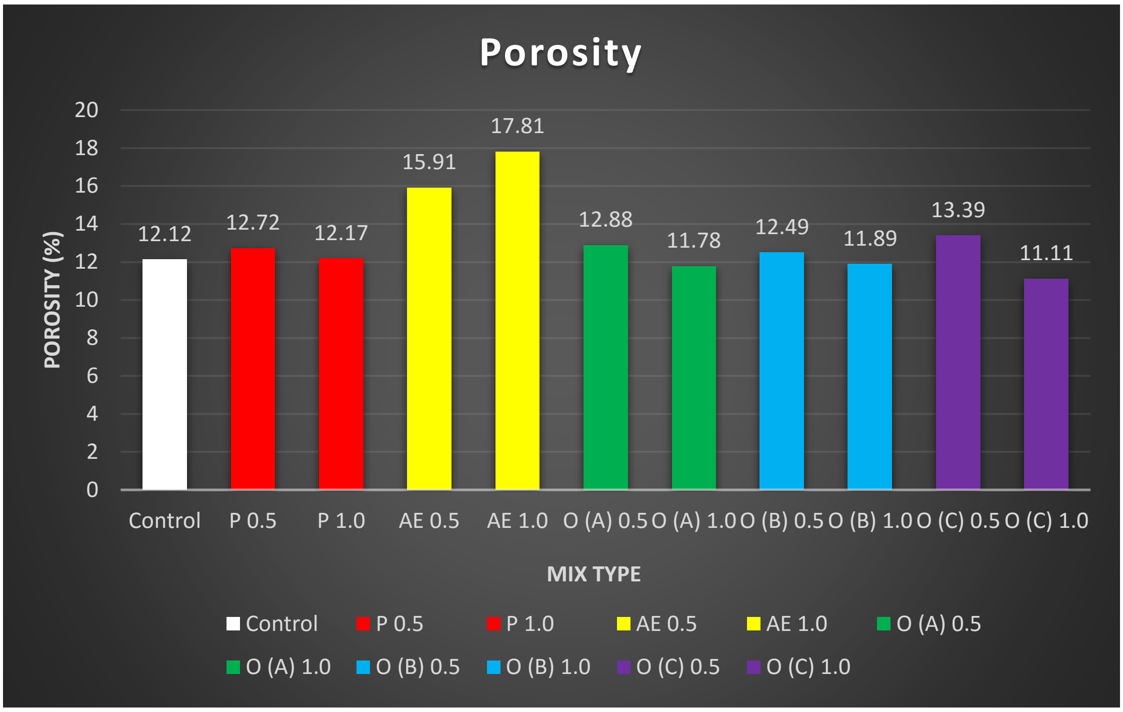

Figure 4.9: Porosity, % of Concrete Mixes at 28 Days

4.5 Correlation between Rebound Hammer and Compressive Strength

Rebound hammer test is to test the hardness of the concrete as discussed in the above section. To analyse the relation, the rebound number against the compressive strength was plotted in Figure 4.10. From the equation, y = 1.1972x + 1.7983, it showed a positive relation between the rebound number and the compressive strength. Concrete with higher rebound number, it means it has a harder surface of the concrete so the strength of the concrete will higher compared to the soft and weak surface concrete.

Table 4.17: Results of Rebound Number and Compressive Strength

Sample	Mean Rebound Number, R	Compressive Strength (N/mm^2)
Control	20.9	31.21
P 0.5	19.5	31.22
P 1.0	21.7	33.17
AE 0.5	20.0	30.93
AE 1.0	17.0	24.89
O (A) 0.5	21.2	33.31
O (A) 1.0	20.5	35.43
O (B) 0.5	21.6	32.73
O (B) 1.0	20.3	33.98
O (C) 0.5	22.0	32.36
O (C) 1.0	23.4	33.10

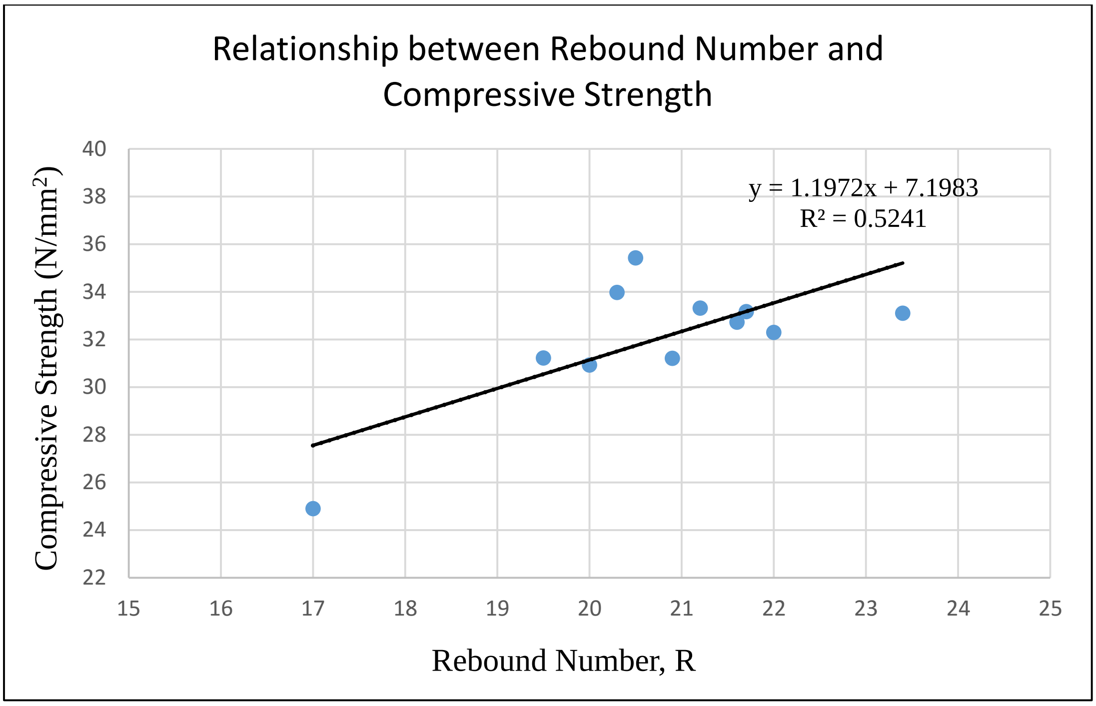

Figure 4.10: Correlation between Rebound Number and Compressive Strength

4.6 The Correlation between Porosity and Compressive Strength

Total porosity is one of the factors which will affects the strength of the concrete. A line graph of porosity against compressive strength was plotted in Figure 4.11 to analyse their relation. From the graph, a negative relationship between the porosity and compressive strength was obtained or it can be concluded that the porosity was inversely proportional to compressive strength. When higher porosity in concrete it has lower strength due to the more voids were present in the concrete. Consequently, this will affects the durability of the concrete.

Table 4.18: Results of Total Porosity and Compressive Strength

Sample	Porosity (%)	Compressive Strength (N/mm^2)
Control	12.12	31.21
P 0.5	12.72	31.22
P 1.0	12.17	33.17
AE 0.5	15.91	30.93
AE 1.0	17.81	24.89
O (A) 0.5	12.88	33.31
O (A) 1.0	11.78	35.43
O (B) 0.5	12.49	32.73
O (B) 1.0	11.89	33.98
O (C) 0.5	13.39	32.36
O (C) 1.0	11.11	33.10

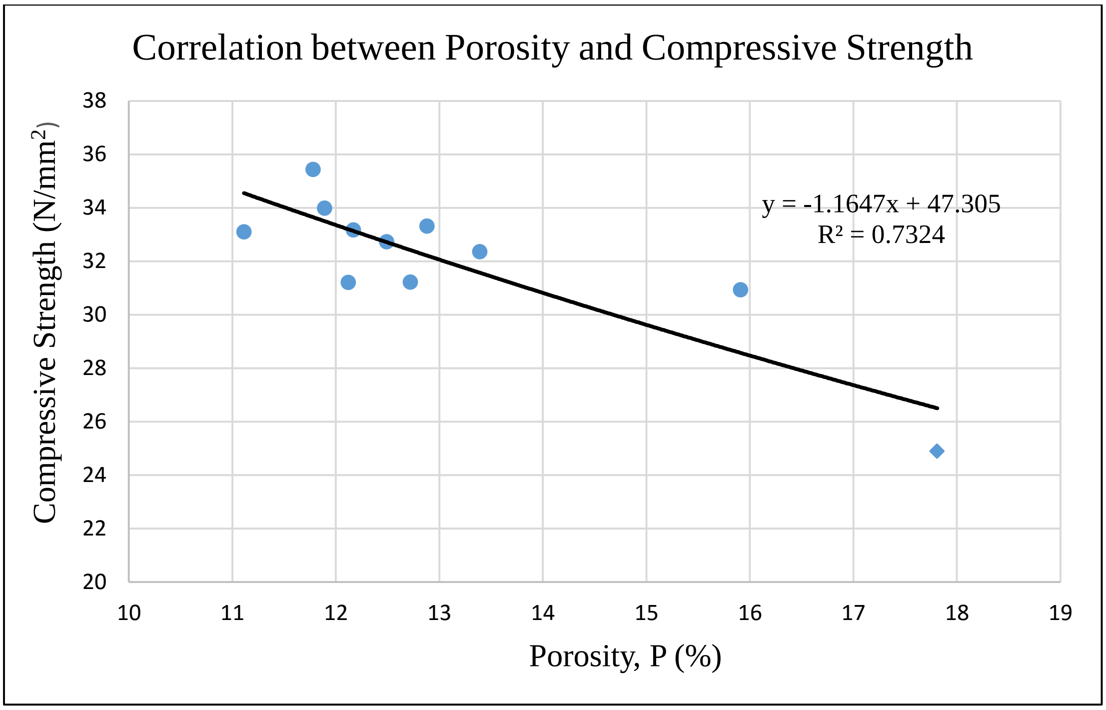

Figure 4.11: Correlation between Total Porosity and Compressive Strength

4.7 Concluding Remarks

From the results that obtained from the experimental programs, the workability of the concrete with UEO improved the slump value which mean that it increase the fluidity of the concrete. This is due to the UEO is the lubricant so it has the greasy effect to make the fresh concrete more workable. Besides that, the compressive strength of the concrete improved and the quality of the concrete still maintained in good quality due to lower porosity of UEO concrete compared to other concrete mix with other chemical admixtures and conventional concrete. When UEO concrete has low porosity, it means that voids present in the concrete are lesser so it can enhanced the durability of the concrete. In addition, the performance of different source of UEOs in concrete were more or less similar. Thus, it can concluded that the UEO has more or less similar characteristics or properties which doesn't have much changes when UEO applied in the concrete.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The aim of this study is to determine the viability of the application of Used Engine Oil in concrete while objectives are to evaluate the workability of Used Engine Oil (UEO) in concrete and to examine the performance of concrete between UEO concrete and other concrete mix with different admixture. Three sources of UEO were collected from Cameron Highlands, Sabak Bernam and Kampar to test the integrity of the UEO in concrete. The performance of concrete was determined by using laboratory test such as slump test, compressive strength test, rebound hammer, ultrasonic pulse velocity test and porosity test. Based on the results that obtained, there are various conclusions that can be made in the following:

i. Application of UEO in concrete have higher slump value than the conventional concrete. Hence, UEO can acts as the chemical plasticizer which increase the workability of the fresh concrete.

ii. Utilize of UEO doesn't affect the strength of the concrete. This is because high workability of concrete will allows easily mix, transport and finishing which will reduce less voids or pores present in the concrete. Thus, the compressive strength of the concrete will not affected.

iii. The quality of the concrete has maintained when application of UEO in concrete.

iv. UEO in concrete has reduced 8.3 % of the porosity compared with the control mix while air entraining has increased the porosity of the concrete. Therefore, lower porosity can improve the durability of the concrete.

5.2 Recommendations

Although the results that obtained was positive, further study needs to be done before recommending the application of the UEO in the concrete industry. This is to collect more accurate and reliable information regarding the application of UEO in the concrete. There are several recommendations for the research areas which include:

i. Conduct Scanning Electron Microscope (SEM) test.

ii. A study on the reaction kinetic of the UEO in concrete.

iii. Analyse the effect of application of UEO in concrete in term of the durability. Example of the durability test are permeability test, carbonation test, hydrochloric acid test and other durability tests.

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