Effect of Used Engine Oil in Properties of Fresh and Hardened Concrete Containing Fly Ash

by

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CERTIFICATION OF APPROVAL

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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HANISAH BINTI SHAM

ABSTRACT

Application of mineral, agricultural and industrial wastes in concrete manufacturing are being popular in current practices. It is due to fact that most of them have proved to be beneficial in enhancing the several characteristics of concrete. Used engine oil is an industrial waste that is hazardous in nature and its safe and legal dispose is an issue. Earlier research on the effects of used engine oil on basic properties of concrete was quite encouraging and concluded that it behaves as superplasticizers without the loss of strength of concrete. In this research strength, porosity and permeability of wide range of concrete mixes containing OPC and OPC blended with fly ash mixes were investigated and the effects of used engine oil on such properties were found quite positive.

ACKNOWLEDGEMENT

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OPC	Ordinary Portland Cement
UEO	Used Engine Oil
NEO	New Engine Oil
SP	Superplasticizers

CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

Engine oil is lubricating oil which is used in automotive engines. After vehicle runs for a certain period of time and mileage, the oil is replaced by new oil and the old one is termed as used engine oil. The used engine oil requires to be dispose off in a proper way to avoid pollution. People who change their own oil may not be careful and end up disposing it at the wrong place and in improper way. According to the U.S. EPA, over 40% of the oil pollution comes from the used engine oil from vehicles. To make use of it, used engine oil could be added as admixtures in concrete with the purpose of enhancing the properties of the fresh and hardened concrete.

1.1 Background Study

The background of the research is to study the effect of used engine oil in concrete by mixing the cement with cement replacement material which is the fly ash. The use of fly ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability. Instead of using used engine oil and new engine oil as the chemical admixtures, super plasticizer also is added into the mix as to compare its effect in cement with fly ash. The main purpose of using super plasticizers is to produce flowing concrete with very high slump. The different dosage of super plasticizers, used engine oil and new engine oil is added in different mix of concrete with fly ash. This is to evaluate the variation of the concrete properties with various mix designs.

1.2 Problem Statement

Used engine oil is a hazardous waste which is requires safe and proper disposal. Although in countries like US, there is law regarding the safe disposal but based on statistics, in US about 40% or more oil from vehicles is illegally disposed off. In concrete manufacturing there are variety of chemical admixtures used to enhance its properties, if used engine oil could be used as super plasticizer and air entraining agent, it may serve the dual purpose, at one way to minimize the illegal disposal and on the other hand a cheap chemical admixture for concrete manufacturing.

1.3 Objective and Scope of Study

The principal objectives of this research project are:

- To investigate the hypothesis that used engine oil behaves as an air entraining agent and superplasticizers in fresh state of concrete.
- To examine the chemical analysis of hydrated cement paste containing used engine oil.
- To determine the effects of used engine oil on compressive strength, total porosity and oxygen permeability of wide range of concrete mixes containing 100%OPC and OPC blended with fly ash.
- To compare the effects of used engine oil on properties of concrete with other additives as superplasticizers and new engine oil.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 By products and wastes used in concrete

Wastes can be defined as not readily avoidable byproducts for which there is no economical demand and for which disposal is required. Processed or unprocessed industrial by-products or wastes can be used as raw materials in cement manufacturing, as components of concrete binder, as aggregates, a portion of aggregate, or ingredients in manufactured aggregates. Some wastes can be used as chemical admixtures and additives, which can alter and enhance selected properties of fresh and hardened concrete. The successful use of industrial byproducts or wastes in concrete depends on the required properties of the end product. Economical factors would ultimately determine if potentially beneficial waste could be used as an ingredient in concrete. These factors are generally influenced by the cost of waste disposal, the cost of transportation of waste to a manufacturing site, and existing environmental regulations [1].

2.2 Used engine oil

According to the U.S. EPA, used motor oil is any petroleum-based or synthetic oil that has been used for vehicle lubrication. As a result of normal use, motor oil becomes contaminated with various impurities such as dirt, water, chemicals or metals from your engine. It is estimated that less than 45% of used engine oil is being collected worldwide while the remaining 55% is thrown by the end user in the environment .Used oil affects both marine and human life. Oil in bodies of water raises to the top forming a film that blocks sunlight, thus stopping the photosynthesis and preventing oxygen replenishment leading to the death of the underwater life. In addition, used oil contains some toxic materials that can reach humans through the food chain. Health hazards range from mild symptoms to death. The main source of contaminants in used oil is due to the break down of additives and the interaction of these substances with others found in nature. In this context, the proper management of used oil is essential to eliminate or minimize potential environmental impacts [1].

2.3 Superplasticizers

Concrete is a composite material in which aggregates (gravel and sand) are bound by hydrated cement paste. The amount of water required for the reaction of hydration represents about 25% of the mass of cement. However, in order to obtain a flowing concrete, which can be either cast or pumped, much more water is required (about double). In the long term, this excess water evaporates, leaving voids in the concrete. The associated porosity decreases both the mechanical strength and the durability, and such concrete does not reach the optimal properties it could have if it could be produced as a more compact material. This is where superplasticizers, also known as High Range Water Reducers (HRWRs), are of interest. Superplasticizers are polymeric dispersants, which when added in small amounts to concrete (typically less than 0.5% of the mass of cement), allow high water reduction for the same workability. The use of superplasticizers will still grow because of their ability to allow the production of concrete exhibiting high durability [2]. The presence of superplasticizers (SP) in a concrete mixture is quite advantageous, in that they assist in the effective dispersion of cement particles and hence improving the workability of concrete. The water to cement ratio is reduced when SP is added to cement paste, which leads to reduced permeability, increased strength and producing durable concrete. SP are broadly classified into four groups, sulphonated melamine- formaldeyde condensate (SMF), sulphonated naphthalene-formaldehyde condensate (SNF), modified lignosulphonates (MLS) and others including sulphonic acid esters and acrylic esters [3].

2.4 Pulverized Fuel Ash

Presently various types of by-product materials, such as fly ash, silica fume, rice husk ash, and others have been widely used as pozzolanic materials in concrete. Their utilization not only improves concrete properties, but also preserves the environment. Fly ash, one of the popular pozzolan, can improve concrete properties such as workability, durability, and ultimate strength in hardened concrete. Fly ash with high fineness exhibits high pozzolanic activity and can be used to produce high strength concrete.

The amount of pulverized fuel ash (PFA) generated by electric power plant in Malaysia is increasing year by year in Malaysia. According to the statistic reported for years 1987 – 1989, 415 million tons of PFA was produced all over the world. Only 16 % of the total was utililised in construction sector. The PFA produced by the power plant has been handled in two different ways in Malaysia; added to cement as a pozzolanic admixture and stockpiled in embankments around the power stations. According to 8th Malaysia Plan, by the years 2005, Malaysia will use about 11.2 million tones of coal per annum. This will produces more than 2 million tones of PFA annually but only a small amount is utilized[4].

Table 2.1: Coal used for electric power plant in Malaysia.

Year	1995	2000	2005
Fuel (%)	11	5.3	3
Coal (%)	9.7	7.9	30.3
Gas (%)	67.8	78.7	61
Hydro (%)	11.3	8	5.4
Others (%)	0.2	0.1	0.1
Total (gw/h)*	41.813	69.371	102.34

* gigawatt/hour

The composition of pulverized fuel ash depends on the nature of the coal source, which can contain more or less calcium oxide. A bituminous coal usually gives rise to class F materials (i.e: with low calcium content). Typically it consist crystallized phases like α-quartz, mullite, hematite and magnetite in a matrix of aluminosilicate glass [4].

Table 2.2: ASTM Specification for PFA classification.

Chemical composition	ASTM C618 Specification
Total SiO_2+ Al_2+O_3+Fe_2O_3	50% min-Class C
	70% min-Class F
CaO	>10%-Class C
	<10%-Class F
SO_3	5% max
Na_2O	1.5% max
Loss of Ignition (LOI)	6% max

Table 2.3: Chemical composition of PFA from Manjung coal power plant.

Chemical composition	%
SiO_2	51.19
Al_2O_3	24
Fe_2O_3	6.6
CaO	5.57
MgO	2.4
SO_3	0.88
K_2O	1.14
Na_2O	2.12

2.5 Porosity

In designing a concrete structure, one of the most important properties which have to be considered, besides the ability of the structure to resist all loads, is its durability. The service life and durability of a concrete structure strongly depend on its material transport properties, such as permeability, sorptivity, and diffusivity which are controlled by the micro structural characteristics of concrete. It is known that the porosity and pore size distribution are the critical components of the microstructure of hydrated cement paste that influence durability. In order to achieve high strength, low permeability, and durable concrete, it is therefore necessary to reduce the porosity of cement paste. It is well known that the incorporation of pozzolanic materials as partial replacement of cement refines the porosity and pore size distribution of the paste [5].

The permeable porosity affects the transport properties and durability of concrete. It is connected to many deterioration processes driven by the transport properties of concrete. For example, the porous medium of concrete permits the transport of chloride, oxygen, carbon dioxide, and moisture, which are known to cause corrosion in reinforcing bars. This is a severe problem in North America owing to the use of deicing salts for winter maintenance. Corrosion-induced deterioration is now plaguing so many concrete structures in this region. There is another deterioration process most commonly occurring in North America. It is the physical deterioration of concrete by freezing and thawing. The deterioration due to freezing and thawing is also related to the permeable porosity of concrete. The permeable pores of concrete accommodate water under saturated condition. This water freezes below freezing temperature, expands and causes hydraulic pressure. Thus, the cracking appears in concrete. Other deterioration processes such as sulfate attack and alkali aggregate reactivity are also linked to the permeable porosity of concrete, as they depend upon the ingress of moisture into the concrete. Furthermore, the permeable porosity of concrete has a major effect on its strength and other mechanical properties. Hence, the permeable porosity of concrete should be determined properly in order to predict the durability and serviceability of concrete structures [6].

Porosity was measured using the vacuum-pressure saturation apparatus developed by Khan and Lynsdale (2001). The schematic diagram of the apparatus is shown in Fig 2.1. A full description of the apparatus and test procedure is given in the literature (Khan 2000; Khan and Lynsdale 2001). The amount of water penetrated into the specimen is a measure of the porosity and is calculated as follows: [7]

$$\text{Permeable porosity} = \frac{W_s - W_d}{W_s - W_b} \times 100\% \tag{2.1}$$

Where, W_b=Buoyant mass of the saturated specimen in water, W_d=Oven-dry mass of the specimen in air, W_s= Saturated surface-dry mass of the specimen in air.

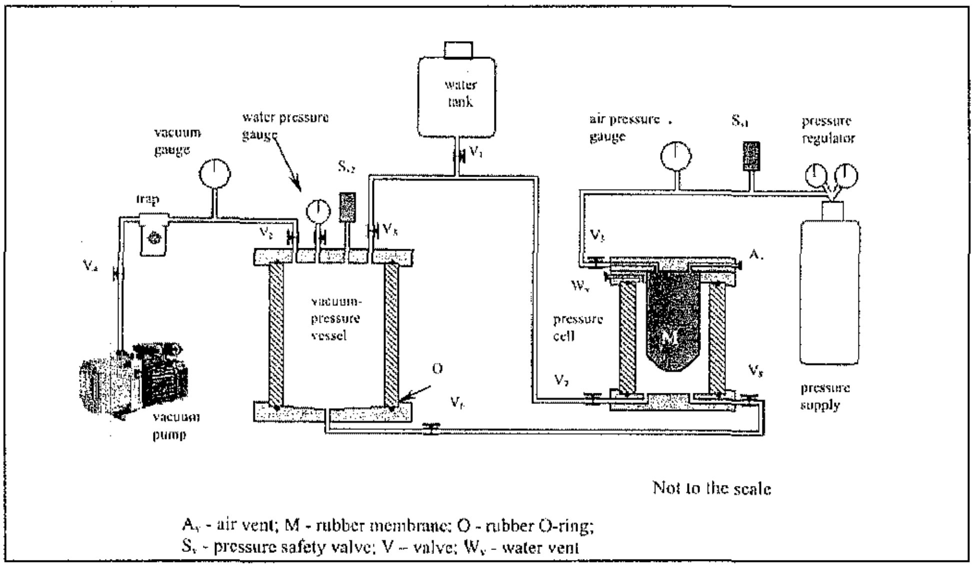


Figure 2.1: Schematic diagram for vacuum pressure saturation system.

2.6 Permeability

There are three fluids principally relevant to durability which can enter concrete: water, pure or carrying aggressive ions, carbon dioxide and oxygen. They can move through the concrete in different ways, but all transport depends primarily on the structure of the hydrated cement paste. As stated earlier, durability of concrete largely depends on the cease with which fluids, both liquids and gases, can enter into and move through the concrete; this is commonly referred to as permeability of the concrete. Strictly speaking, permeability refers to flow through a porous medium. Now, the movement of the various fluids through concrete takes place not only by flow through the porous system but also by diffusion and sorption, so that our concern is really with penetrability of concrete. Nevertheless, the commonly accepted term permeability will be used for the overall movement of fluids into and through concrete except where for clarity distinctions between the various types of flow need to be made [8].

One of the fastest and easiest techniques for measuring the gas permeability of concrete and mortar is the method of differential pressure. In general, the time required to accomplish the test can vary for different concretes depending upon their microstructure and the degree of saturation. For example, it requires less than half an hour for completely dried sample, whereas it can last for few days when the degree of saturation is higher than 80%. Therefore, the gas permeability is the function of open porosity (fraction of unsaturated pores) in the concrete and mortar samples; it decreases with the filling of pore system with water. In case of concrete samples containing a moisture content corresponding to a relative humidity between 40% and 75% of the ambient air, there is a little change in their permeability [9].

The permeability of non-compressible fluid (such as water) is calculated using Darcy's law as shown in equation 2.1. In case of compressible fluid such as oxygen, a modification in Darcy's equation was proposed by Grube and Lawrence (1984) that considers the volume of fluid at an average pressure within the samples.

$$\frac{Q}{A} = -\frac{K}{\mu}\left(\frac{dp}{dL}\right) \qquad (2.2)$$

Figure 2.2 demonstrates the schematic diagram of the Leeds permeameter. In order to determine the coefficient of permeability for compressible fluid such as oxygen, the quantity (Q) will vary with the pressure (p), however, the viscosity of a gas is independent of pressure. If for each of the element (dL) there is a pressure drop of (dp) and (Q) is the mass flow rate through the concrete specimen at the steady state flow. Then:

$$Q = R\left(\frac{p}{p_{Out}}\right) \qquad (2.3)$$

The oxygen permeability was measured by a gas permeameter developed by Cabrera and Lynsdale (1988) using the following expression suggested by Grube and Lawrence (1984). Following equation is the modified form of the Darcy's equation that' is proposed by Grube and Lawrence (1984) for calculating the permeability of compressible fluid.

$$K = \frac{2\mu p_{Out} QL}{A\left(p_{In}^2 - p_{Out}^2\right)} * 10^{-5} \qquad (2.4)$$

Equation-2.4 is the generalised form that is used to calculate the coefficient of gas permeability (K). In equation 7.3, the multiplying factor 10^{-5} is used to describe the pressure unit in N/m^2, hence, the coefficient of permeability (K) is expressed in m^2. The intrinsic permeability "K" of concrete differs from the more commonly used coefficient of permeability "k". The intrinsic permeability incorporates the properties of the flowing fluid, such as dynamic viscosity and specific weight, and is therefore a more rational approach [9].

Where:

Q = Volume flow rate (m^3/s)

A = Cross sectional area of specimen (m^2)

L = Specimen thickness (m)

dp = Fluid pressure head across specimen (bar)

K = Intrinsic permeability (m^2)

k = Coefficient of permeability (m/s)

μ = Viscosity of fluid (Ns/m^2)

p = Net or effective pressure across concrete specimen (bar)

R = Gas flow rate at outlet pressure, p_{Out} (m^3/sec)

p_{Out} = Pressure at outlet (approximately equals to 1 bar)

p_{In} = Pressure at inlet (bar)

v = Velocity of gas (m/s)

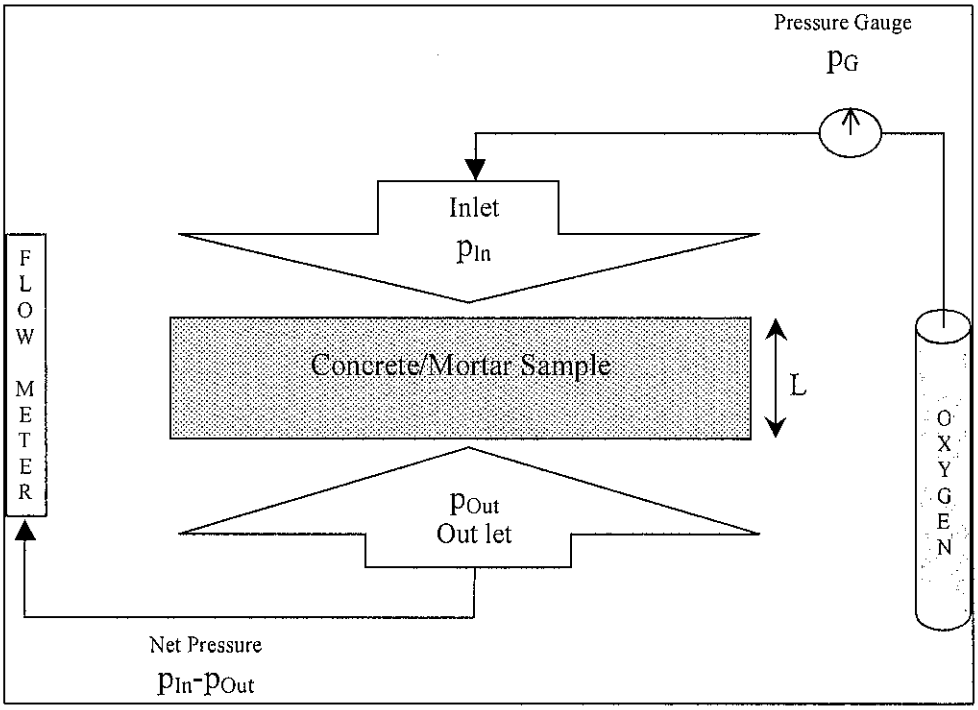


Figure 2.2: Schematic Diagram of Oxygen Permeability Test.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.0 METHODOLOGY AND PROJECT WORK

A few steps shall be taken to achieve the objectives of the study and completing the tasks successfully for the smoothness of the project.

3.1 Research

A few research had been conducted by referring to journals, reference books and website. This is one of method to write the literature review for understanding purposes. The source of journals is obtained from the online journals and the reference books are come from the library.

3.2 Laboratory works

The purpose of laboratory work is to prepare concrete cubes in order to determine the properties of the concrete. The tasks involved such as mixing and sampling the fresh concrete, slump test for measuring the workability of the concrete, air entrainment test is to obtain the uniformity of air in concrete, compressive test is to determine the strength of hardened concrete and the porosity test is to verify amount of void in the concrete after it is hardened. The equipments involved will be the concrete mixer, concrete moulds, compression testing machine, truncated conical mould 100mm in diameter at the top, 200mm at the bottom and 300mm high, coring machine and air entrainment meter with hand operated pump. Results for slump test and air entrainment test can be gain during the preparation of fresh concrete. While the results for hardened concrete can be obtained from the compressive test and porosity test by testing the concrete cubes for every 3,7,28 and 90 days after curing process.

3.2.1 Slump test

Slump test is conducted to measure the workability of a sample from a batch of fresh concrete of a given mix (as recommended by BS 1881: Part 102:1983).The test is very useful in detecting variations in the uniformity of a mix of given nominal proportions. This test is done 6 minutes after water is added to dry concrete mix. If the specimen collapses off laterally, the test is repeated with another sample of the same batch of concrete.. In concrete mixes, changes in slump most often reflect changes in the amount of water in the mix, or changes in temperature, hydration and setting. The British Standard specifies that the slump should be measured to the highest point of the concrete.

- To perform a slump test, the cone is filled with concrete in three equal layers, each layer is compacted with twenty five tamps of the tamping rod.
- The cone is slowly raised and the concrete is allowed to slump under its own weight.
- The slump is measured using the upturned cone and slump rod as the guide.
- A change in slump generally means a change in amount of water in the mix but it may also mean other changes such as air content, aggregate gradation, sand content, temperature, hydration rate or setting time.

Figure 3.1: Slump test

3.2.2 Air entrained test

Air entrainment test was conducted to obtain the uniformity of the proportion of air in the concrete. The test was based on BS 1880: Part 106:1983.

- Air entrained concrete contains many extremely small air bubbles. These bubbles are so small that there are millions of them in a cubic inch of air-entrained concrete that contains 4 to 6 percent air. These air bubbles act as frictionless ball bearings in fresh concrete.
- Air content of freshly mixed air-entrained concrete should be checked regularly because too little air will not provide freeze-thaw resistance and too much air will result in low strength.
- The air content is measured by using pressure method that works on the principle that changes in air pressure results in a change in the volume of concrete. The change in volume is assumed to be caused by compression of air voids in the fresh concrete.
- The pressure meter is added with water to fill the cover assembly up to a certain level. A cap then seals the assembly and water is added constantly through an open hole until the water goes down through the pipe and the percentage of air content was read at the meter gauge.

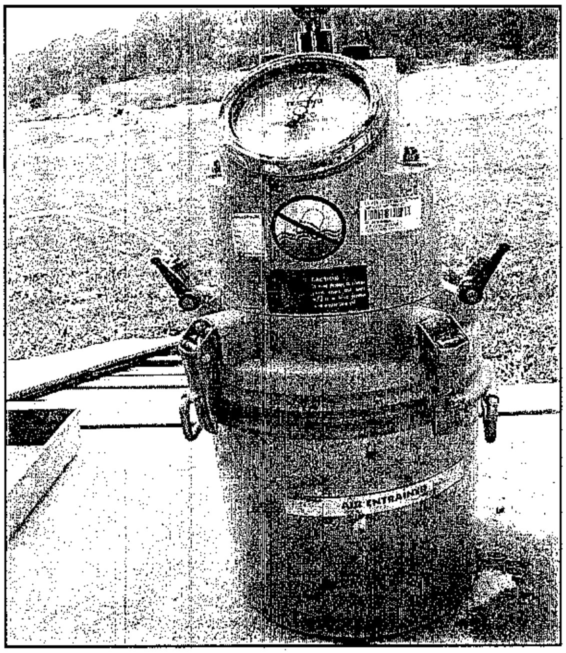


Figure 3.2: Air Entrained

3.2.3 Compressive test

Before tested for compressive test, the concrete cubes will be cured for a specified period to representing the quality of the concrete. Compressive strength test on specimens treated in a standard manner which includes full compaction and wet curing for specified period give results representing the potential concrete.

- The specimens are cast in steel mould sized 150mm x 150mm x 150mm. the mould and its base must be clamped together during casting in order to prevent leakage of mortar.
- A thin layer of mineral oil is applied inside surfaces of the mould in order to prevent the development of bond between the mould and the concrete.
- The standard practice prescribed by BS 1881:108:1983 is to fill the mould in three layers. Each layer is compacted by vibrator.
- According to BS 1881: Part 111:1983, after top surface of the cube has been finished by means of float, the cube is stored undisturbed for 24± 4 hours at a temperature of 20±5°C. The cube is further cured in the water.
- In the compression test, the cube while still wet is placed with the cast faces contact with the platens of the testing machines. According to BS 1881: Part 116:1983, the load on the cube should be applied at a constant rate of stress

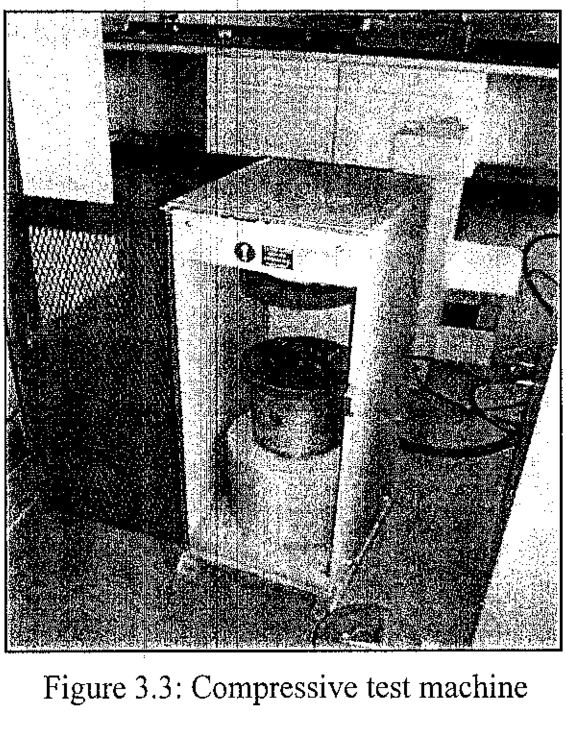


Figure 3.3: Compressive test machine

3.2.4 Porosity test

Porosity of concrete is an important factor is classifying its durability. Generally, concrete of a low porosity will afford better protection to reinforcement within it than concrete of high porosity. Porosity can be measured by vacuum saturation of a concrete specimen, measuring its weight gain and expressing this as a percentage of the mass of the sample. The vacuum saturation apparatus used in this investigation is similar to that developed by RILEM (1984) for measuring the total porosity. The sample prepared by casting the concrete slab seized 315 x 205 x 48. Cylindrical cores (55-mm diameter and approximately 40-mm high) were drilled out from slab. Then, the core samples were vacuum saturated in the vacuum desiccator in the air for first thirty minutes. After that, the samples were vacuum saturated in the water for six hours. The samples were immersed in the water for a night before the specimens were weighed in the air (W_{SA}) and in the water (W_{SW}) on the next day. Finally, they were dried in an oven at 105°C to constant weight (W_d).

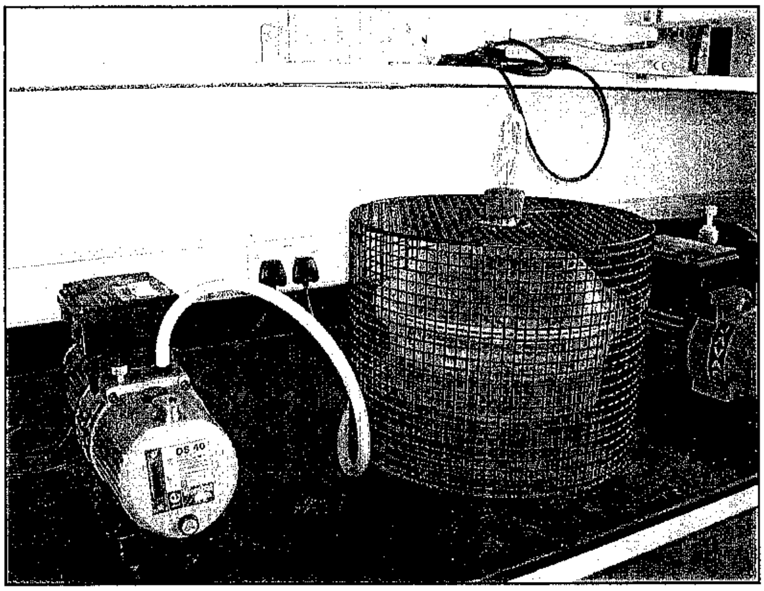


Figure 3.4: Vacuum saturation equipment

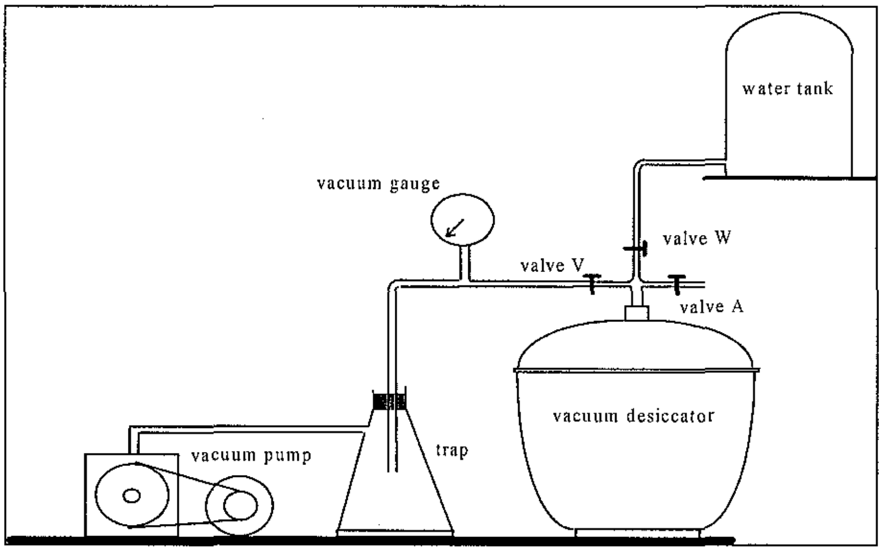


Figure 3.5: Schematic Diagram of Vacuum Saturation Apparatus

3.2.5 Oxygen permeability

Cylindrical concrete specimens of 50-mm diameter and 40-mm height were tested for oxygen permeability. Normally, the same concrete specimens from the earlier porosity test were used during the oxygen permeability procedure. From each of the concrete mixes, three samples were oven dried before testing. One day before testing, the samples were prepared by applying a thin layer of silicon rubber compound all along the curved surface in order to seal the boundary. The test was carried out within 3, 28 and 90 days after the samples reached equilibrium conditions.

After loading the samples into the cells, the oxygen was released to the desired pressure (p_G) between 2 to 4 bars as shown in Figure 3.7. On achieving the steady state flow, the flow speed was measured by introducing a bubble in a flow meter of the size 1.7 mm or 5 mm. The length of bubble flow versus time was monitored for determining the gas flow rate; five readings were taken for each sample. The measured data was recorded in a data sheet, and a small spread sheet program to calculate the oxygen permeability (K_O) [9].

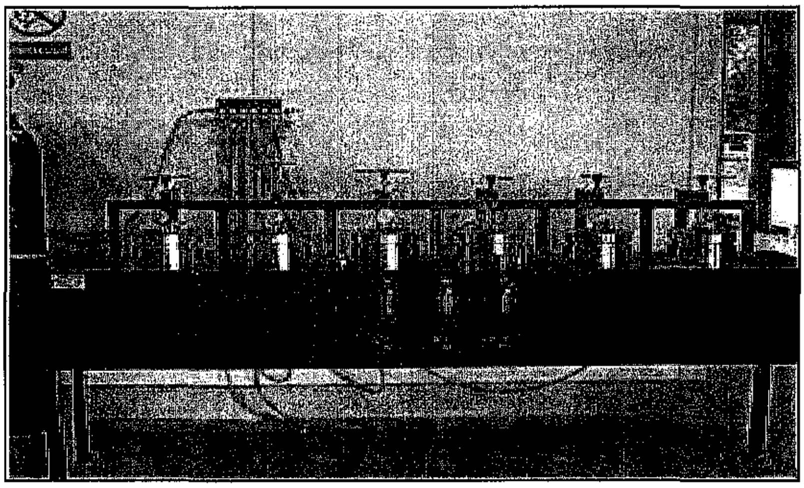
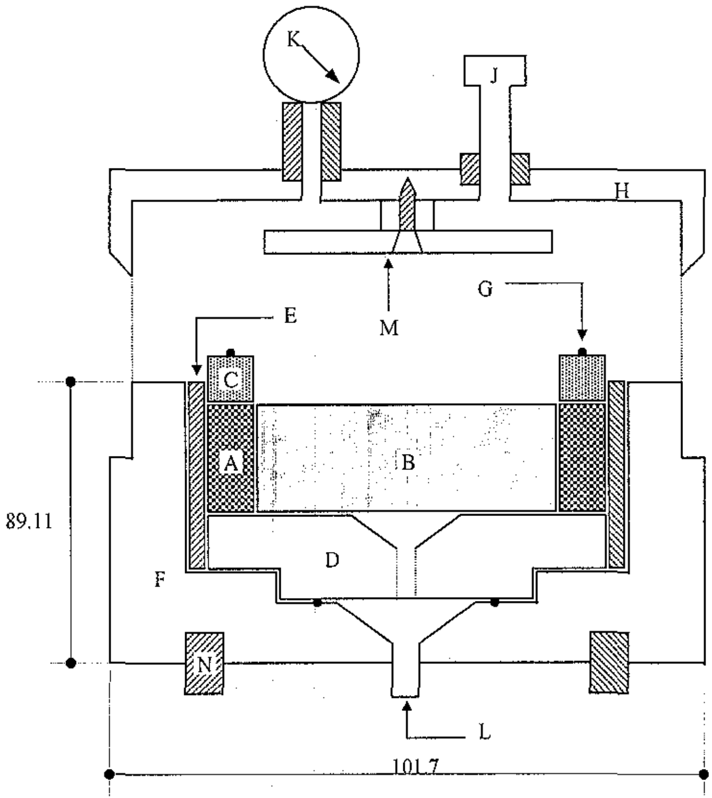


Figure 3.6: UTP Oxygen Permeability



A = Inner silicon Rubber Cylinder
B = Sample
C = Stainless Steel O-Ring
D = Bottom Stainless Steel Seating
E = PVC Collar
F = Outer Stainless Steel Body of Cell
G = Rubber O-Ring

H = Stainless Steel Cap of Cell
J = Gas Inlet
K = Pressure Gauge
L = Gas Outlet
M = Plastic Baffle
N = Sitting gui

Figure 3.7: Schematic Diagram of the Leeds Cell Permeameter

CHAPTER 4
RESULTS AND DISCUSSION

4.0 Concrete mix proportion

The main objective of this research is to investigate the effects of used engine oil are similar to the commercially available superplasticizers in term of fresh and hardened concrete properties containing PFA. 21 trial concrete mixes were prepared with the concrete weight by ratio 1(cement):2.33(sand):3.5(gravel):0.55(w/c).

Table 4.1: Test variables

Group	**Mix type**	**OPC (kg/m3)**	**PFA(kg/m3)**	**CA (kg/m3)**	**FA**	**W/C (kg/m3)**	**Admixtures**	**Dosage**
Group A	1	325	0	1137.5	757.25	178.75	-	-
	2	325	0	1137.5	757.25	178.75	UEO	0.15%
	3	325	0	1137.5	757.25	178.75	NEO	0.15%
	4	325	0	1137.5	757.25	178.75	SP	0.15%
	5	195	130	1137.5	757.25	178.75	-	-
	6	195	130	1137.5	757.25	178.75	UEO	0.15%
	7	195	130	1137.5	757.25	178.75	NEO	0.15%
	8	195	130	1137.5	757.25	178.75	SP	0.15%
	9	162.5	162.5	1137.5	757.25	178.75	-	-
	10	162.5	162.5	1137.5	757.25	178.75	UEO	0.15%
	11	162.5	162.5	1137.5	757.25	178.75	NEO	0.15%
	12	162.5	162.5	1137.5	757.25	178.75	SP	0.15%
Group B	13	325	0	1137.5	757.25	178.75	UEO	0.30%
	14	325	0	1137.5	757.25	178.75	NEO	0.30%
	15	325	0	1137.5	757.25	178.75	SP	0.30%
	16	195	130	1137.5	757.25	178.75	UEO	0.30%
	17	195	130	1137.5	757.25	178.75	NEO	0.30%
	18	195	130	1137.5	757.25	178.75	SP	0.30%
	19	162.5	162.5	1137.5	757.25	178.75	UEO	0.30%
	20	162.5	162.5	1137.5	757.25	178.75	NEO	0.30%
	21	162.5	162.5	1137.5	757.25	178.75	SP	0.30%

The trial concrete mixes were divided into two different groups. Group A was for concrete mixes added with 0.15% of admixtures and group B was for concrete mixes added with 0.3% admixtures. The variables in the experiments were the dosage of fly ash and chemical admixtures added during concrete mixing. The amounts of fly ash that replaced the OPC were 40% and 50% from the overall cement content. The chemical admixtures used were used engine oil, new engine oil and superplasticizers.

All of 21 mixes were designed to achieve the compressive strength at 90 days. In all mixes, the Ordinary Portland Cement Type 1 was used because it was suitable for general concrete construction. The fine aggregate was natural sand. The coarse aggregate was crushed gravel with the maximum size of 20mm. The new engine oil used was lubricant oil and the used engine oil was from the used oil from the lubricant oil. Superplasticizer that applies in the project was Sikament–N1 and the type used was Naphthalene Formaldehyde Sulphonate. The cement replacement material or pulverized fly ash was obtained from Manjung Power Plant. The chemical compositions of the sample have been examined and the PFA used are of ASTM Class F.

Table 4.2: Properties of PFA used in the study

Test Type	%	BS EN 450 : 1995	Result
45µ Sieve residue	%	Max : 40	22.32
Loss of ignition (LOI)	%	Max : 6	4.21
Sulphuric Anhydride (SO_3)	%	Max : 3	0.88
Silica (SiO_2)	%	Max : 25	51.19
Chloride(Cl)	%	Max : 0.1	0.01
Free Calcium Oxide (CaO)	%	Max : 1.0	0.05
Activity index : 28 days	%	Min : 75	84
: 50 days	%	Min : 85	97
Soundness	mm	Max : 10	N/A
Density	kg/m3	none	2290
Magnesium Oxide(MgO)	%	none	2.4
Iron Oxide (Fe_2O_3)	%	none	6.6
Aluminium Oxide(Al_2O_3)	%	none	24
Calcium Oxide (CaO)	%	none	5.57
Potassium Oxide (K_2O)	%	none	1.14
Sodium Oxide (NaO)	%	none	2.12

By using X-ray fluorescence (XRF) and X-ray diffractometry (XRD), the chemical composition of used engine oil and new engine oil were obtained. Both of these machines are being used for identification and quantitative analyses of admixtures used in the experiments.

Table 4.3: Chemical composition of used engine oil

Chemical composition	used engine oil (%)
SiO_2	-
Fe_2O_3	0.43
CaO	15.9
SO_3	37
P_2O_5	8.95
ZnO	17.7
Cl^-	15.9

Table 4.4: Chemical composition of new engine oil

Chemical composition	new engine oil(%)
SiO_2	0.85
Fe_2O_3	0.18
CaO	21
SO_3	36.3
P_2O_5	13.4
ZnO	25.6
Cl^-	-

From the XRD and XRF testing, the chemical composition that differed between used engine oil and new engine oil is Cl^-. In used engine oil, there is the presence of chloride ion and the amount was15.9%. However in new engine oil, there was none of chloride ion. Chloride was well known for its corrosive behaviour and the permissible limit of chlorine in concrete is below 1% from the overall cement content. The addition of used engine oil in concrete was only between 0.15% and 0.3%. So, there was no effect to the performance of the concrete since the percentage of used engine oil in the concrete was in the allowable range. Besides, the XRD and XRF testing were done to observe the chemical reactions after 28 days casting of specimens for cement paste of 100% OPC and compared the compositions with cement paste of 100% OPC added with used engine oil, new engine oil and superplasticizers. This was to determine the oxide composition of all specimens if there were differences that might cause hazardous to the concrete containing used engine oil. From the observation, the oxide composition was almost similar to all cement pastes. Therefore, by adding used engine oil, the concrete was safe even though the used engine oil itself containing chloride ions.

Table 4.5: Oxide composition of 100%OPC of cement paste

Oxide composition	Percentage
SiO_2	20.7
Al_2O_3	5.29
Fe_2O_3	5.17
CaO	62.9
MgO	1.36
SO_3	2.92
K_2O	0.67
Na_2O	0.12

Table 4.6: Oxide composition of 100%OPC of cement paste with used engine oil

Oxide composition	Percentage
SiO_2	20.4
Al_2O_3	5.21
Fe_2O_3	5.29
CaO	63.1
MgO	1.26
SO_3	2.94
K_2O	0.68
Na_2O	0.13

Table 4.7: Oxide composition of 100%OPC of cement paste with new engine oil

Oxide composition	Percentage
SiO_2	20.6
Al_2O_3	5.52
Fe_2O_3	5.19
CaO	62.9
MgO	1.38
SO_3	2.87
K_2O	0.6
Na_2O	0.1

Table 4.8: Oxide composition of 100%OPC of cement paste with superplasticizers

Oxide composition	Percentage
SiO_2	20.3
Al_2O_3	5.11
Fe_2O_3	5.33
CaO	63.4
MgO	1.3
SO_3	2.98
K_2O	0.5
Na_2O	0.1

The mixing process was conducted in the laboratory using a standard concrete mixer. The casting process was same for all trial mixes where 18 concrete cubes were prepared by using concrete mould size of 150mm x 150mm x 150mm for compressive strength test purposes and 3 slabs formworks from wood from sizes 4.8cm x 31.5cm x 20.5 cm for porosity and permeability test purposes.

The tested properties of fresh concrete were slump test and air entrained. While for hardened concrete were based on the compressive strength and porosity test. The procedure of the tests involved was explained in Chapter 3: Methodology /Project work section.

4.1 Group A

4.1.1 Slump test

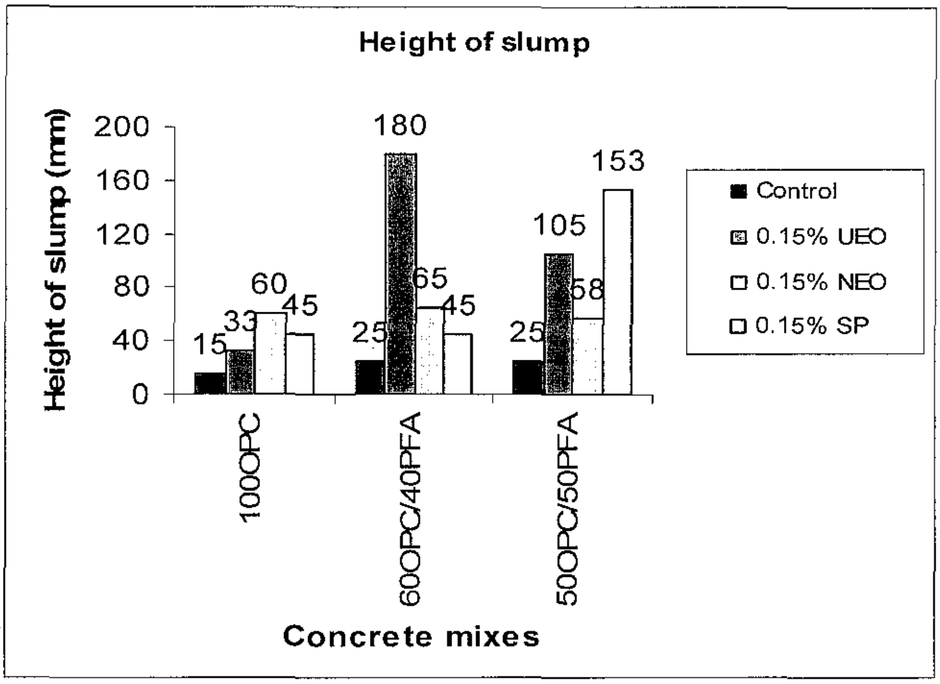


Figure 4.1: Variation of slump for different chemical admixtures: dosage of 0.15%.

From Figure 4.1, the slumps for 100% OPC with used engine oil, new engine oil and superplasticizers were higher than the control mix of 100% OPC. The slump for control mix for 100% OPC was 15mm. The addition of 0.15% used engine oil with 100% OPC doubled the slump up to 33mm. However, the 100% OPC with 0.15% new engine oil increased the slump four times higher than the control mix which the value was 60mm. The additions of superplasticizers also increased the slump three times higher than the control mix. From observation, these chemical admixtures improving the fluidity and workability of the concrete thus increase the slump height. The slumps of control mixes of 60%OPC with 40%PFA and 50%OPC with 50%PFA was greater than control mix of 100% OPC. The slumps for all mixes with different dosage of chemical admixtures of 60% OPC with 40% PFA and 50% OPC with 50% PFA were improved than concrete mixes of 100%OPC with the same addition of chemical admixtures. From the result above, the addition of pulverized fly ash (PFA) increased the workability of the concrete thus increasing the slumps of the fresh concrete. The spherical particle shape of fly ash improved the workability of fly ash concrete because of the so-called "ball bearing" effect. Besides, the particles size also confers significant benefits to the fluidity of the concrete.

4.1.2 Air entrained test

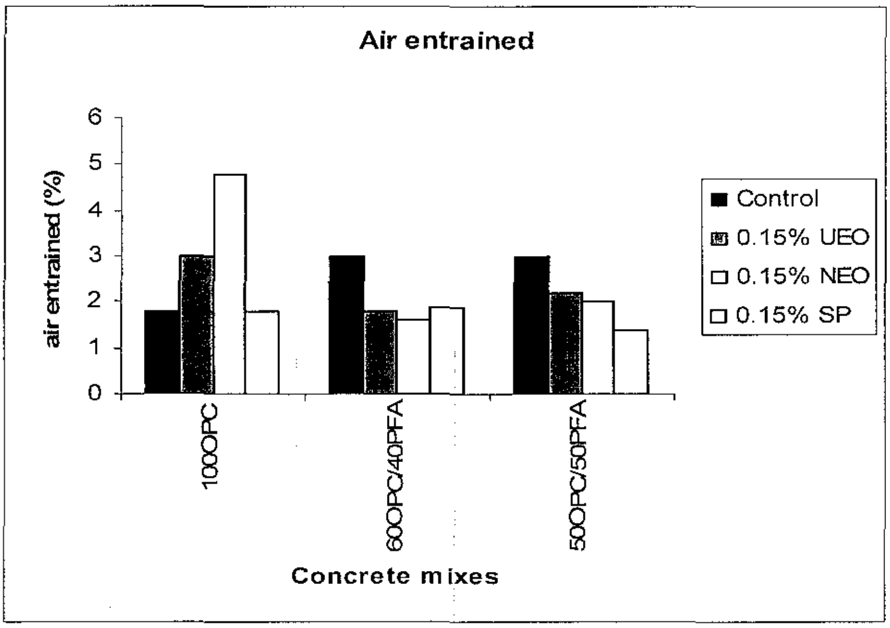


Figure 4.2: Variation of air content for different mixes: dosage of 0.15%.

Air entrainment test was conducted to check the total of air voids in the concrete. The spacing of air voids depend on the admixtures added into the mix. From Figure 4.2, the percentage of air entrained increased when slump was improved for 100% OPC. For concrete mix added with used engine oil, the air entrained is 3.2%. Even though superplasticizer increases the slump, it tends to decrease or eliminate entrained air. Thus the value of air entrained is only 1.8%.

The percentage of air entrained for both control mixes: 60 %OPC with 40% PFA and 50%OPC with 50% PFA is 3% which was higher than concrete mix of 100% OPC. So, when the PFA added, it improved the air content in the concrete. For 60 % OPC with 40% PFA and 50%OPC with 50% PFA, both were added with used engine oil, the air entrained were 1.8% and 2.2%.The percentage of air entrained was lower than the concrete mix of 100% OPC. While for concrete containing new engine oil, the percentage of air entrained were 1.6% and 2.0% and the air content also was lower than the concrete of 100% OPC. For concrete mixes of 60% OPC with 40% PFA and 50% OPC with 50% PFA added with 0.15% superplasticizers, the percentage of air entrained were 1.9% and 1.4%. Based on V.S. Ramachandran, the air content may decrease with the addition of SNF and SMF based admixtures [10].

4.1.3 Compressive strength

Compressive strength was measured for every 3,7,28 and 90 days. Each result for compressive strength is the average of three test values.

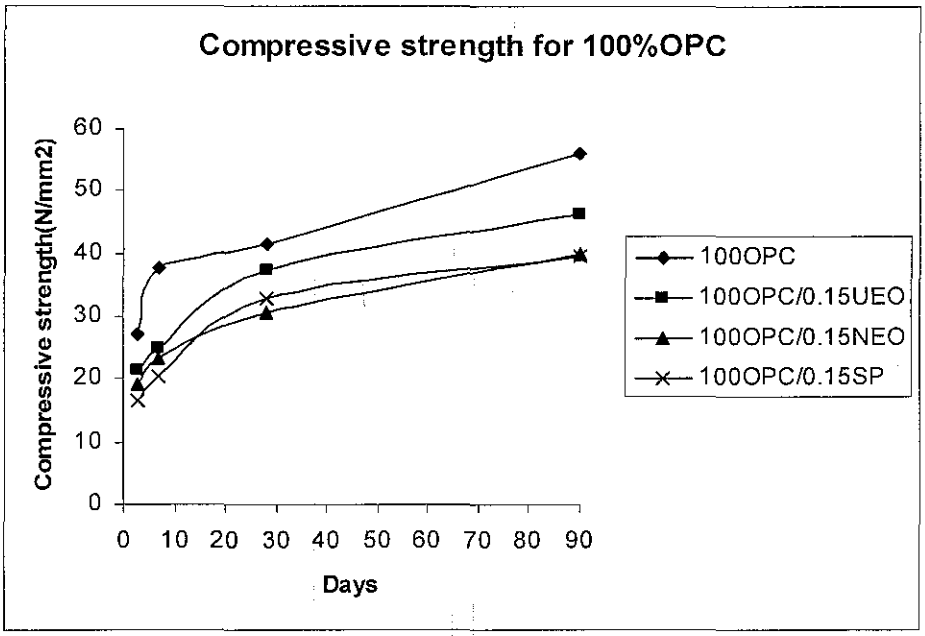


Figure 4.3: Compressive strength for 100% OPC with 0.15% dosage of different chemical admixtures.

From figure 4.3, compressive strength for 100% OPC was the highest at 90 days compared with 100%OPC added with various type of chemical admixtures. The strength for 90 days for 100% OPC was 56.07 N/mm^2. For concrete mix with used engine oil and new engine oil, the strength was relatively similar. For strength development at 90 days, the compressive strength for 100%OPC with used engine oil was 46.37 N/mm^2. While, for compressive strength of 100%OPC with new engine oil was 40.05 N/mm^2. Compressive strength for 100%OPC with superplasticizers was the lowest at 90 days since the value was 39.58 N/mm^2. Based on fresh concrete properties, the concrete mix of 100%OPC with used engine oil had better performance as it provided better slump compare to 100%OPC concrete mix. So it had better workability. In term of strength development, the compressive strength was significantly similar between 100%OPC concrete mix and 100%OPC added with used engine oil.

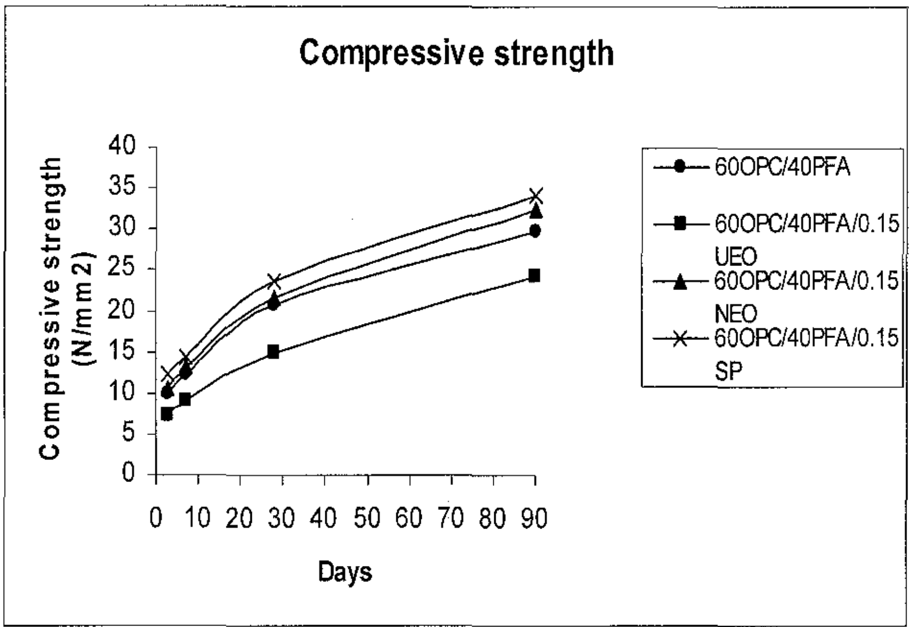


Figure 4.4: Compressive strength for 60% OPC and 40% PFA with 0.15% dosage of different chemical admixtures.

From figure 4.4, the early strength development of concrete mixes blended with PFA was low. However, the strength was increasing gradually at 28 and 90 days. The compressive strength of 60% OPC with 40% PFA at 90 days was 29.91N/mm^2. While, the compressive strength for 60% OPC with 40% PFA added by used engine oil at 90 days was 24.15N/mm^2. The compressive strength for 60% OPC blended with 40% PFA added by new engine oil at 90 days was 32.53 N/mm^2. For compressive strength of 60% OPC and 40%PFA with super plasticizers at 90 days was 34.1N/mm^2.

From the observation, the slump test influenced the compressive strength of the concrete. If the slump was high, there was possibility to produce concrete with low compressive strength. This was notified during the strength development of 60%OPC and 40%PFA with used engine oil; the slump was 180mm which is too high compared with other trial concrete mixes. Therefore, it affected the result of compressive strength of the concrete. Besides, the compressive strength of blended cement with PFA decreased with an increase in the replacement of PFA [5]. To obtain, high performance concrete with PFA, it was necessary to reduce the dosage of PFA or substitute the recent PFA used in the study with Ultrafine PFA [12].

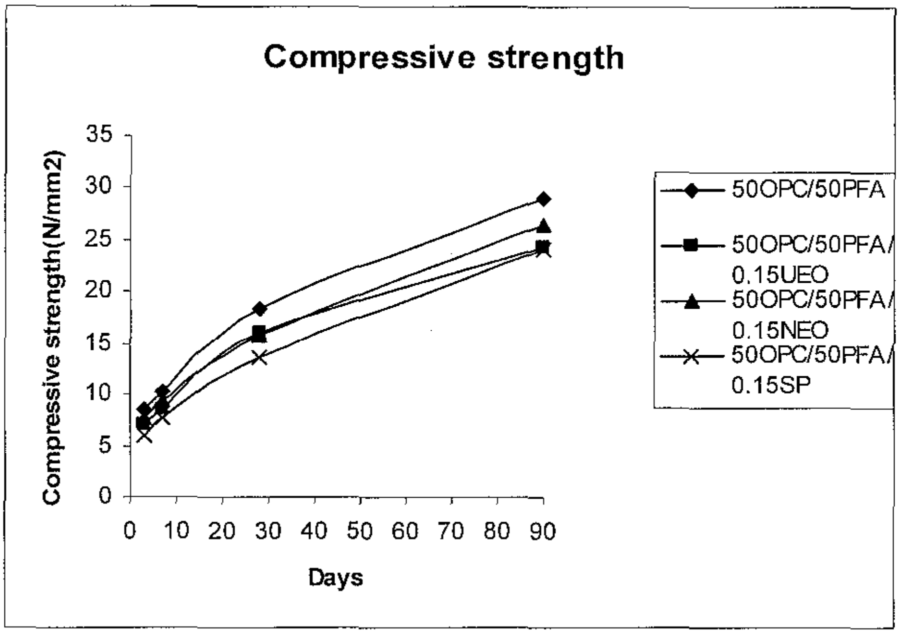


Figure 4.5: Compressive strength for 50% OPC and 50% PFA with 0.15% dosage of different chemical admixtures.

From figure 4.5, the early strength development of the concrete mixes was lower when more dosage of PFA was blended together in the concrete mixes. The compressive strength for 50% OPC with 50% PFA at 90 days was 28.96N/mm^2. While, the compressive strength for 50% OPC with 50% PFA added by used engine oil at 90 days was 24.27N/mm^2. The compressive strength for 50% OPC and 50% PFA with new engine oil at 90 days was 26.42N/mm^2. For compressive strength of 50% OPC and 50%PFA with super plasticizers at 90 days was 24.17N/mm^2.

From the observation, the slump test influenced the compressive strength of the concrete. If slump was higher, compressive strength will decrease. This can be seen at concrete mix of 50%OPC and 50%PFA with used engine oil and superplasticizers. The slumps for both trial concrete mixes were 105mm and 153mm. Thus, decreasing their compressive strength due excessive moisture of fresh concrete compared to other trial concrete mixes. Moreover, the addition of PFA was beyond the optimum value. The optimum value for PFA was about 40% of cement. The ratio of fly ash and cement is an important factor determining the efficiency of the fly ash [11].

4.1.4 Porosity test

Porosity test was important to represent the content of pores irrespective of whether they are inter-connected and may or may not allow the passage of fluid or gas. The penetration of concrete by fluids or gas may adversely affect the concrete durability

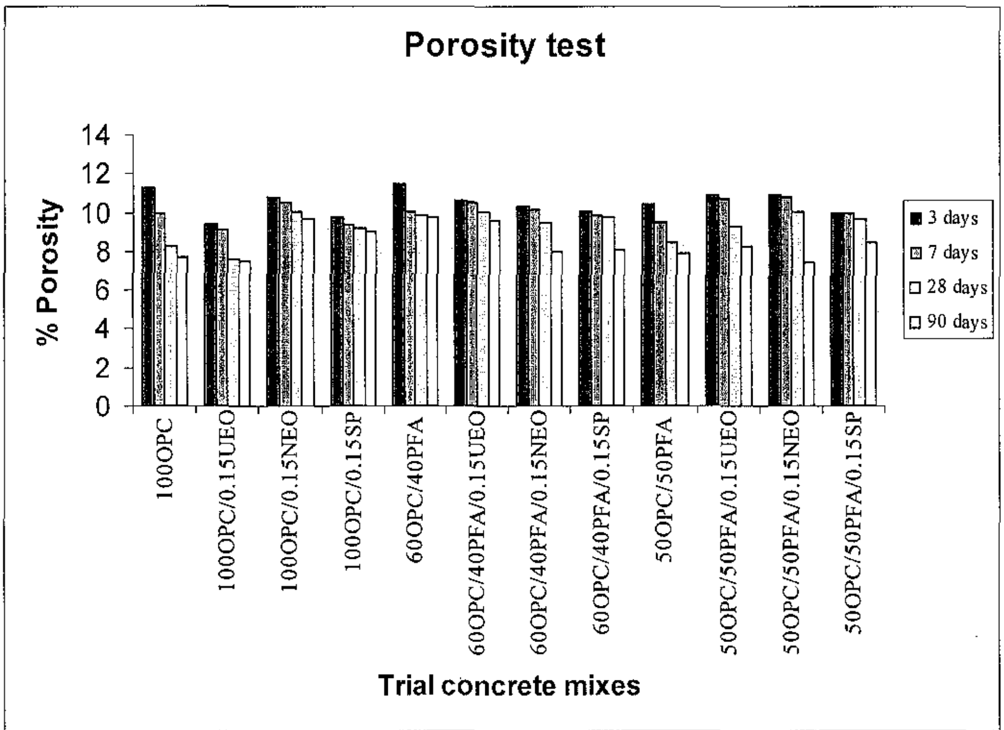


Figure 4.6: Porosity test for trial concrete mixes with 0.15% dosage of different chemical admixtures.

From the observation, the porosity depended on the porous of concrete. So it was influenced by the pore sizes of the concrete. When the concrete was cured in the water, the water penetrated, saturated the capillary pores and fills the voids. The longer the curing process, more voids will be filled by water and cause less air voids. This will reduce the porosity.

From the graph, it was concluded that the porosity was decreasing in time. The 3-days porosity test was higher than the porosity test conducted at 90 days.

4.2 Group B

4.2.1 Slump test

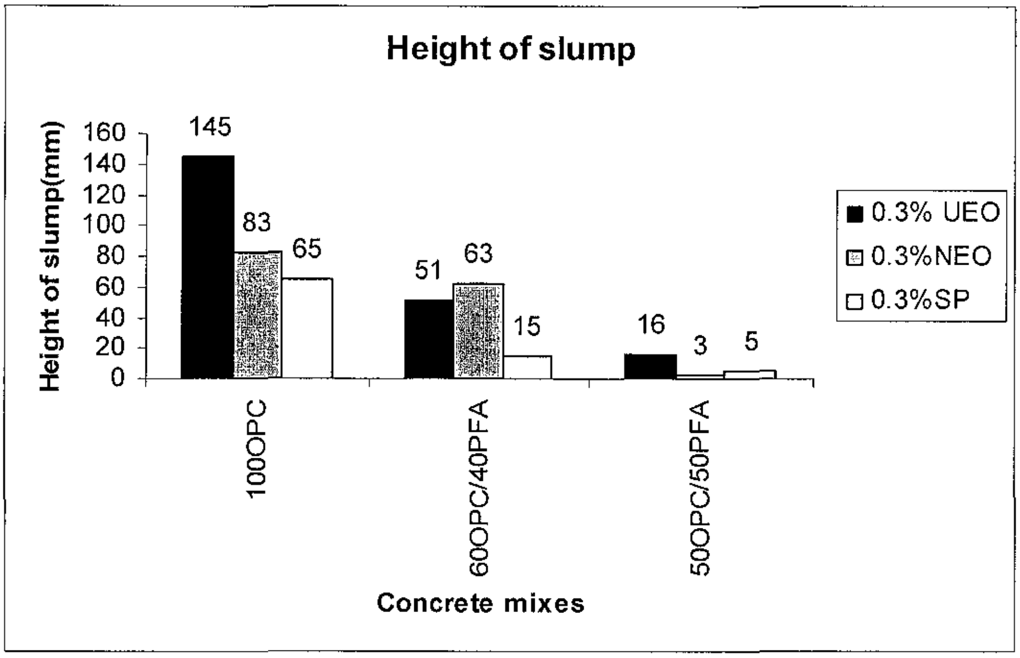


Figure 4.7: Variation of slump for different chemical admixtures: dosage of 0.3%.

From figure 4.7, for 100%OPC of concrete mixes, the slumps were increasing when added with used engine oil, new engine oil and superplasticizers. The slumps were 145mm, 83mm and 65mm. For 60%OPC and 40%PFA concrete mixes added with the same chemical admixtures, the slumps were increasing except concrete mix added with superplasticizers. While, for 50%OPC and 50%PFA added the same dosage of chemical admixtures, the slump was lower than the control mix of 100%OPC. As stated before, the addition of PFA should improve the fluidity and workability of the concrete, so the slump should be higher than the normal concrete mix of 100%OPC. The slumps of 50%OPC and 50%PFA might be affected by the moisture of the concrete constituent during mixing and also the process during handling the fresh concrete. All of these factors could influence the performance of fresh concrete.

4.2.2 Air entrained

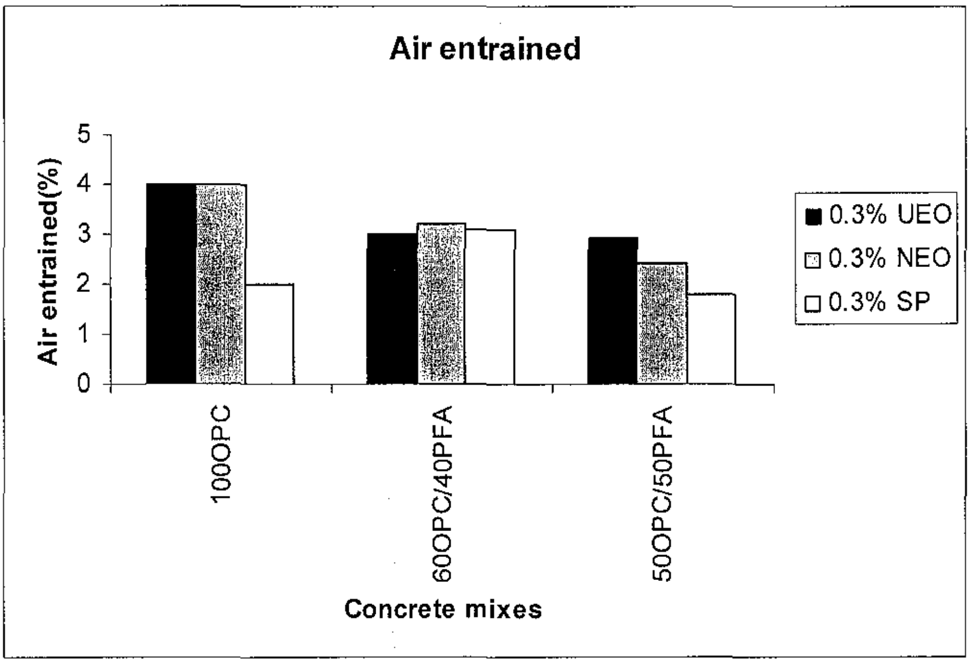


Figure 4.8: Variation of air content for different mixes: dosage of 0.3%.

From figure 4.8, the air entrained for trial concrete mixes of 100%OPC added with used engine oil and new engine oil was 4%. While, 100%OPC added with superplasticizers, the air entrained was low because superplasticizer tends to eliminate the entrained air. For concrete mixes of 60%OPC and 40%PFA added with the same dosage of chemical admixtures, the values of entrained air were 3%, 3.2% and 3%. All of these values were similarly to the air entrained of control mix of 60%OPC and 40%PFA .For concrete mix of 50%OPC and 50%PFA with used engine oil, new engine oil and superplasticizers, the values of entrained air were 2.9%, 2.4% and 1.8%. The total air content of an air-entrained concrete undergo change in the presence of a superplasticizer. At low dosages the difference in air content was marginal, but at higher dosages air content may decrease with the addition of SMF- and SNF-based admixtures [10].

4.2.3 Compressive strength

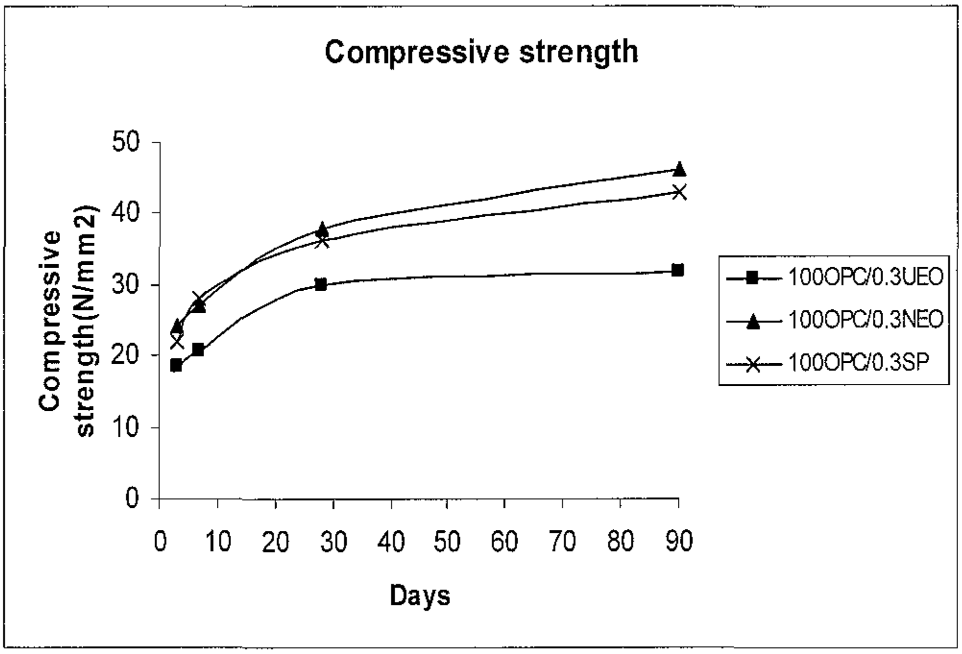


Figure 4.9: Compressive strength for 100% OPC with 0.3% dosage of different chemical admixtures.

From figure 4.9, compressive strength for 100% OPC added with used engine oil at 90 days was 31.93 N/mm^2 and it was the lowest strength compared 100%OPC added with new engine oil and superplasticizers. The compressive strength for both trial concrete mixes added with new engine oil and superplasticizers were 46.14N/mm^2 and 42.9N/mm^2.The result of compressive strength generally affected by the result of slump test. Based on earlier slump test observation, the slump for 100%OPC with used engine oil was 145mm. If it was compared with the slump of 100%OPC added with new engine oil and superplasticizers, the slump for concrete mix with used engine oil was much higher. Fundamentally, the values of the slump test give major consequence to the relative strength development of hardened concrete. The higher the slump, the concrete had more fluidity, thus provided more air voids to the concrete and decreased the strength of the concrete.

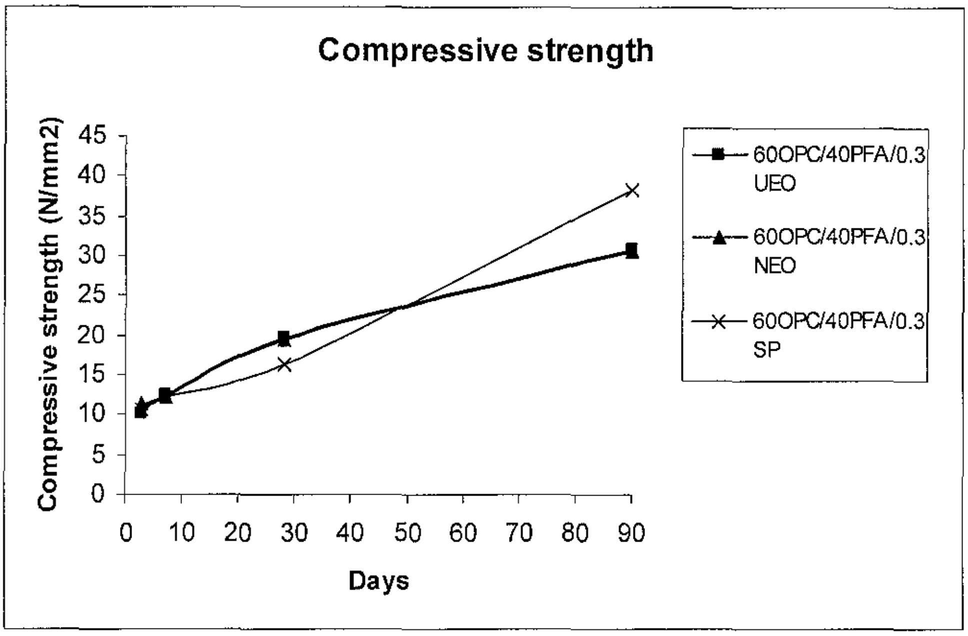


Figure 4.10: Compressive strength for 60% OPC and 40% PFA with 0.3% dosage of different chemical admixtures.

From figure 4.10, the compressive strength of 60%OPC with 40%PFA added with used engine at 90 days was 30.7N/mm^2. The compressive strength for 60% OPC blended with 40% PFA added by new engine oil at 90 days was 30.45 N/mm^2. For compressive strength of 60% OPC and 40%PFA with super plasticizers at 90 days was 38.22N/mm^2. The compressive strength of 60%OPC and 40%PFA added with used engine oil lower than the compressive strength of concrete mix added with superplasticizers since its slump was three times higher. Superplasticizers added into the concrete improved the fluidity of the concrete but in the same increased the strength of the concrete. This was one of the factors that contributed to the better performance of hardened concrete properties. Furthermore, the quantity of the PFA should be taken into consideration during concrete mixing because it gave great influence to the development of concrete strength.

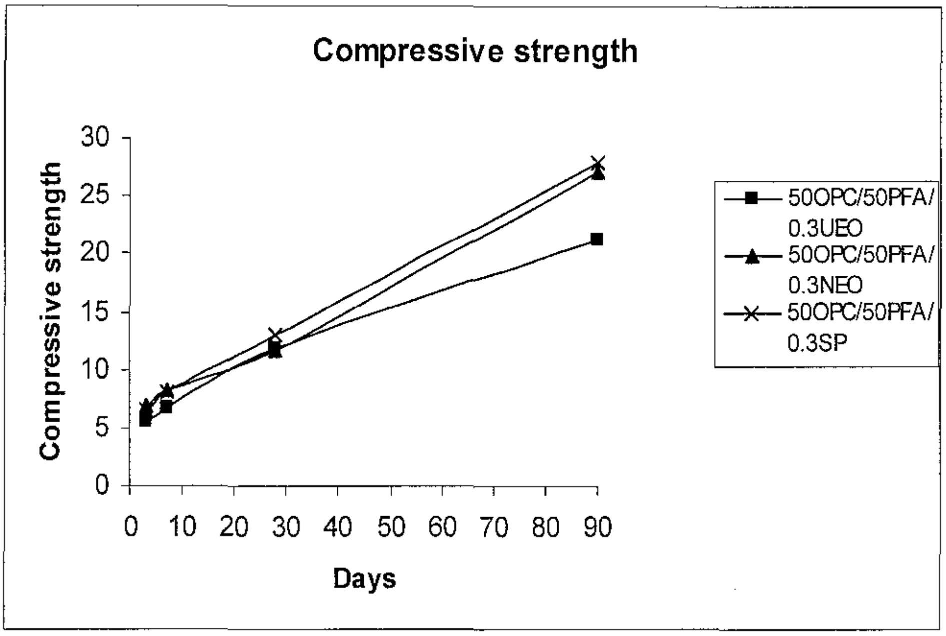


Figure 4.11: Compressive strength for 50% OPC and 50% PFA with 0.3% dosage of different chemical admixtures.

From figure 4.11, the early strength development of the concrete mixes was low when more dosage of PFA was blended together in the concrete mixes. The compressive strength for 50% OPC with 50% PFA added by used engine oil at 90 days was 21.12N/mm^2. The compressive strength for 50% OPC and 50% PFA with new engine oil at 90 days was 27.13N/mm^2. For compressive strength of 50% OPC and 50%PFA with super plasticizers at 90 days was 27.83N/mm^2.

The results of compressive strength for all concrete mixes were low because the addition of PFA to replace OPC in the concrete was beyond the optimum mix design. The optimum mix design for concrete blended with PFA should be not more than 40% of the cement. However, the composition of PFA to replace the OPC also depended on the fineness of the PFA [5].

4.2.4 Porosity test

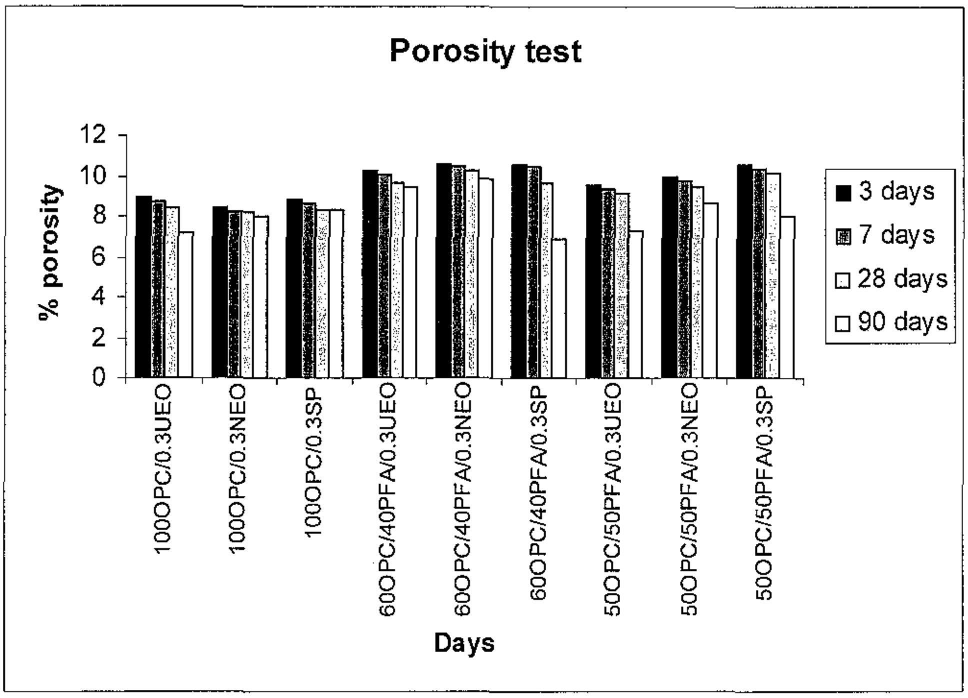


Figure 4.12: Porosity test for trial concrete mixes with 0.3% dosage of different chemical admixtures.

From the observation, porosity related to the porous of the concrete. Porosity and pore structure, in turn, are influenced by the original packing of cement, mineral admixtures, and the aggregate particles; the water-to-solid ratio; the rheology; and the conditions of curing [9]. When the concrete was cured in the water, the water penetrated, saturated the capillary pores and fills the voids. The longer the curing process, more voids will be filled by water and cause less air voids. This will reduce the porosity.

From the graph, it could be concluded that the total porosity was decreasing in time. However, the total porosity increased with an increase in the replacement of PFA during the observation at early curing period. But at 90days, the porosity is decreasing.

4.3 Oxygen permeability for Group A and Group B

Table 4.9: Oxygen permeability for concrete mixes with 0.15% and 0.3% dosage of chemical admixtures.

Trial concrete mixes	3 days(Ko)	28 days(Ko)	90 days(Ko)
100OPC	1.17976E-16	7.82456E-17	5.03407E-17
100OPC/0.15UEO	2.22758E-16	1.20352E-16	7.74152E-17
100OPC/0.15NEO	3.89475E-16	1.17029E-16	1.42157E-16
100OPC/0.15SP	4.26073E-16	1.90183E-16	5.26914E-17
60OPC/40PFA	5.04616E-16	3.41132E-16	1.32279E-16
60OPC/40PFA/0.15UEO	8.79902E-16	3.60922E-16	1.10539E-16
60OPC/40PFA/0.15NEO	7.92492E-16	2.20826E-16	1.01883E-16
60OPC/40PFA/0.15SP	8.8224E-16	2.0892E-16	1.56808E-16
50PFA	2.92433E-16	4.89654E-16	1.50591E-16
50OPC/50PFA/0.15UEO	7.95499E-16	6.12003E-16	1.68861E-16
50OPC/50PFA/0.15NEO	9.26811E-16	3.85121E-16	8.79703E-17
50OPC/50PFA/0.15SP	9.86482E-16	3.59365E-16	1.15851E-16
100OPC/0.3UEO	1.62335E-16	1.21027E-16	2.4751E-16
100OPC/0.3NEO	1.51774E-16	1.639E-16	1.28707E-16
100OPC/0.3SP	1.3463E-16	1.07808E-16	1.70273E-16
60OPC/40PFA/0.3UEO	2.5226E-16	2.54993E-16	1.49596E-16
60OPC/40PFA/0.3NEO	3.33605E-16	3.004E-16	2.66151E-16
60OPC/40PFA/0.3SP	5.02896E-16	2.74626E-16	1.7469E-16
50OPC/50PFA/0.3UEO	2.42363E-16	2.69227E-16	1.17201E-16
50OPC/50PFA/0.3NEO	4.31621E-16	4.04103E-16	2.41122E-16
50OPC/50PFA/0.3SP	4.24873E-16	5.07644E-16	2.30803E-16

Bamforth (1987) mentioned that the typical structural concrete which is likely to have an intrinsic permeability in the range 10^{-19} to 10^{-17} m^2, gas permeability values may be one to two orders of magnitude higher. For example, at a mean pressure of 5 atmospheres (absolute), concrete with water permeability coefficient of 10^{-18} m^2 may have a gas permeability coefficient of about 10^{-17} m^2. He further mentioned that the difference between gas and liquid permeability coefficient is greater for concrete of low permeability. For typical structural concrete, which may have water permeability coefficient of the order of 10^{-18} m^2, the gas permeability determined at a mean pressure of $6x10^5$ N/m^2 absolute may be about one magnitude higher [9]. And from the results above, the oxygen permeability coefficient for this research were in the range of 10^{-17} to 10^{-16} m^2.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Following are the main conclusions drawn from the results:

- Used engine oil improves the consistency of fresh concrete and increases the slump value for more than 50% as compare to control mix containing the same water content.
- Effects of engine oil on properties of fresh concrete containing fly ash are different than the concrete containing 100% OPC. For example 0.3% dosage of used engine oil showed higher air content as compare to control mix, where for 0.15% dosage of used engine oil, showed lower air content than the control mix.
- Strength development of fly ash blended cement concrete at earlier ages was slow for all concrete mixes. Effects of used engine oil on compressive strength are different with different concrete mixes. However, the results are within the range of 15% variation as compared to the control mix.
- In general used engine oil reduced the oxygen permeability and total porosity in most of the concrete mixes than the control mixes.
- Effects of used engine oil on properties of fresh hardened mixes are similar to concrete containing superplasticizers, even on strength and durability they are better.

5.2 Recommendations

- The dosage of PFA blended in the OPC should be decrease in order to obtain better performance of concrete. Eventhough there was a recent study conducted by using the same amount of PFA in this experiment, the fineness and the condition where the PFA was produced is different.
- Besides, the experiments also should be conducted by using different PFA from the different power plant to investigate the factors that affected the performance of the concrete.
- During experiments, the moisture of the aggregates and the mixer should be maintained at the allowable limit to prevent excessive moisture of concrete during mixing.

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APPENDICES

Compressive strength for 100% OPC with 0.15% dosage of chemical admixtures

Marking	Date cure	Days	Date of Comp. test	Weight (kg)	Weight/Vol kg/m3	Fail Load kN	Strength N/mm2	Average N/mm2
Control	24/8/2006	3	28/8/2006			675.2	30	**27.16**
						406.5	18.06	
						752	33.42	
		7	1/9/2006	8.53		900	40	**37.7**
				7.72		760.8	33.8	
				7.99		884.1	39.3	
		28	21/9/2006	8.34		672.9	29.9	**41.51**
				8.06		1031	**45.82**	
				8.42		1098	**48.8**	
		90	23/11/2006	8.16		1376	61.16	**56.07**
				7.86		1252	55.64	
				7.99		1516	51.42	
UEO	9/9/2006	3	13/09/2006	8.46		483.3	21.48	**21.3**
				8.17		455.5	20.24	
				8.14		498.9	22.173	
		7	16/09/2006	8.37		528.8	23.5	**24.78**
				8.15		533.7	23.72	
				8.09		610.1	27.12	
		28	9/10/2006	8.39		832.9	37.02	**37.2**
				8.28		826.9	36.75	
				8.15		857.4	37.84	
		90	9/12/2006	8.37		994.9	44.22	**46.37**
				8.48		1015	45.12	
				8.42		1120	49.78	
NEO	14/09/2006	3	18/09/2006	8.08		440.5	19.58	**19.24**
				8.13		403.7	17.94	
				8.36		454.6	20.2	
		7	22/09/2006	8.29		497.5	22.1	**23.2**
				8.17		517.8	23.01	
				8.26		550.8	24.48	
		28	13/10/2006	8.26		665.6	29.58	**30.6**
				8.18		683.1	30.36	
				8.06		717.1	31.87	
		90	14/12/2006	8.2		844.9	37.55	**40.05**
				8.13		914.5	40.64	
				8.14		944	41.97	
SP	15/09/2006	3	19/09/2006			350.8	15.59	**16.74**
						392.3	17.44	
						386.8	17.19	
		7	23/09/2006	8.31		473.9	21.06	**20.37**
				8.15		437.5	19.4	
				8.22		464.3	20.04	
		28	14/10/2006	8.33		713.8	31.73	**33**
				8.13		741.1	32.94	
				8.2		772.3	34.32	
		90	15/12/2006	8.26		890.6	39.58	**39.58**
				8.15		935.4	41.57	
				8.39		845.9	37.6	

Compressive strength of 60% OPC and 40% PFA with 0.15% dosage of admixtures

Marking	Date cure	Days	Date of Comp.test	Weight (kg)	Weight/Vol kg/m3	Fail Load kN	Strength N/mm2	Average N/mm2
Control	1/9/2006	3	4/9/2006			239.2	10.63	**9.8**
						224.2	9.96	
						198.3	8.81	
		7	8/9/2006			267.6	11.89	**12.19**
						280	12.45	
						275.2	12.23	
		28	29/9/2006	7.95		461	20.48	**20.87**
				8.14		456.7	20.3	
				8.33		491	21.82	
		90	1/12/2006	8.03		603.9	26.84	**29.91**
				8.28		751.4	33.4	
				8.37		663.7	29.5	
UEO	16/09/2006	3	20/09/2006	7.93		152.7	6.786	**7.383**
				7.82		166.1	7.381	
				8.07		179.6	7.982	
		7	24/09/2006	7.95		200.8	8.926	**9.05**
				8.04		215.3	9.568	
				7.9		194.5	8.643	
		28	15/10/2006	8.11		322.6	14.34	**14.93**
				7.82		333.8	14.83	
				7.89		351.3	15.61	
		90	16/12/2006	8.08		570.1	25.34	**24.15**
				7.85		522.3	23.23	
				8		537.3	23.88	
NEO	23/09/2006	3	26/09/2006	8.24		247.6	11	**10.56**
				8.13		232.9	10.35	
				8.05		232.2	10.32	
		7	30/09/2006	8.22		290.8	12.92	**13.07**
				8.17		286.3	12.72	
				8.37		305.3	13.57	
		28	22/10/2006	8.17		464.4	20.64	**21.58**
				8.13		538.5	23.93	
				8.19		454	20.18	
		90	23/12/2006	8.13		731.6	32.52	**32.53**
				8.11		720.2	32.01	
				8.56		744.1	33.07	
SP	27/09/2006	3	1/10/2006	8.27		279	12.4	**12.34**
				8.2		278.7	12.39	
				8.25		275.3	12.24	
		7	5/10/2006	8.08		313	13.91	**14.41**
				8.24		320.7	14.25	
				8.31		339.5	15.09	
		28	26/10/2006	8.49		529.6	23.54	**23.69**
				8.33		532.7	23.68	
				8.2		536.9	23.86	
				8.42		795.2	35.34	
		90	27/12/2006	8.43		744.6	33.09	**34.1**
				8.11		762	33.86	

Compressive strength for 50% OPC and 50% PFA with 0.15% dosage of admixtures

Marking	Date cure	Days	Date of comp.test	Weight	Weight/Vol kg/m3	Fail Load kN	Strength N/mm2	Average N/mm2
Control	7/9/2006	3	11/9/2006			188.8	8.392	**8.544**
						198.2	8.807	
						189.7	8.432	
		7	14/09/2006	8.31		224.7	9.98	**10.22**
				8.38		229.8	10.21	
				8.23		235.4	10.46	
		28	6/10/2006	8.35		423.6	18.83	**18.29**
				8.14		400.2	17.79	
				8.27		410.8	18.26	
		90	6/12/2006	8.3		660.5	29.36	**28.96**
				8.36		667.3	29.66	
				8.36		626.7	27.85	
UEO	22/09/2006	3	26/09/2006	8.11		133.9	5.95	**7.05**
				8.2		177	7.87	
				8		164.7	7.32	
		7	30/09/2006	8.1		203	9.02	**8.47**
				7.9		197.9	8.796	
				8.02		170.8	7.59	
		28	21/10/2006	8.42		364	16.18	**16.1**
				8.15		341	15.15	
				8.33		381.8	16.97	
		90	23/12/2006	8.1		522.8	23.23	**24.27**
				8.28		564.3	25.08	
				8.07		551.3	24.49	
NEO	25/09/2006	3	29/09/2006	8.23		180.2	8.01	**7.74**
				7.92		166.1	7.38	
				8.26		176.1	7.83	
		7	3/10/2006	8.21		218	9.69	**9.32**
				7.89		194	8.62	
				8.07		217	9.64	
		28	24/10/2006	8.09		355.3	15.79	**15.84**
				8.16		357.4	15.89	
				8.15		374.2	16.63	
		90	25/12/2006	8.28		602.8	26.79	**26.42**
				7.94		574.3	25.52	
				8.33		606.6	26.96	
SP	28/09/2006	3	2/10/2006	8.14		135.1	6	**5.9**
				7.88		137.1	6.09	
				8.07		126.1	5.6	
		7	6/10/2006	8.09		167.5	7.44	**7.64**
				8.1		155.7	6.992	
				8.38		190.7	8.478	
		28	27/10/2006	8.16		310	13.78	**13.71**
				8		306.9	13.64	
				8.16		269.4	11.98	
				8.13		432.2	19.21	
		90	28/12/2006	8.13		544.7	24.21	**24.17**
				8.03		542.9	24.13	

Compressive strength for 100% OPC with 0.3% dosage of chemical admixtures

Marking	Date cure	Days	Date of Comp. test	Weight (kg)	Weight/Vol kg/m3	Fail Load kN	Strength N/mm2	Average N/mm2
UEO	5/12/2006	3	9/12//2006	8.24		427.8	19.01	**18.44**
				8.28		417.6	18.56	
				8.31		399.6	17.76	
		7	13/12/2006	8.24		487.8	21.68	**20.77**
				7.97		465.4	20.69	
				8.16		448.6	19.94	
		28	3/1/2007	8		668	29.64	**29.9**
				8.15		597.7	26.56	
				8.19		677.2	30.1	
		90	7/3/2007	8.43		659.1	29.29	**31.93**
				8.2		709	31.51	
				8.25		727.7	32.34	
NEO	7/12/2006	3	11/12/2006			548.4	24.37	**24.16**
						522.6	23.23	
						559.5	24.87	
		7	15/12/2006			596.9	26.53	**27.21**
						624.7	27.76	
						615.4	27.35	
		28	5/1/2007			874.3	38.86	**37.97**
						798.2	35.48	
						834	37.07	
		90	8/3/2007	8.62		1053	46.79	**46.14**
				8.37		984.1	43.74	
				8.29		1024	45.49	
SP	9/12/2006	3	13/12/2006	8.28		488	21.69	**21.96**
				8.38		489.2	21.74	
				8.34		505.2	22.45	
		7	17/12/2006	8.21		622.9	22.69	**28.11**
				8.27		622.1	27.65	
				8.31		652.5	29	
		28	7/1/2007	8.52		777.9	34.57	**36.28**
				8.4		831	36.93	
				8.46		801.7	35.63	
		90	10/3/2007	8.36		976.6	43.4	**42.97**
				8.36		946.8	42.08	
				8.29		977.1	43.43	

Compressive strength for 60% OPC and 40% PFA with 0.3% dosage of chemical admixtures

Marking	Date cure	Days	Date of Comp.test	Weight (kg)	Weight/Vol kg/m3	Fail Load kN	Strength N/mm2	Average N/mm2
UEO	11/12/2006	3	15/12/2006	8.13		261.1	11.6	**10.21**
				8.05		227.9	10.13	
				8.02		231.6	10.29	
		7	19/12/2006	8.33		296	13.15	**12.4**
				8.06		272.2	12.1	
				7.97		285.8	12.7	
		28	91/2007	8.02		435.8	19.37	**19.64**
				8.03		447.8	19.9	
				8.39		473.2	21.03	
		90	12/3/2007	8.13		658.7	29.28	**30.7**
				8.24		743.1	33.03	
				8.27		670.4	29.8	
NEO	12/12/2006	3	16/12/2006	7.96		269.1	11.96	**11.46**
				8.18		239.8	10.66	
				8.19		264.3	11.75	
		7	20/12/2006	8.16		260.7	11.69	**12.21**
				8.17		285.9	12.71	
				8.08		263.2	11.7	
		28	10/1/2007	8.22		472.2	20.99	**19.44**
				8.3		407.1	18.16	
				8.19		433	19.24	
		90	13/3/2007	8.11		695.9	30.93	**30.45**
				8.31		689.9	30.66	
				8.09		669.4	29.75	
SP	16/1/2007	3	20/1/2007	8.19		233.37	10.37	**10.68**
				8.38		205.1	11.78	
				8.25		247.2	10.99	
		7	24/1/2007	8.47		283.2	12.59	**12.28**
				8.27		228.7	10.17	
				8.04		269	11.96	
		28	14/2/2007	8.31		356.1	15.83	**16.39**
				8.27		385.6	17.14	
				8.15		364.4	16.19	
		90	17/4/2007			927	41.2	**38.22**
						868.5	38.6	
						784.35	34.86	

Compressive strength for 50% OPC and 50% PFA with 0.3% dosage of chemical admixtures

Marking	Date cure	Days	Date of Comp.test	Weight (kg)	Weight/Vol kg/m3	Fail Load kN	Strength N/mm2	Average N/mm2
UEO	18/1/2007	3	22/1/2007	8.21		110.2	4.897	**5.6**
				8.17		115	5.111	
				8.14		124.7	5.542	
		7	26/1/2007	8.27		153.9	6.842	**6.77**
				8.13		162.5	7.22	
				8.26		150.9	6.705	
		28	16/2/2007	8.21		276.2	12.28	**11.87**
				8.12		222.4	9.887	
				8.05		257.5	11.45	
		90	18/4/2007	8.28		504.6	22.43	**21.12**
				7.87		426.6	18.96	
				8.17		494.6	21.98	
NEO	24/1/2007	3	28/1/2007	8.15		176.3	7.836	**6.96**
				8.29		159	7.067	
				8.25		154.3	6.86	
		7	1/2/2007	8.28		181.6	8.07	**8.19**
				8.32		187.1	8.313	
				8.53		172.3	7.658	
		28	22/02/2007	8.4		265.9	11.82	**11.58**
				8.24		254.9	11.33	
				8.15		224.6	9.981	
		90	25/4/2007			585.45	26.02	**27.13**
						636.75	28.3	
						60.8.85	27.06	
SP	27/1/2007	3	31/1/2007			132.5	5.891	**6.5**
						145.9	6.482	
						146.5	6.513	
		7	4/2/2007			200.2	8.899	**8.08**
						185.7	8.255	
						178	7.91	
		28	25/2/2007	8.59		330.8	14.7	**12.97**
				8.45		220.2	9.787	
				8.53		252.8	11.23	
		90	28/4/2007			626.85	27.86	**27.83**
						649.575	28.87	
						602.55	26.78	

Total Porosity for 100% OPC with 0.15% dosage of chemical admixtures

Marking	Date cure	Days	Date of test	Weight in air(bf)	Weight in water (bf)	Weight in air(af)	Porosity
Control	24/8/2006	3	28/8/2006	203.3	76	192.4	
				205.1	75.7	193.5	**11.29**
				200.6	70.9	189	
		7	1/9/2006	200.2	88.8	188.6	
				211.5	85.1	198.7	**9.94**
				221.4	90.6	208.4	
		28	21/9/2006	198.9	74.7	188.4	
				182.2	64.8	173.1	**8.31**
				195.6	72	185.5	
		90	23/11/2006	206.7	69	196.55	
				211.2	70.5	200.33	**7.68**
				198.5	62.8	187.66	
UEO	9/9/2006	3	13/09/2006	179.6	62.3	168.7	
				169.8	57.9	160	**9.39**
				172.1	60.6	162.3	
		7	16/09/2006	180.4	65.1	170	
				183.3	64.4	169.6	**9.11**
				180.1	66.3	172.5	
		28	9/10/2006	231.9	96	220.98	
				227.5	93.3	217.26	**7.64**
				228.3	94.6	218.69	
		90	9/12/2006	218.3	82.9	206.5	
				225.2	88.6	213.7	**7.55**
				220.3	82.9	207.8	
NEO	14/09/2006	3	18/09/2006	231.4	94.4	216.6	
				232.4	92.6	217.7	10.82
				231.3	93.8	216	
		7	21/09/2006	226.8	93.2	212.1	
				224.5	90.6	210.4	10.53
				236.7	97.3	221.6	
		28	12/10/2006	242.9	93.2	226.9	
				238.5	92.1	223.79	10.05
				240.4	93	225.76	
		90	14/12/2006	235.6	91.8	221.7	
				231.1	88.8	217.4	9.65
				229	87.9	215.9	
SP	15/09/2006	3	19/09/2006	221.6	90	208.8	
				218.8	88.3	207.2	**9.73**
				216.1	86.7	204.2	
		7	22/09/2006	217.4	88.9	205.3	
				213.2	86.1	201.8	**9.42**
				221.6	91.4	209.9	
		28	13/10/2006	232.3	94.1	211.2	
				211.7	79	198.9	**9.23**
				207.5	76.4	195.4	
		90	15/12/2006	203.1	72.4	192.1	
				207.3	76.4	196.2	**9.02**
				206.5	75.7	194.7	

Total porosity for 60% OPC and 40% PFA with 0.15% dosage of chemical admixtures

Marking	Date cure	Days	Date of test	Weight in air(bf)	Weight in water (bf)	Weight in air(af)	Porosity
Control	1/9/2006	3	4/9/2006	200.6	87.8	187	
				203.2	89.2	189.1	**11.48**
				201.6	87.5	188.5	
		7	8/9/2006	214.3	76.7	200.4	
				206.3	71.7	193	**10.1**
				200	68.4	186.9	
		28	29/9/2006	233.1	95.8	219.6	
				228	94.6	215.1	**9.83**
				232.5	97.1	219.3	
		90	1/12/2006	225.7	86.7	213.5	
				223.5	85	212	**9.79**
				205.1	74.3	193.7	
UEO	16/09/2006	3	20/9/2006	190.1	70	173.3	
				196.8	73.1	183.7	**10.59**
				198.6	74.9	186.3	
		7	24/9/2006	189	70.4	176.8	
				191.1	70.8	178.4	**10.52**
				202	77.5	188.9	
		28	15/10/2006	223.2	82.3	208.4	
				218.2	72.8	204.2	**10.06**
				206.7	79	192.8	
		90	17/12/2006	208.9	75.3	196.1	
				211.1	76.6	199.1	**9.58**
				214.6	78.4	202.7	
NEO	23/09/2006	3	26/09/2006	197.4	76.3	185.5	
				183.9	68.1	173.9	**10.29**
				189.9	71.7	179.5	
		7	30/09/2006	205.7	83.5	193.36	
				207	83.6	194.48	**10.16**
				205.9	83.3	193.36	
		28	21/10/2006	208.5	75.4	195.9	
				207.1	74.2	194.05	**9.49**
				208.5	75.8	196.32	
		90	23/12/2006	198.1	70.3	188.1	
				196	68.9	185.8	**8.03**
				194.7	68.5	184.6	
SP	27/09/2006	3	1/10/2006	210	85.7	197.42	
				201.4	80.4	188.93	**10.03**
				198.7	79	187.15	
		7	5/10/2006	200.1	83.8	189.09	
				216.3	94.5	204.03	**9.84**
				192.3	87.5	181.83	
		28	26/10/2006	223.4	85.4	209.17	
				223.9	84.8	210.53	**9.73**
				223.5	85.1	210.67	
		90	28/12/2006	214	80	203.4	
				194.8	68.7	184.6	**8.09**
				202.9	73.7	193	

Total porosity for 50% OPC and 50% PFA with 0.15% dosage of chemical admixtures

Marking	Date cure	Days	Date of test	Weight in air(bf)	Weight in water (bf)	Weight in air(af)	Porosity
Control	7/9/2006	3	11/9/2006	190.1	70	173.3	
				196.8	73.1	183.7	**10.59**
				198.6	74.9	186.3	
		7	14/09/2006	189	70.4	176.8	
				191.1	70.8	178.4	**10.52**
				202	77.5	188.9	
		28	5/10/2006	223.2	82.3	208.4	
				218.2	72.8	204.2	**10.06**
				206.7	79	192.8	
		90	6/12/2006	208.9	75.3	196.1	
				211.1	76.6	199.1	**9.58**
				214.6	78.4	202.7	
UEO	22/09/2006	3	25/09/2006	197.4	77.2	186	
				187.8	70.2	177.1	**10.93**
				186.6	68.7	175.3	
		7	29/09/2006	212.2	86.8	198.82	
				216.1	88.4	202.64	**10.67**
				215.2	81.4	201.39	
		28	20/10/2006	215.3	80.8	202.16	
				209	75.8	196.88	**9.33**
				196.3	68.4	184.64	
		90	22/12/2006	199.4	71	188.8	
				205.4	74.2	194.1	**8.28**
				189.9	68.9	179.6	
NEO	25/09/2006	3	29/09/2006	216.1	87.6	203.2	
				219.4	89.6	206.6	**10.93**
				213.5	86	200.5	
		7	3/10/2006	219.2	92.4	205.27	
				214.9	89.6	201.79	**10.82**
				221.6	94.3	207.82	
		28	24/10/2006	230	88.9	214.89	
				236.2	91.9	221.62	**10.1**
				228.7	87	213.6	
		90	26/12/2006	220	82.9	209.3	
				220.8	84.1	211.3	**7.45**
				212.4	78.5	202.9	
SP	28/09/2006	3	2/10/2006	204.5	82.5	192.2	
				203.5	82.1	191.57	**9.95**
				224.2	92.9	209.51	
		7	6/10/2006	233.6	97.2	221	
				222.2	90	210.8	**9.92**
				220.7	89.5	209.5	
		28	27/10/2006	199.9	72.7	187.4	
				200.9	71.8	188.44	**9.65**
				238.4	93	233.14	
		90	29/12/2006	191.6	70.4	181.3	
				188.5	64.1	178	**8.47**
				193.4	68	184	

Total Porosity for 100% OPC with 0.3% dosage of chemical admixtures

Marking	Date cure	Days	Date of test	Weight in air(bf)	Weight in water (bf)	Weight in air(af)	Porosity
UEO	5/12/2006	3	9/12//2006	179.2	59.1	169.3	
				181.8	59.9	171.3	**8.9**
				179.3	58	168.5	
		7	13/12/2006	186.4	67.7	176	
				177.6	59.1	166.7	**8.76**
				176.9	57.2	167.5	
		28	3/1/2007	160.2	52.9	150.4	
				156.6	51.2	146.2	**8.39**
				154.4	49.5	145.6	
		90	5/3/2007	158.5	51	148.8	
				154.7	47.5	145.2	**7.18**
				153.3	47.3	143.8	
NEO	7/12/2006	3	11/12/2006	186.1	63.9	176	
				185.6	63.2	175.5	**8.39**
				186.8	64.1	176.5	
		7	15/12/2006	183.1	63.2	172.6	
				187.5	63.7	177.3	**8.24**
				182	60.8	172.1	
		28	6/1/2007	184.6	67.3	173.8	
				189	70.1	178.2	**8.18**
				171	59.4	160.8	
		90	8/3/2007	185.6	68.4	176	
				183	65.9	172.4	**8.03**
				186	68.9	176.6	
SP	9/12/2006	3	13/12/2006	186.7	65.5	176.9	
				185.7	64.1	176.7	**8.86**
				180.9	61.8	172.2	
		7	17/12/2006	186.2	63.5	176.7	
				184.7	62.1	174.1	**8.65**
				189.5	66	179.8	
		28	7/1/2007	164.5	56.4	155.5	
				171.2	60.1	162	**8.33**
				170.9	57.1	160.9	
		90	10/3/2007	172.1	64.8	163.2	
				173.8	65.8	164.8	**8.29**
				170.7	63.5	161.2	

Total porosity for 60% OPC and 40% PFA with 0.3% dosage of chemical admixtures

Marking	Date cure	Days	Date of test	Weight in air(bf)	Weight in water (bf)	Weight in air(af)	Porosity
UEO	11/12/2006	4	15/12/2006	185.3	62.4	174.1	
				173.2	55.8	164.2	**10.25**
				175.5	56.5	165.1	
		7	19/12/2006	177.8	57.7	167.8	
				173.7	55.2	162.8	**10.03**
				187.5	63.1	175.8	
		28	9/1/2007	184.8	66.3	172.8	
				182.4	64.6	170.2	**9.68**
				176.2	61.5	165.1	
		90	12/3/2007	180.1	67.5	168.9	
				187.9	72.3	176.3	**9.44**
				181.2	68.9	170.6	
NEO	12/12/2006	3	16/12/2006	186.1	63.7	175.3	
				188.4	64.7	176.7	**10.56**
				185	61.9	172.9	
		7	20/12/2006	183.8	60.5	172.8	
				173.6	54.4	163.6	**10.51**
				189.5	64.3	178.1	
		28	10/1/2007	202.9	77.6	190	
				199.9	72.6	185.9	**10.26**
				201.5	76.7	188.7	
		90	13/3/2007	210.3	83.1	197.1	
				207.1	80.8	194.7	**9.82**
				214.6	84.6	201.3	
SP	16/1/2007	3	20/1/2007	162.2	49.1	153.1	
				165.1	50.7	156.2	**10.61**
				163.4	49.2	154	
		7	24/1/2007	167.8	53.9	158.6	
				153.1	43.4	144.9	**10.48**
				160.7	48.2	152	
		28	14/2/2007	169.9	67.2	159	
				168.9	66.8	158.2	**9.63**
				162.9	64.3	153.4	
		90	17/4/2007	169	59.2	161.2	
				174.5	62.6	167.3	**6.88**
				171.9	60.7	164	

Total porosity for 50% OPC and 50% PFA with 0.3% dosage of chemical admixtures

Marking	Date cure	Days	Date of test	Weight in air(bf)	Weight in water (bf)	Weight in air(af)	Porosity
UEO	18/1/2007	3	22/1/2007	182.6	60.4	171.6	
				190.1	63.9	178.1	**9.51**
				174.4	55	163.3	
		7	26/1/2007	170	50.6	158.9	
				165.4	52	154.7	**9.3**
				168.5	51.4	157.3	
		28	16/2/2007	209.5	85.5	197.1	
				194	75.4	182.4	**9.14**
				184.6	70.8	174.2	
		90	18/4/2007	208.2	87.1	199.1	
				212.1	88.6	203.6	**7.3**
				211.7	88.9	202.5	
NEO	24/1/2007	3	28/1/2007	203.3	75.7	192.3	
				202.3	74.8	191.4	**9.97**
				204.7	76.2	193.7	
		7	1/2/2007	206.6	87.1	195.3	
				210.2	88.8	198.1	**9.75**
				202.1	85.3	191	
		28	22/2/2007	201.5	80.5	188.8	
				198.4	78.1	186.2	**9.46**
				205.7	82.6	193.7	
		90	25/4/2007	196.2	83.2	184.2	
				207.3	87.7	193.2	**8.62**
				197.8	84.4	186.2	
SP	27/1/2007	3	31/1/2007	210.9	81	199.7	
				210.3	79.8	198.2	**10.55**
				206.6	77.2	194.4	
		7	4/2/2007	213.7	91.4	200.8	
				213.7	91.1	200	**10.38**
				214.3	91.9	201.6	
		28	25/2/2007	200.4	79.2	188.1	
				200.9	79.8	188.2	**10.15**
				209	85.1	197.4	
		90	28/4/2007	205.4	78	195.2	
				207.8	77.8	197.3	**8**
				204.2	75.2	194	

Oxygen permeability coefficient for concrete mixes with 0.15% chemical admixtures

Concrete mix	3 days(Ko)	28 days(Ko)	90 days(Ko)
100OPC	1.17976E-16	7.82456E-17	5.03407E-17
100OPC/0.15UEO	2.22758E-16	1.20352E-16	7.74152E-17
100OPC/0.15NEO	3.89475E-16	1.17029E-16	1.42157E-16
100OPC/0.15SP	4.26073E-16	1.90183E-16	5.26914E-17
60OPC/40PFA	5.04616E-16	3.41132E-16	1.32279E-16
60OPC/40PFA/0.15UEO	8.79902E-16	3.60922E-16	1.10539E-16
60OPC/40PFA/0.15NEO	7.92492E-16	2.20826E-16	1.01883E-16
60OPC/40PFA/0.15SP	8.8224E-16	2.0892E-16	1.56808E-16
50PFA	2.92433E-16	4.89654E-16	1.50591E-16
50OPC/50PFA/0.15UEO	7.95499E-16	6.12003E-16	1.68861E-16
50OPC/50PFA/0.15NEO	9.26811E-16	3.85121E-16	8.79703E-17
50OPC/50PFA/0.15SP	9.86482E-16	3.59365E-16	1.15851E-16

Oxygen permeability coefficient for concrete mixes with 0.3% chemical admixtures

Concrete mix	3 days(Ko)	28 days(Ko)	90 days(Ko)
100OPC/0.3UEO	1.62335E-16	1.21027E-16	2.4751E-16
100OPC/0.3NEO	1.51774E-16	1.639E-16	1.28707E-16
100OPC/0.3SP	1.3463E-16	1.07808E-16	1.70273E-16
60OPC/40PFA/0.3UEO	2.5226E-16	2.54993E-16	1.49596E-16
60OPC/40PFA/0.3NEO	3.33605E-16	3.004E-16	2.66151E-16
60OPC/40PFA/0.3SP	5.02896E-16	2.74626E-16	1.7469E-16
50OPC/50PFA/0.3UEO	2.42363E-16	2.69227E-16	1.17201E-16
50OPC/50PFA/0.3NEO	4.31621E-16	4.04103E-16	2.41122E-16
50OPC/50PFA/0.3SP	4.24873E-16	5.07644E-16	2.30803E-16