DURABILITY STUDY OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH FLY ASH AND EGGSHELL POWDER

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ABSTRACT

It is well known that construction industry has accounted for 7% of total carbon dioxide emission globally. During the production of concrete, it needs a lot of raw material and it is also one of the source for greenhouse gas emission, creating global warming and climate change. Therefore, it is necessary to reduce the cement content in concrete by using green and reusable waste materials. In this study, fly ash and eggshell powder was used as partial replacement of Ordinary Portland Cement. Fly ash are by-products from power plant and eggshell is waste from hatcheries or food industries. These waste are being disposed in landfill and cause environmental pollution. The properties of these materials are suitable to be use to substitute limestone. Four different percentages of cement replacement by fly ash and eggshell powder with a water to cement ratio of 0.4 were used for this research. Mechanical and durability properties of the produced concretes were studied. The investigations focused on compressive strength, water absorption, water penetration, acid attack and sulphate attack test at different percentages of replacement. From the investigation, all the concrete cubes have achieved the desired strength of 30MPa for 28days curing. For the mixes with fly ash and eggshell powder, 30FA 5ESP has the highest strength of 48.58MPa. The rate of water absorption and water penetration reduced with the increase of cement replacement by FA and ESP. However, when the replacement exceed 40%, the percentage of water absorption and depth of water penetration increase. The mass loss percentage and strength loss percentage due to acid attack was minimum for 30FA 5ESP mix and maximum for normal concrete. The strength loss percentage due to sulphate attack was minimum for 30FA 5ESP mix. The further replacement will increase the percentage of strength loss and the strength loss is higher than the normal concrete. The results obtained indicate that a total of 35% replacement is the most optimum replacement percentage. The concrete strength dropped and durability became lower when further increase the percentage of replacement. Thus, it is possible to contribute to construction sustainability and build more durable structures by substituting the cement content in concrete with fly ash and eggshell powder.

ABSTRAK

Memang diketahui umum bahawa industri pembinaan telah menyumbang sebanyak 7% daripada jumlah karbon dioksida global. Banyak bahan mentah perlu digunakan dalam penghasilan konkrit, dan proses penghasilan konkrit juga merupakan salah satu sumber untuk pelepasan gas rumah hijau, pemanasan global dan perubahan iklim. Oleh yang demikian, langkah proaktif perlu diambil untuk mengurangkan kandungan simen dalam konkrit dengan menggunakan bahan-bahan buangan hijau dan boleh diguna semula. Dalam kajian ini, serbuk abu terbang dan serbuk kulit telur boleh digunakan sebagai pengganti separa simen Portland biasa. Serbuk abu terbang adalah produk sampingan daripada loji janakuasa dan kulit telur adalah sisa daripada pusat atau industri makanan. Sisa ini akan dilupuskan di tapak pelupusan sampah dan menyebabkan pencemaran alam sekitar. Ciri-ciri bahan ini adalah sesuai untuk digunakan untuk menggantikan batu kapur. Empat peratusan yang berbeza penggantian simen dengan serbuk abu terbang dan serbuk kulit telur dan air nisbah simen 0.4 telah digunakan untuk penyelidikan ini. Sifat mekanikal dan ketahanan konkrit yang dihasilkan telah dikaji. Penyiasatan ke atas kekuatan mampatan, penyerapan air, penembusan air, asid serangan dan ujian serangan sulfat pada peratusan yang berbeza penggantian. Daripada penyiasatan, semua kiub konkrit telah mencapai kekuatan yang dikehendaki 30MPa untuk 28days. Untuk bancuhan dengan abu terbang dan kulit telur serbuk, 30FA 5ESP mempunyai kekuatan tertinggi 48.58 MPa. Kadar penembusan penyerapan air dan air berkurangan dengan peningkatan penggantian simen oleh FA dan ESP. Walau bagaimanapun, apabila penggantian lebih daripada 40%, peratusan penyerapan air dan air kedalaman penembusan meningkat. Peratusan kehilangan jisim dan kerugian peratusan kekuatan yang disebabkan oleh serangan asid adalah minimum untuk campuran 5ESP 30FA dan maksimum bagi konkrit biasa. Peratusan kehilangan kekuatan akibat serangan sulfat adalah minimum untuk campuran 5ESP 30FA. penggantian tambahan akan meningkatkan peratusan kehilangan kekuatan dan kehilangan kekuatan akan lebih tinggi daripada konkrit biasa. Keputusan yang diperolehi menunjukkan bahawa sejumlah penggantian 35% adalah peratusan penggantian yang paling optimum. Kekuatan konkrit menurun dan ketahanan menjadi lebih rendah apabila peratusan penggantian meningkat. Oleh itu, adalah kemungkinan untuk menyumbang kepada kemampanan pembinaan dan membina struktur yang lebih tahan lama dengan menggantikan kandungan simen di dalam konkrit dengan abu terbang dan serbuk kulit telur.

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LIST OF SYMBOLS

%	Percent
mm	Millimeter
MPa	Mega Pascal
kg	Kilogram
N	Newton
kN	Kilo newton
mm^2	Millimeter square
m^3	Meter cubic
w/c	Water to cement ratio
N/mm^2	Newton per millimeter square
nm	Nano meter
µm	Micro meter

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British standard
$CaCO_3$	Calcium carbonate
CO_2	Carbon dioxide
C-S-H	Calcium silicate hydrate
e.g.	For example
EN	European standards
ESP	Eggshell powder
etc.	Et cetera
FA	Fly ash
GGBS	Ground granulated blast furnace slag
GHG	Greenhouse gases
i.e.	That is
MS	Malaysian standard
OPC	Ordinary Portland cement
POFA	Palm oil fuel ash
RHA	Rice husk ash

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Concrete is being extensively used for construction purpose to build buildings, dams, bridges etc. Cement is one of the major constituent to produce concrete. Cement industry is the major cause of greenhouse gases (GHG) emissions, especially in the energy consumption and calcinations process. It is getting worst by the growth of the cement industry, rising from 5% to 8% each year up to 2015 (Zhang *et al.*, 2014). Due to the high demand of concrete nowadays, several studies were made to replace cement in concrete. Indeed, an appropriate waste and reusable material is encouraged and needed to substitute cement in concrete production.

Malaysia is one of the largest egg consumption country in the world. Malaysians consume a total of 20 million eggs daily (Lee, 2011). Teo Seng Capital Bhd, one of the largest egg producer company said the current level of egg consumption by Malaysian is about 36.5 million eggs per day and it is expected it will still grow 3% to 5% by year 2015 (Chong, 2015). The huge amount of egg consumption had left a large amount of eggshells waste products that just disposed in landfill. The discarded egg shells create undesirable smells and will lead to severe environmental pollution. The protein membrane in eggshell will promote the growth of bacteria and attract rats and worms (Doh *et al*, 2014). Recently, researchers have work on egg shells and found that it has added values which can be applied in different field. One of the usage is used egg shells powder as partial replacement for cement. This is due to the rich content of $CaCO_3$ in eggshell.

Fly ash is a type of byproduct from the burning of pulverized coal in power generation plant. Globally, fly ash create a significant environmental problem because there was more than 2 billion tonnes of fly ash are dumped in landfill sites. In Malaysia, it was estimated 8.5 million tonnes of coal ash are being produced annually (Akmal *et al.*, 2017). The volume of fly ash is forecasted to increase expeditiously duo to the expansion of energy demand in this rapid growth economic era. Dumping of fly ash without prior treatment will cause land pollution, air pollution and water pollution. Fly ash exhibit pozzolanic properties which make them can react chemically with calcium hydroxide. This make them suitable to be used for cement replacement in concrete production. Therefore, this research is to investigate the optimum amount of eggshell and fly ash replacement in cement.

1.2 PROBLEM STATEMENT

Concrete is a composite material with high tensile strength but relatively low tensile strength. Due to rapid development of urban and sub urban, the quantity of concrete use also increase rapidly. However, concrete itself is not sustainable or environmental friendly. During the production of concrete, it needs a lot of raw material and it is also one of the source for greenhouse gas emission, creating global warming and climate change (Kumar *et al.*, 2016).

There was more than 69 billion tonnes of cement was produced and used since year 1930. During 2013, around 3.6 billion tonnes of cement was poured for infrastructure and construction buildings. Cement manufacturing has contributed six per cent of entire carbon dioxide emission and the amount of carbon dioxide released is around 38.2 Giga tonnes (Nogrady, 2016).

Therefore, we need to find alternative sources to replace all the raw materials to preserve natural resources for future generation. Fly ash as waste products from coal combustion and egg shells as waste products from agricultural industry can be used as cement replacement in concrete production. This will save the cost on landfill and solve the concrete industry problems.

Eggshell consists of 94% calcium carbonate, 1% magnesium carbonate, 1% calcium phosphate and 4% organic matter (Rivera *et al.*, 1999). The chemical composition of eggshell is very similar to cement, so it can be used to replace cement.

Fly ash is a fine, glass powder by product from the burning pulverized coal during the electricity power generation. It is primarily made up of silica, alumina and iron. The composite materials of fly ash, lime and water will form a cementitious compounds which has properties similar to Portland cement. So, it can be used as supplementary material to cement on concrete production (Gowsika *et al.*, 2014). Basically, fly ash can be categorized into two major types which are class F fly ash and class C fly ash. The lime content or calcium is the difference between Class F and Class C fly ash. Class C fly ash has higher calcium content than class F fly ash. Class C fly ash comprise more than 20% lime while for class F fly ash is less than 10%.

Limestone is the typical calcium carbonate source for cement production. However, limestone is non-renewable material. Therefore, suitable and effective green renewable materials are needed to replace limestone. Current research shows that the optimum replacement of cement by fly ash alone in concrete production is in the range of 25-35%. An alternative source of calcium carbonate can be introduced to increase the percentage of replacement. Eggshell consist of 94% calcium carbonate is suitable to be used for blended cement production. Besides, the use of eggshell powder in construction field is still very less and not popular.

1.3 OBJECTIVES

The objectives of this study are:

i. To identify the compressive strength of concrete cubes as cement is partial replaced by fly ash and eggshell powder.

ii. To determine the water absorption and water penetration performance of concrete cube with fly ash and eggshell powder as partial replacement of cement.

iii. To examine the durability of blended cement in different conditions by exposed the concrete cube to sulphate and acid solution.

1.4 SCOPE OF RESEARCH

This research will focus on the compressive strength and durability of blended cement concrete. The composition of fly ash will be fixed to 30% while the composition of eggshell powder will be manipulated variable. Cement will be replaced in different percentage such as 5%, 10%, and 15% by eggshell powder.

The concrete was casted and poured into 150mm x 150mm x 150 mm and 100mm x 100mm x 100 mm mould. After 24 hours, they will be demoulded. Then, the hardened concrete will be cured in water. Then, compressive strength test and several durability test such as sulphate resistance, acid resistance, water absorption test and water penetration test will be carried out. Compression test is conducted on 7, 14 and 28 days to determine the strength of concrete. While for durability test, all the concrete cubes will undergo 28 days water curing. Water absorption and water penetration test will be tested after 28 days water curing. The concrete cubes for sulphate attack and acid attack test will further immersed in respective solution for 90 days before testing are being carried out.

1.5 RESEARCH SIGNIFICANCE

Researchers have conducted studies to determine the mechanical and durability properties of replacement of OPC with eggshell powder in producing concrete. Fly ash has also been used to replace cement in certain percentage in cement industries to increase concrete durability. Research has been proved that eggshell powder has the chemical composition almost similar with cement.

This research will focus on the replacement of cement by eggshell powder and fly ash with certain percentage. The concrete cube produced will undergo several durability tests. Durability test is to determine the resistance of concrete towards adverse environments. The tests conducted are water absorption test, water penetration test, sulphate resistance and acid resistance test. Besides, this is also one of the effort to reduce the usage of cement because cement is the most expensive materials in producing concrete. With the use of waste products, it is more sustainable and environmental friendly for concrete industry and at the same time reduce the use of landfill.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND

The overwhelming demand for green environment and sustainable materials reinvigorated many researchers to find alternative sources to solve the problems. Many materials were studied and observed to replace cement. Materials such as palm oil fuel ash (POFA), rice husk ash (RHA), ground granulated blast furnace slag (GGBS), fly ash (FA) and egg shell powder (ESP) has been studied and replaced successfully part of the cement in certain percentage. However, the research about replacement of cement by egg shell powder is little.

The literature relating to fly ash, egg shell powder and durability test on concrete are established in this chapter.

2.2 CONCRETE

Concrete is widely used in construction field to build structures, bridges, buildings etc. Hence, it has been labelled as the backbone to the infrastructure development of a nation. Sometimes people are confused with the terms of cement and concrete, concrete is actually the end product from cement (Madeleine, 2016). Besides water, the second most utilization material is concrete. In general, every individual on earth will use three tons of concrete annually. Therefore, a huge amount of concrete is necessary for the blooming of infrastructure.

Concrete are composite materials that exhibit complex randomness with various length scales from nanometers to millimeters. The largest particle size of material in concrete are aggregate, in millimeters. Hydrated cement paste has diameters between 50 – 10,000 nm for large capillary pores, diameters of 10 – 50 nm for medium capillary pores and smaller than 10nm particle size for gel pores. Concrete structure should have the ability to resist loads and good durability properties. Permeability, sorptivity, and diffusivity are material properties which can affect durability and service life of concrete structure (Chindaprasirt *et al*., 2007).

2.3 ORDINARY PORTLAND CEMENT

There are two major types of cement available in market, such as ordinary Portland cement and hydraulic blended cement. Portland cement is the main ingredients for hydraulic binding of aggregates and produce concrete, composed primarily of hydraulic calcium silicates. The main components in producing cement is limestone and clay-like materials. This two materials are heated in a kiln at 1400^0C to produce clinker. Gypsum is then added into clinker to form cement (Madeleine, 2016).

However, process of producing Portland cement is energy intensive process (4 GJ/tonne of cement), and can emit nearly one tonne of CO_2 to environment for every one tonne of portland cement produced. The CO_2 produced is both directly or indirectly enter the atmosphere, whereby CO_2 is release directly during heating of limestone and indirectly during the process of burning of fossil fuels to heat the kiln. About 7 percent of the global CO_2 emissions is contributed by portland cement as 1.5 billion tonnes of cement has been produced yearly (Mehta and Monteiro, 2006).

Blended cement is produced by replaced certain proportion of the limestone-based clinker by coal fly ash, ground granulated blast furnace slag or rice husk ash. The advantages of blended cement is it could reduce around 20% CO_2 emissions (Madeleine, 2016). Therefore, supplementary cementitious materials is needed to reduce emission of CO_2. Table 2.1 shows the percentage of chemical composition of ORANG KUAT branded OPC by weight.

Table 2.1 Percentage of Chemical Composition of ORANG KUAT branded OPC by Weight.

Chemical composition	**Percentage (%)**
CaO	65
SiO_2	21
Al_2O_3	6
Fe_2O_3	3.5
MgO	0.7
SO_3	1.5
Free lime	2

Source: Ali *et al.* (2008)

2.4 CONCRETE COMPRESSIVE STRENGTH

Eggshell powder as partial cement replacement help in increasing concrete compressive strength. 10% of cement replace by eggshell powder can increase concrete compressive strength by 12%. However compressive strength will drop if cement replacement up to 30% (Tan *et al*., 2017).

Research by Jayasankar *et al*., (2010) shows that 5wt% of eggshell in concrete mix can achieve highest concrete compressive strength as compared to other mix ratio. The strength will dropped if higher dosage was used. Okonkwo et al. studies shown that concrete specimens which have 8wt% cement and 10wt% eggshell waste will improve compressive strength of concrete up to 35%.

Pliya and Cree (2015) has used limestone from eggshell as replacement in Portland cement mortar. The result from the investigation shows that 5wt% of eggshell added to mortar mix was the optimum composition as the compressive strength can achieved 54.0MPa at 28 days, whereby the strength increased 8% as compared to plain mortar. 10wt% and 20wt% eggshell added will decreased the compressive strength by 12% and 19% respectively.

2.5 CONCRETE DURABILITY

Durability is the ability to remain functional for a long term period without notable deterioration. Nowadays, construction industry does not only focus on high concrete strength, but also emphasis on producing durable concrete which can last longer. In the study of concrete, durability means the ability of concrete to withstand weathering action, chemical attack and abrasion while the engineering properties of concrete are remained. In order to decrease the long term impact to the structure, it is desirable to create a durable structure. The degree of durability of concrete are mostly rely on the exposure surrounding conditions (Deepika *et al*., 2017).

Durability is important with regards to a structure's lifespan. It is the characteristic that dictates how long a structure can live to perform its desired function. Therefore it has a direct impact on strength. The durability problems of concrete structure originate from the environmental actions of aggressive agents on concrete, they can cause premature material deterioration, impair structural service performance and, in extreme cases, can even induce the structural failure. The common durability phenomena have been relatively well defined, including steel corrosion by concrete cover carbonation, steel corrosion by chloride penetration, concrete damage by freeze-thaw cycles in cold climates, concrete scaling by salt crystallization in dry climates, long-term leaching of concrete solid phase by soft water as well as chemical attack of concrete by acid rain or aggressive ions in ground water and soil (Li *et al.*, 2008).

Generally, concrete deterioration is gradual and depending on their service and environment. Deterioration of materials at the initial stage will result in durability issues. It does not have instantaneous safety issue on the structure, but it will damage the structure in long term. Concrete deterioration can be classified into three major sources which are mechanical, physical and chemical. There are many studies done by researchers to solve the durability problems. For instance, problems related to sulphate attack, corrosion of reinforcing bar, carbonation and alkali aggregate reaction (Tang *et al.*, 2015).

Partial replacement of Portland cement in concrete with pozzolanic materials can increase concrete properties. During hydration process, water will react with cement produce calcium silicate hydrate and by- products of calcium hydroxide. Pozzolanic materials will then react with calcium hydroxide to generate calcium silicate hydrate gel. C-S-H gel has the ability to increase concrete strength, better durability and impermeability of concrete.

Permeability is defined by the ease with which gases and liquids can penetrate and move into the concrete. Permeability will influence the primary method of transport of moisture and aggressive ions into the concrete and is responsible for the increased rate of damage. High permeability concrete increase the ease of penetration of aggressive agents into concrete and lead to rapid concrete deterioration and corrosion of reinforcement bar (A. Amriou *et al.*, 2017). Water cement ratio is one of the major factor that will influence concrete permeability. The higher the W/C ratio, the higher the permeability and thus the higher the porosity of concrete. Thus to produce dense, impermeable and durable concrete, the water cement ratio should be control as minimum as possible. The lower W/C ratio also add value to concrete because concrete are not vulnerable to chemical attack, corrosion, and other deterioration. There are close relationships between microstructure and durability. Concrete with higher ratio of fine porosity, reasonable pore size distribution, and higher microhardness has corresponding higher compressive strength (Duan *et al.*, 2013).

A well perform concrete should have a good resistance to severe environment. However there are many factors that can affect the durability of concrete. Concrete may deteriorate when exposed to some chemical environments regardless strength of concrete.

2.5.1 PRINCIPAL TYPES OF CHEMICAL REACTION AND ATTACK ON CONCRETE

Deterioration can be categorised into two phases which are initial phase and propagation phase. The initial phase (period) in which there is no noticeable weakening of properties, except protective barrier (the duration of this phase is about 15 years). Corrosion occurs initiated by chlorides or carbonation. The propagation phase with active deterioration mechanisms that develop increasingly with time. The propagation period consists of the propagation with minor damage and the accelerated period (the duration of this phase is about 15 years). After that follow the accelerated period with widespread cracking and spalling of the protective layer (Folic, 2009).

Sulphates of sodium, potassium, calcium, or magnesium can be found naturally in soil or dissolved in groundwater. Sulphates can also be found in seawater, but the severity is not as high as sulphates in ground water. There is less calcium sulphate and more other form of sulphate present in ground water due to the low solubility of calcium sulphate. The extensive utilization of fertilizers, sewage waste and industrial effluents has increased the amount of ammonium sulphate in agricultural soil and water. H_2S is formed from the decomposition of organic matters. Bacterial can further transform H_2S to sulphuric acid (Swaroop *et al*., 2013).

Ordinary Portland Cement (OPC) concrete is highly alkaline in nature and susceptible to strong acid attack. When concrete is exposed to acidic environment, a neutralization reaction is occurred between hydrogen ion in acid and $Ca(OH)_2$ in the cementitious materials. The alkalinity of concrete will be reduced and lead to the dissolution of the hydration products (Usman *et al*., 2017).

Cracking of concrete is a manifestation of distress and may result from externally applied load or by internal changes in the material, or by a combination of the two. This can occur while the concrete is either in the prehardened or hardened state. The fracture strength of the concrete dictates its susceptibility to cracking and hence to accelerated deterioration. Its importance in controlling the rate of degradation is therefore self-evident.

Research has shown that pozzolans such as fly ash, ground granulated blast furnace slag can improve concrete performance when exposed to sulfates (Portland Cement Association, 2002).

2.5.1.1 ACID ATTACK

Sulphuric acid (H_2SO_4) is categorised as highly ionised mineral acid and the pH value may less than 2. The main consequence of acid attack on concrete is the breakdown of cement paste components. This will cause the concrete to become weaker. Sulphuric acid will cause the decomposition of calcium hydroxide and dissolution of cementitious particles by decalcifying C-S-H gel, thus resulting in strength loss (Venkateswara *et al*., 2012).

Portland cement concrete does not have good feature on resisting acidic environment. In fact, hydraulic cement concrete can't withstand in a solution with a pH of lower or equal to 3 despite the composition of concrete. Calcium hydroxide from hydrated Portland cement will react with acid. Acid can come be the products of combustion of fuels, animal wastes, acid rain, any solution that contain bicarbonate ion or calcium absorptive acidic soil. Generally, Portland cement concrete will undergo surface protective treatment to protect from acidic environment and attack by acid. Concrete should also be cured in proper way to reduce permeability and thus reduce rate of attack of acid (Portland Cement Association, 2002).

2.5.1.2 SULPHATE ATTACK

Besides concrete also susceptible attack by sulphate by reacting with calcium hydroxide of hydrated compounds in hardened concrete. The necessary medium for sulphate attack are sulphate anions (SO_4^{2-}). The ions such as SO_4^{2-}, NH_4^+, Mg^{2+} and H^+ which dissolved in ground water and soil pore water as well as acid rain in industrial polluted regions are aggressive to concrete (Li *et al*., 2008). Sulphate anions will attack water soluble containing salts on concrete. The common salt compounds are sodium, potassium, calcium and magnesium. These reactions will cause loss of cohesion and strength because the cement paste is damaged by the pressure. Ettringite is formed when calcium aluminate hydrate is being attacked by calcium sulphate. The reaction between calcium hydroxide, calcium aluminate hydrate and sodium sulphate will lead to the formation of ettringite and gypsum. The attack mechanism of magnesium sulphate is almost identical to sodium sulphate. The formation from the reaction are ettringite, gypsum, and brucite. Brucite is magnesium hydroxide and can be found on concrete surface. It will consumes calcium hydroxide, reduce pore solution's pH value, and then deteriorates the C-S-H.

Therefore, it is essential to have dense and well compacted concrete structure to prevent the diffusion of anions into concrete surfaces. Generally, the chemical reaction between sulphates and concrete components are intricate and continuous (Venkateswara *et al*., 2012).

2.5.1.3 CORROSION

Corrosion of steel reinforcement is the most serious durability problem of reinforced concrete structures. It impairs not only the appearance of the structure, but also its strength and safety, due to the reduction in the cross-sectional area of the reinforcement and to the deterioration of bond with the surrounding concrete. The various forms of damage detected on structures that suffer by steel corrosion show that it is necessary to interpose for the static rehabilitation of these structures. This interposition (either pre or post-earthquake) is imperative in the case of buildings, which are currently in use or are places of large gatherings such as schools, hotels, churches, etc. One of the most complex matters faced by the international scientific groups involved in the static rehabilitation of such structures is the precise knowledge of the actual mechanical characteristics of the main construction materials, such as the reinforcing steel and concrete, as well as the wear mechanisms which cause the degradation of the mechanical properties. In recent years, although the problem of the actual residual strength degradation of aging reinforced concrete structures has attracted considerable attention, it is far from being fully understood and even less resolved. It is worth noting that up to now, little work has been done to account for the effects of corrosion on the mechanical properties of the reinforcing steel bars and hence on the degradation of the load bearing ability of a reinforced concrete element. Such effects are the reduction of the effective cross-section of the reinforcing steel, micro and macro cracking of concrete and finally the spalling of the concrete cover (Apostolopoulos, 2016).

2.6 APPLICATION OF INDUSTRIAL WASTE AS CEMENT REPLACEMENT MATERIAL

Nowadays, disposal of large amount of industrial waste such as ground granulated blast furnace slag (GGBS), palm oil fuel ash (POFA) and rice husk ash (RHA) has pose a significant environmental issue. These materials can be recycled and used in construction field to replace cement. This will help to preserve and reduce the usage of raw material and the associated environmental impact of extraction processes.

2.6.1 GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

Ground granulated blast furnace slag (GGBS) is by-product of iron manufacture, and it is generated during the melting process in steel making operations. GGBS is a non-metallic product that consists of silicates and aluminates of the calcium base. The advantages of incorporating GGBS in concrete is to improve concrete workability and reduce the temperature rise in concrete hardening process which help to avoid early-age thermal cracking. In terms of chemical composition, GGBS can be assumed to improve the resistance of concrete to chloride ingress (and thereby reduce the risk of reinforcement corrosion), sulphate attack and alkali–silica reaction (Lye *et al.*, 2016). A GGBS-blended concrete paste can improve fluidity and reduce bleeding. The GGBS blended concrete has also a reduced pore volume and pore connection which aids the concrete in resisting sulphate attacks and chloride induced corrosion (Teng *et al.*, 2013).

The reaction between GGBS with water and calcium hydroxide will form cement hydration product, extra C–S–H gel in the paste through pozzolanic reaction. Denser microstructure or lower porosity results from higher C–S–H content that represents higher GGBS replacement percent- age and higher durability of concrete. It was investigated that the use of GGBS decreased the water penetration depth from 26 mm (Portland cement concrete) to 14 mm (Özbay *et al.*, 2016).

The use of slag as supplementary cementitious material improves the durability of concrete as it reduces the permeability of GGBS concrete and significantly inhibits the ingress of sulphates. Al-Otaibi concluded that replacing 60% of OPC by GGBS results in an increase in porosity compared to the OPC mix of the same w/c ratio while it results in lower porosity when compared to the OPC mix with the same workability level (Al-Otaibi, 2008).

2.6.2 PALM OIL FUEL ASH (POFA)

Palm Oil fuel Ash (POFA) is a by-product of palm oil industry. It is generated from the combustion of pressed fibre and shell which are used as fuel in the generation of steam and energy. Malaysia is one of the largest producer and exporter of palm oil country in the world and 3 million tons of palm oil were produced in 2007 (Sofri *et al.*, 2015). The waste of palm oil has used up a lot of landfill to dump the ash and posed a lot of environmental issue. Therefore, research has been carried out to determine the potential of the ash in construction field.

The chemical composition of POFA has a large amount of silica. The high silica oxide content in POFA is suitable for cement replacement because it is responsible for pozzolanic reaction. Higher amount of calcium silicate hydrate (C-S-H) is produced in pozzolanic reaction. It is a gel compound contribute for concrete strength and thus reduce the amount of calcium hydroxide. The concrete produced is stronger and denser and the durability of the concrete is enhanced. The silica content (SiO_4) of POFA is in the range of 59.62% to 66.91%. The higher the percentage of POFA replacement, the lower the workability of concrete mix. POFA concrete need higher water content compared to normal concrete (Ali *et al.*, 2017). POFA will reduce the amount of $Ca(OH)_2$ in concrete and enhanced the microstructure. This is due to the pozzolanic reaction and microfilling effects of POFA.

Ranjbar *et al.* (2016) had concluded that incorporation of POFA in concrete would enhance the resistance of concrete towards acid and sulphate solution. The better resistance of the concrete containing POFA against acid attack was attributed to the pozzolanic reaction of POFA conversion of calcium hydroxide $Ca(OH)_2$ to the secondary C–S–H gel leading to denser concrete. POFA concrete was found more resistant to deterioration in acid solution than Portland concrete. The compressive strength of Portand concrete at 1800 hours revealed a reduction ratio difference of about 24 % compared to the specimens replaced with 20%

POFA with particle size of 10μm where only 15.9 % reduction on compressive strength (Budiea *et al.*, 2010).

Tangchirapat *et al.* (2009) had reported that concrete containing POFA showed better resistance in a 10% $MgSO_4$ solution. Concretes containing POFA also showed a smaller degree of expansion and loss in compressive strength than concrete made from Portland cement and the recommended percentage was up to 20% replacement. Tangchirapat *et al.* (2012) had immersed the concrete specimens in a 5% Na_2SO_4 solution for 9 months and they concluded that the use of ground POFA to replace Portland cement at all rates in concrete increased the sulphate resistance in terms of the expansion compared to the concrete without ground POFA.

2.6.3 RICE HUSK ASH (RHA)

Rice husk ash (RHA) is an agricultural waste material which contributed for 20% of the 649.7 million tons of rice produced annually worldwide. The husk is burnt under controlled temperature at 500^0C to 700^0C to produce ash in amorphous form. RHA is efficient as a pozzolanic material composed of high amorphous silica content. According to Dabai *et al.*, (2009), RHA has high silica content, 68.12% which is much more higher than that of cement with 23.43% only. 10% RHA replacement has the highest compressive strength and up to 20% replacement of cement replacement the concrete strength is still higher than normal concrete (Habeeb *et al.*, 2010).

RHA which act as supplementary cementitious material will reduce the emissions of carbon dioxide caused by the cement production. It can also improve the mechanical and durability properties of concretes. The use of the ultrafine RHA maintained or increased the mechanical behaviour of the reference concrete. 20% of RHA in concrete mix presented a superior performance for all ages (Cordeiro *et al.*, 2009).

The specimens containing RHA were found resistant to the sodium sulphate attack. It was concluded that as the percentage of RHA was increased, a larger expansion reduction was obtained. The specimens containing RHA were also found to be more resistant to the hydrochloric acid solution than those without RHA as studied by the reduced mass loss. The overall improved performance is due to the pozzolanic reaction by the use of RHA, resulting in the conversion of calcium hydroxide to C–S–H (Rodríguez, 2010).

Chatveera *et al*. (2011) had concluded that replacement of 20% of Portland cement by RHA leads to a positive effect in decreasing the corrosion of concrete under both HCl and H_2SO_4 attacks. 20% of cement replacement by RHA also yielded the lowest weight loss of concrete due to HCl and H_2SO_4 attacks.

2.7 FLY ASH (FA)

FA is an industrial by-products material which is typically finely divided mineral residue produced from the burning of powdered coal in the coal-fired furnaces. The volume of FA produced around the world is very huge, thermal power plants can produced around 1 billion tonnes of FA yearly. The huge volume of FA will be a main concern for power plant company because they need a larger space to store the ash. Their cost will be increase to obtain a larger landfill to deposit the ash.

Currently, approximate 28% of electricity in Malaysia is generated by pulverized coal firing, which used up about 8 million tonnes of coal annually. The use of FA in the cement manufacturing has been established for decades. Fly ash has the cementitious properties for hydraulic, or pozzolanic activity or both where it can react with calcium hydroxide released by the cement hydration process to form calcium silicate and aluminate hydrates. These hydrates fills the voids within the concrete, withdrawing the lime and thus reduce concrete permeability. This process will increase concrete workability, reduce and prevent the chance of occurrence of segregation, bleeding and alkali to silica reaction and increase concrete durability. The utilization of fly ash can reduce pollution and contribute for sustainable development (Kupaei *et al.*, 2013).

Fly ash can be classified into two main types which are siliceous fly ash (class F fly ash) and calcareous fly ash (class C fly ash). Class lime contain of class F fly ash is less than 5% while class C fly ash contains more than 10% of lime. The main constituent of fly ash is silicon dioxide aluminum oxide and Iron (III) Oxide. Table 2.2 shows the chemical content of Tanjung Bin coal ash using XRF analysis (Muhardi *et al.*, 2010). The shape of fly ash is glassy sphere, well-rounded and has smooth surface. Increasing of curing age of specimens will rise the number of irregular shaped particles. The particle size also increased with the increased of curing period, from 10 μm to 24 μm. Figure 2.1 shows the electron micrographs of fly ash obtain from SEM analysis (Muhardi *et al.*, 2010).

Table 2.2 Chemical content of Tanjung Bin coal ash using XRF analysis

Chemical contents	**Fly ash**	**Bottom Ash**
SiO_2	51.80%	42.70%
Al_2O_3	26.50%	23.00%
Fe_2O_3	8.50%	17.00%
CaO	4.81%	9.80%
K_2O	3.27%	0.96%
TiO_2	1.38%	1.64%
MgO	1.10%	1.54%
P_2O_5	0.90%	1.04%
Na_2O	0.67%	0.29%
SO_3	0.60%	1.22%
BaO	0.12%	0.19%

Source: Muhardi *et al.* (2010)

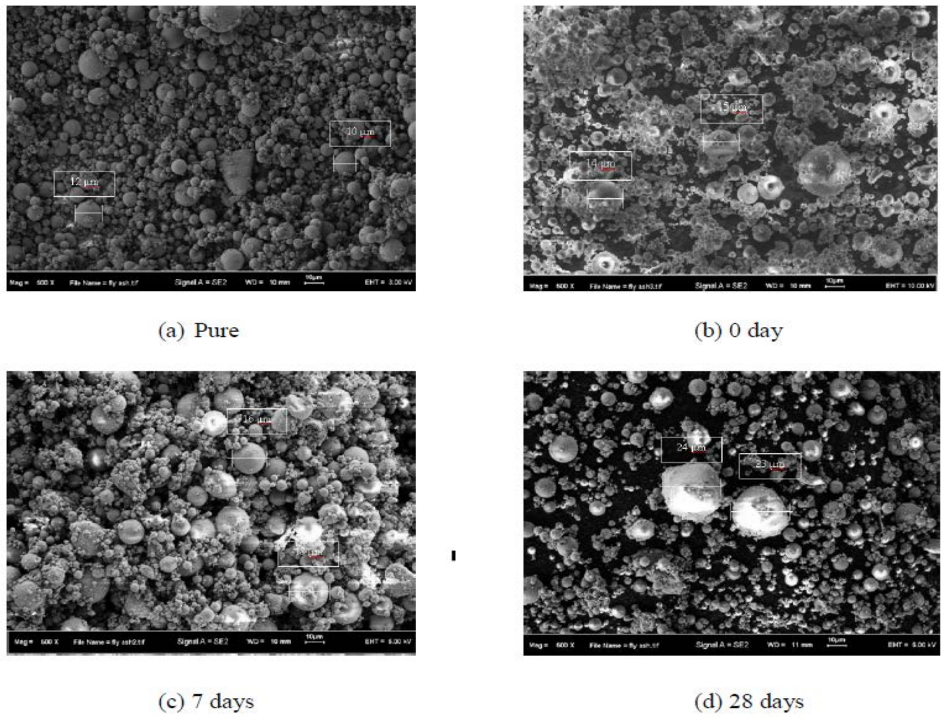

Figure 2.1 SEM photomicrographs of Tanjung Bin fly ash

Source: Muhardi *et al.* (2010)

Replacement of cement by fly ash enhance mechanical properties, durability of concrete and minimize alkali aggregate reaction. Fly ash has the ability to improve compressive strength of cement paste due to its small particle size. High fly ash composition in concrete can improve concrete durability towards chloride resistance (Hemalatha *et al.*, 2016).

The reactive silica in fly ash will combine with free lime to produce calcium silicate hydrate (C-S-H) gel which has binding properties. The gel is similar to cementitious compounds formed by the hydration of Portland cement. Therefore, fly ash concrete normally has relatively slower strength gain at early ages of curing (Dhanalakshmi *et al.*, 2015).

Namagga *et al.* (2009) had conducted research on optimization of fly ash in concrete. They concluded that fly ash replacement of 25 to 35% provides the most optimal (best strength) results. With further increase proportion of replacement of cement will reduce the rate of strength development of concrete. With an increase of percentage of fly ash replacement, the concrete can yield higher strength. However when proportion is more than 30%, it will has adverse effect on concrete strength. Fly ash replacement up to 30% at 28 days and 90 days can produce concrete strength exceeding or equal to 40MPa. The higher percentage of fly ash replacement will only be considered if the age of concrete mix is considered as 90 days. (Saha *et al.*, 2014).

Swaroop *et al.* (2013) had conducted experiments to study the durability on concrete with fly ash and GGBS. They concluded that the use of fly ash between 20-40% replacement with cement can have concrete with better strength and durability properties. The consumption of fly ash is assessed to be around 30% for the purpose of various engineering properties essentials (Sivakumar and Kameshwari, 2015). The specific gravity of fly ash is in the range of 1.73 to 2.71, and natural soils are lies between 2.5 to 2.7.

20% of cement replaced by FA shows a good response for durability criteria when the specimens is immersed in sulphuric acid solution (Swaroop *et al*., 2013). The permeable voids present in the concrete, indirectly representing the permeability, decreased with an increase in fly ash dosage. The deterioration of concrete subjected to 3% H_2SO_4 solution showed that the weight loss significantly decreased with increasing fly ash replacement percentage in self compacting concretes (Dinakar *et al*., 2008).

The test of concrete specimens on sulphate solution showed the superiority of high volume fly ash concrete by staying intact without changes to the physical appearance in the solution for 550 days while the 0% fly ash concrete completely lost the strength. After 1000 hours of exposure of concrete specimens to acid solution, it was noticed that the 0% fly ash concrete suffered the highest weight loss but the high volume fly ash concrete had only suffered minor surface erosion. The strength loss was also highest for 0% fly ash concrete as compared to that in high volume fly ash concrete specimens for all levels of fly ash replacements for acid attack test (Balakrishnan *et al*., 2014).

The incorporation of the fine fly ash had reduced the expansion of the mortar bars immersed in the sodium sulphate solution. The fine fly ash reduced the w/c of the mortar and thus made it denser as well as stronger (Chindaprasirt *et al*., 2004). The strength loss percentage in acid solution was the highest compared to sodium chloride and sodium sulphate solution. At 90 days of water curing the resistance of high fly ash concrete to salt, acid and sulphate solution is more than normal concrete. The rate of percentage strength loss is very high for normal concrete and least for the high fly ash concrete for 180 days of water curing (Sahoo *et al.*, 2015).

2.8 EGGSHELL POWDER (ESP)

Eggshells are normally thrown away by consumers as a waste. Hatcheries and food industries are the main sources of eggshell waste products. Majority of the waste will be just dumped in landfill without any prior treatment. This has been created a lot environmental issue because eggshell waste will release unpleasant smell and cause growth of bacterial which can cause illness and allergies. Besides, disposal of egg shell also used a lot of landfills.

Eggshells/shell membranes have multiple uses in nutrition, medicine, construction and art works. Eggshell powder has been reported to increase bone mineral density in people and animals with osteoporosis. Discarded eggshells are often used as a plant fertilizer and are effective liming sources. This is because eggshells contain calcium that raises, or neutralizes, the pH level of overly acidic soil. Eggshell membrane consists of collagen as a component. Collagen is a type of protein, fibrous in nature that connects and supports other bodily tissues, such as skin, bone, tendons, muscles and cartilage. Collagen has been isolated mainly from bovine and swine skins and bones Collagen used in medicine, biochemical, pharmaceutical, food and cosmetics industries (King`ori A.M., 2011).

Generally, good quality eggshells contain approximately 2.2 g of calcium in the form of calcium carbonate from commercial layers. About 95% of the dry eggshell is calcium carbonate weighing 5.5 g (Amu & Salami, 2010). Eggshell has chemical properties almost similar as limestone. The shell itself is about 95% $CaCO_3$. The other 5% consists of magnesium carbonate, calcium phosphate and soluble and insoluble proteins. The high calcium content in eggshell make it suitable to replace cement in concrete. This will reduce the use of natural lime. The use of eggshell will minimize environmental impact and conserve the natural lime by minimize the use of cement (Yerramala, 2014).

Olarewaju *et al*. (2011) studied suitability of eggshell stabilized soil as subgrade material for road construction. Previous research by Yerramala (2014) shown that by replacing 5% of eggshell into cement will increase the mechanical properties of normal weight concrete. The study by Gowsika, *et al*. (2014) had also shown similar result as result done by Yerramala.

Doh and Chin (2014) studied on eggshell powder as potential additive to concrete. In their research, concrete mix of grade M25 had been produced by replace cement with five different percentages of egg shell powder. Their research shown that water cement ratio of 0.4 produces medium workability. Eggshell powder act as filler in concrete can increase concrete compressive strength. Concrete with addition of 10% eggshell powder as filler showed the highest compressive strength of 42.82 N/mm^2. Besides eggshell powder as filler can reduce the rate of absorption of water by the concrete specimens. The water penetration of concrete also reduce up to 82.3% as compared with the control concrete.

Gajera (2015) studied the utilization of egg shell waste in concrete and soil stabilization has shown that 10% is the optimum eggshell powder replacement. Control sample and 10% replacement ratio have the same compressive strength. Segregation, bleeding, micro cracks would happen on concrete if the replacement up to 20%. Praveen *et al.* (2015) concluded 15% was the optimum eggshell-cement replacement in the study on partial replacement of cement with egg shell powder.

The research done by Mohamed *et al*. (2016) is the study of the effect of replacement of cement by ESP in proportion such as 10%, 15% and 20 %. The results shows that the compression test and water absorption test are satisfied, and eggshell powder is suitable to use as cement replacement materials. They proved that the optimum replacement proportion is about 10 % to 15 % and further increase of eggshell powder percentage will decrease the compressive strength.

Tan *et al.* (2017) concluded that amount of replacement of eggshell powder will affect the compressive strength of the eggshell concrete specimens. The results shown that 15% of partial cement replacement by eggshell can get the most optimum results. The compressive strength is the highest for this proportion, 49.23MPa. When the eggshell powder replacement up to 20%, the strength decrease dramatically to 37MPa only. Besides, eggshell concrete also has higher compressive strength as compared to normal plain concrete. Table 2.3 shown the physical properties of egg shell powder (Parkash, 2017).

Table 2.3 Physical Properties of Egg Shell Powder

Name	Physical Properties
Specific Gravity	0.85
Moisture content	1.18
Bulk Density (g/m^3)	0.8
Particle Density (g/m^3)	1.012
Porosity (%)	22.4 BET
Surface area m^2/g	21.2

Source: Parkash (2017)

In Table 2.4 shown the chemical composition of the eggshell powder that obtained through X- ray fluorescence spectrometer (Tan *et al*., 2017) and the chemical composition of eggshell (Jayasankar *et al*., 2010).

Table 2.4 Chemical composition of eggshell powder

Chemical composition	**Tan *et al*. (2017)**	**Jayasankar *et al*. (2010)**
Calcium oxide (CaO)	61.71	50.7
Silicon dioxide (SiO_2)	0.61	0.09
Aluminium oxide (Al_2O_3)	0.07	0.03
Iron oxide (Fe_2O_3)	0.63	0.02
Magnesium oxide (MgO)	0.36	0.01
Potassium oxide (K_2O)	0.22	
Sulphur trioxide (SO_3)	1.32	0.57
Na_2O		0.19
P_2O_5		0.24
SrO		0.13
NiO		0.001
Cl		0.219

2.9 AGGREGATE

Aggregate is one of the main components to produce concrete. It does not involve in the hydration process, so basically it act as an inert filler in concrete to fill up the void in concrete. Aggregate can be categorized into two main types which are coarse aggregate and fine aggregate. The particle size of coarse aggregate is larger than 4.75 mm, and the range is from 4.75 to about 50 mm, while the fine aggregate has particle size smaller then 4.75mm. Well-graded fine aggregate is necessary to produce workable concrete because it can fill up the voids in the concrete and thus minimize the volume of cement used. At the same time, the workability strength and aesthetics of concrete are preserved.

Jimoh and Awe (2013) characterised the effect of gravel sizes on the compressive behaviour of concrete. The study is carried out by varying the aggregate type and size combination with quarry dust and granite in eight different design mixtures. Gravel mean diameter ranging from 20 to 28 mm was used in casting a concrete cube specimen. They reported that as the coarse aggregate size increases, concrete strength decreases and the rate of fall in strength is highest with concrete containing granite and quarry dust.

The effect of maximum particle size of coarse aggregate on the compressive strength and water absorption of normal concrete was investigated by Hassan and Mohammed (2014). Five different sizes of coarse aggregates, that is, 5, 12, 20, 25 and 38 mm were used in this study. The research revealed that water absorption of the coarse aggregates increases with the decrease in aggregate size, consequently, the water demand in the concrete mix. It was also found that of the coarse aggregates, size 20 mm produced concrete with highest compressive strength in all the mixes irrespective of water/cement ratio and curing age.

2.10 WATER TO CEMENT RATIO

Water cement (W/C) ratio is a factor that will affect the strength of concrete. A satisfactory mix design can produce good concrete, and low water cement ratio is one of the criteria to follow. For proper chemical reaction to occur adequate amount of water is needed. However addition of water content will increase concrete workability and reduce concrete strength. The water to cement ratio adopted for normal weight concrete is between 0.4-0.6.

Lower water to cement ratio can contribute to higher strength and high quality of concrete. Concrete with high water to cement ratio is more likely to have cracking and shrinkage problems. Shrinkage will weaken concrete and cause micro-cracks on concrete. During placement of concrete surplus water will be pressed out of the paste by the weight of the aggregate and the cement paste and as a result of bleeding. The loss of large amount of water will create small capillary pores inside the concrete which make the concrete become weak zones and lead to micro-cracks (Girard, 2011). Therefore, concrete should adopted with lower possible water cement ratio to avoid disintegration of concrete.

2.11 SUMMARY

Limestone is crucial for the manufacturing of Portland cement. Due to the limitation of obtaining limestone, there will be a reducing trend for enrolment and construction related to cement industry. Hence, new and sustainable material should be found and adopted to minimize and replace the use of limestone.

Many researchers have done studies on many recyclable waste material to be turn into construction material. This research will focus on replacement of cement by eggshell and fly ash. Eggshell powders which is rich in calcium carbonate which play an important role in hydration process. It can replace certain ratio of cement in the blended Portland cement to reduce the cement content involved in concrete mixing. With the incorporation of these two materials, landfill will be preserved as the waste materials are being used to replace cement and limestone is being conserved as alternative materials are used. Thus, issues of concrete on environmental impact can be resolved.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter the detail on the procedure to carry out the experimental work and laboratory test to achieve the objective of this study will be discussed. First, it will present the details of ingredients and preparation of material used for the mixing specimens. Then, it present on mix design of blended cement by fixed the fly ash percentage in blended cement and manipulate the composition of eggshell in the concrete. Besides, it will also discuss the type of test used in this research. The mechanical test is compressive strength test, while the test for durability properties are such as water absorption, water penetration, sulphuric acid, and sulphate attack test. Figure 3.1 summarizes the flow chart of preparation of material and method of testing.

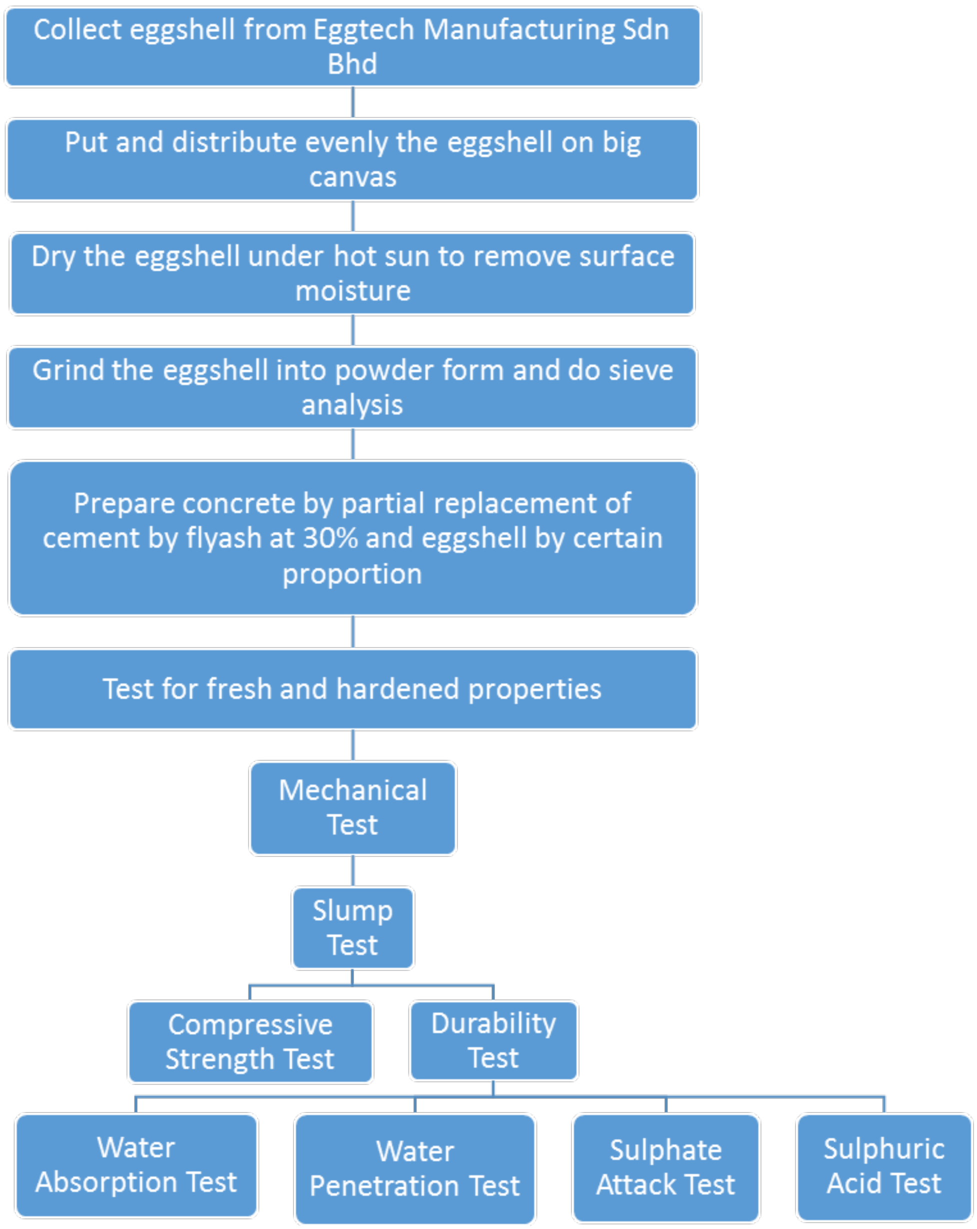

Figure 3.1 Flow chart of preparation of material and test

3.2 MIXING INGREDIENTS

The main ingredients of this blended cement is eggshells powder, fly ash, Ordinary Portland Cement (OPC), sand, 10mm natural aggregate, 20mm natural aggregate and water.

3.2.1 EGGSHELL POWDER

The eggshell used in this research was waste products collected from Egg-tech Manufacturing Sdn Bhd at Puncak Alam Selangor. Eggshell is cleaned by water to remove the egg stick on the eggshell. Eggshell is dried under hot sun until the surface is completely dry as shown in Figure 3.2. Then, it will be grinded into powder form which passing through 150μm and used as partial cement replacement at 5%, 10% and 15%. Figure 3.3 shows the grinding machine used to grind the eggshell into powder from. The eggshell powder was kept in air-tight container to ensure it was in dry condition. Figure 3.4 shows the eggshell powder to be used in this research.

Figure 3.2 The eggshell dry under hot sun

Figure 3.3 Grinding machine used to grind eggshell into powder form

Figure 3.4 The eggshell powder

3.2.2 FLY ASH

Class C fly ash was used in this research and it was bought from Rylan Tech Sdn Bhd. The source of the fly ash is from a power plant located in Port Dickson. Figure 3.5 shows the fly ash used for this research.

Figure 3.5 Fly ash

3.2.3 ORDINARY PORTLAND CEMENT (OPC)

Cement is essential for chemical reaction, hydration process to occur. It will sets and hardens in water after hydration took place. YTL ORANG KUAT branded ordinary portland cement was used in this research. ORANG KUAT is certified to MS EN 197-1:2014, CEM I 42.5N / 52.5N. This type of cement is suitable for structural concreting, brickmaking, precast and all general construction purpose applications. Throughout the whole research period, only Orang Kuat cement was used to ensure reliable results from this research. OPC was kept dry in concrete laboratory before using. Figure 3.6 shows the ORANG KUAT cement used in this research.

Figure 3.6 YTL ORANG KUAT Ordinary Portland Cement

3.2.4 FINE AGGREGATE (SAND)

Fine aggregate used in this research was obtained from Panching, Kuantan as shown in Figure 3.7. The sand will air day at least for 24 hours to remove moisture on the particles. Excess moisture in sand will affect the strength of concrete. Then, the fine aggregate used was undergo sieve analysis. Generally, the size of fine aggregates particles are from 75 µm to 4.75 mm. The aggregate will pass through No.4 (4.76mm) and retained on No.200 which comply with ASTM125. Then the aggregate were kept in dry condition and free from mixing with other impurities to ensure accuracy and consistency results. Figure 3.8 shows the mechanical shaker used for sieve analysis.

Figure 3.7 Sand

Figure 3.8 Mechanical shaker used for sieve analysis

3.2.5 COARSE AGGREGATE

Coarse aggregate used in this research is crushed aggregate obtained from Panching, Kuantan as shown in Figure 3.9. Coarse aggregates mainly responsible for providing concrete strength comes from different sizes and shapes. The types of aggregates used is crushed granite which has the highest compressive strength as compared to basalt and limestone. The grading of coarse aggregates used in this research range from 5mm up to 20mm.

Figure 3.9 Coarse aggregate

3.2.6 WATER

In this research, ordinary potable water or tap water was used in both concrete mix and curing process. The tap water is supply by Pengurusan Air Pahang Berhad (PAIP). Water is necessary ingredients for hydration process to occur. When water is react with cement, chemical reaction, hydration will take place and produce C-S-H gel which leads to increment in concrete strength. Water used is free from any impurities or harmful materials to ensure the hydration process and durability of concrete is not affected.

3.3 MOULD

Two different types of mould size were used in this research. Cubes with dimension of 100 mm x 100 mm x 100 mm were used to cast concrete for water penetration test and water absorption test. Cubes with dimension of 150 mm x 150 mm x 150 mm were used to cast concrete for compressive strength test, sulphate attack test and sulphuric acid test. The mould was coated with a thin layer of oil before fresh concrete was poured into the mould so that demoulding process will be easier. The mould will be filled in with 3 layers. Compaction is done by vibrating on vibrating table for each layer. Figure 3.10 shows the mould used for this research.

Figure 3.10 Plastic cube mould of size 100mm and 150mm

3.4 MIX DESIGN FOR OPTIMUM BLENDED CEMENT WITH FLY ASH AND EGGSHELL POWDER

Trial mix method was adopted in this research. Two set of cube specimens were prepared. First set was control specimen which was purely made out of cement. Another set consist of fly ash and eggshell powder as partial replacement of cement. The total percentage of fly ash replacement was fixed at 30%. While the percentage of replacement of cement by eggshell is 5%, 10%, and 15%. The amount of coarse and fine aggregate and water were fixed for each mix. The concrete mix were then poured into cube moulds (100mm x 100mm x 100mm) and (150mm x 150mm x 150mm) for different tests purpose. Table 3.1 shown the proportion of design concrete.

Table 3.1 Proportion of Design Concrete

Mix Design	Cement, kg/m^3	Water, kg/m^3	ESP, kg/m^3	F, kg/m^3	CA, kg/m^3	FA, kg/m^3	w/cm
0% FA 0% ESP	468	186	0	0	1220	500	0.4
30% FA 5% ESP	304	186	140	24	1220	500	0.4
30% FA 10% ESP	281	186	140	47	1220	500	0.4
30% FA 15% ESP	258	186	140	70	1220	500	0.4

ESP - Eggshell powder
F - Fly ash
CA - Coarse aggregate
FA - Fine aggregate
cm - Cementitious materials

3.5 CURING PROCESS

Curing plays an important role in concrete strength gaining and improve durability of concrete. All the cube casted will undergo curing process after they were demoulded. Water curing method will be chosen for this research. This is to assure continued hydration of the cement in the presence of sufficient water and temperature and increase the rate of strength gain at surface. Curing concrete with water allows controlling the evaporation of moisture from the surface and the reaction of concrete with water will eventually harden the concrete. The concrete specimen will be immersed in water for 28 days before soak in other solutions and being tested. The water temperature was kept within 25ºC-30ºC. Figure 3.11 shows the specimens undergo water curing process.

Figure 3.11 Water curing

3.6 ENGINEERING PROPERTIES MEASUREMENT

3.6.1 MECHANICAL TEST

3.6.1.1 COMPRESSIVE STRENGTH TEST

Concrete compression test is to determine the compressive strength of hardened concrete specimen. The specimens were tested until the maximum load has been achieved. Once failure occurred on the specimens, it indicates satisfactory on the specimens. For each proportion of replacement of cement by eggshell powder, three concrete cube specimens will be casted and tested. This is to obtain more reliable results. The test will be conducted after 7, 14 and 28 days of curing. Cubic specimens with dimension of 150 mm x 150 mm x 150 mm were used in compression test. The compressive strength test is compliance with BS1881: Part 116:1983. Figure 3.12 shows the compressive strength test machine used to test for cube strength.

Figure 3.12 Compressive Strength Test Machine

3.6.2 DURABILITY TEST

3.6.2.1 WATER ABSORPTION TEST

Water absorption test is to determine the rate of moisture absorption by concrete. It is done by measuring the increase in mass of specimen after the specimen exposed to water. The concrete cubes of size 100 mm were prepared and used for this research. The cubes were dried in the oven for three days at 50°C. The initial weight of concrete cubes (W1) were recorded before the cubes were immersed in the water. The cubes were weighed repeatedly after 24, 48 and 72 hours. The cubes were dried by wiping off the water on the surface with dry cloth. The test was conducted according to modified BS 1881: Part 122. Figure 3.13 shows the cubes immersed in water for water absorption test.

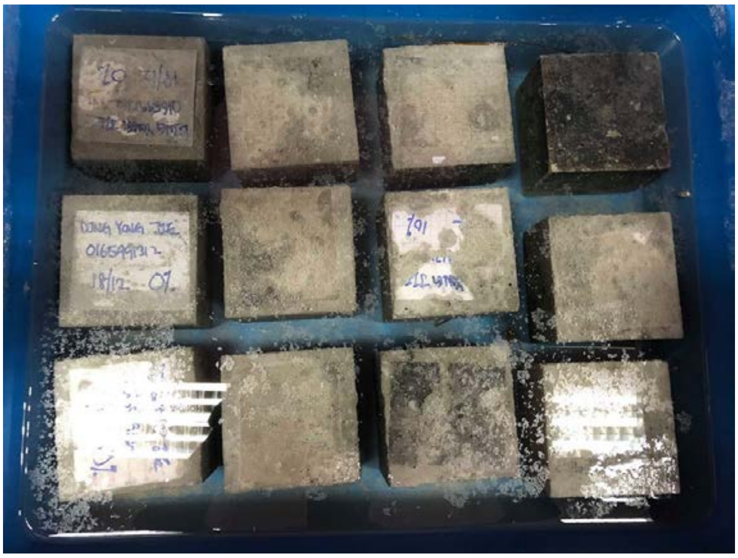

Figure 3.13 Cubes immersed in water for water absorption test

3.6.2.2 WATER PENETRATION TEST

Water Penetration test is to determine the rate movement of water through the porous material under capillary action. The concrete cubes of size 100 mm were prepared and used for this research. The cubes were dried in the oven for three days at 50°C. Vinyl electrician's tape was used to seal the sides to ensure one directional flow of water. The bottom surface of the cubes ware immersed in distilled water for 24 hours. Only 2-4 mm of the height of the cubes were immersed. The rate of water penetration was determined by observing and measuring the colored water mark on the cut cubes. The test was conducted according to BS EN-12390-8. Figure 3.14 shows the process of cutting cube for water penetration test.

Figure 3.14 Water penetration test

3.6.2.3 SULPHURIC ACID ATTACK TEST

The concrete cube specimens with size 150mm are prepared and tested according to modified ASTM C 267-01 test method. After 28 days of water curing for the specimens, the cubes were immersed in 3% sulphuric acid solution. The 3% sulphuric acid solution was prepared by diluting 98% concentrated sulphuric acid with water. After 90 days from the date of immersion of the cubes, the cubes were dried in normal room temperature. Then, the cube specimens were undergo compressive strength test.

3.6.2.4 SULPHATE ATTACK TEST

Compressive strength test was conducted to examine the resistance of concrete towards sulphate attack based on BS 1881: Part 116. 150mm size of cubes were prepared and then cured in water for 28 days before immersed in sulphate solution. The sulphate solution was prepared by having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$) by weight of water. The compressive strength of the cubes were determined and tested after 90 days of immersion in sulphate solution. After the cubes were removed from sulphate solution, the water on the cube was wiped off before tested for compressive strength.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results and discussions of all the experiments conducted according to standard as mention in methodology. The results obtained from compressive strength test, and durability test of the concrete samples are presented in the form of table and graph. Compressive strength represent the mechanical properties of the concrete cube samples. Durability tests conducted are such as water absorption test, water penetration test, acid attack test and sulphate attack test. For water absorption and water penetration test, these test are straight conducted after 28days curing. For acid attack and sulphate attack test, after 28 days of water curing, the concrete samples will further immerse in repective solution for 90 days before testing being carried out.

In this study, concrete samples of 4 different mix types are used. The name of concrete samples of different percentage of partial replacement of cement by fly ash and eggshell powder is tabulated in table 4.1.

Table 4.1 Concrete label for different composition of concrete cube

Concrete cube (%)	Composition
0 FA 0 ESP	0% of fly ash and 0% eggshell powder
30 FA 5 ESP	30% of fly ash and 5% eggshell powder
30 FA 10 ESP	30% of fly ash and 10% eggshell powder
30 FA 15 ESP	30% of fly ash and 15% eggshell powder

4.2 COMPRESSIVE STRENGTH TEST

Compressive strength test is one of the important properties in concrete where it determines physical and characteristic strength of the concrete according to the British Standard (BS 1881: Part 116). The cube specimens were subjected to water curing and tested by compressive strength machine for its compressive strength on 7, 14 and 28 days where 3 cube sizes (150mm x 150mm x 150mm) were used for each concrete proportion. The results obtained is the average reading between 3 concrete specimens for each curing day. The results obtained from the compressive strength test is recorded and tabulated in table 4.2 and graph for compressive strength against age of curing is plotted in Figure 4.1.

Table 4.2 Compressive strength, MPa at different curing age result

Concrete Cube	Average strength (MPa)		
	7 days	14 days	28 days
0% FA 0% ESP	40.97	53.34	61.35
30% FA 5% ESP	34.88	42.36	48.58
30% FA 10% ESP	32.97	37.22	45.02
30% FA 15% ESP	28.30	31.69	36.52

Table 4.2 shows the compressive strength of cube specimens at different curing age. All the concrete cubes show increase trend in compressive strength from 7th to 28th day. The concrete cube is design to have a concrete strength of grade 30. Although there is a decreasing trend in compressive strength when the eggshell powder composition increased, all the samples are still able to achieve the design strength at the age of 28 days.

From the table 4.2, at the curing age of 7 day, concrete cube 0FA 0ESP recorded the highest strength with a reading of 40.97 MPa as compare to 30FA 5ESP, 30FA 10ESP, and 30FA 15ESP which recorded compressive strength of 34.88 MPa, 32.97 MPa, and 28.30 MPa respectively. At the curing age of 14 days, concrete cube 0FA 0ESP still recorded the highest concrete strength of 53.34 MPa. The total of 35% replacement of cement, 30FA 5ESP has a reduction of 20.58% of strength as compared to 0FA 0ESP. 30FA 10ESP and 30FA 15ESP has also show the same trend in the reduction of strength. 30FA 10ESP and 30FA 15ESP can only achieve concrete strength of 37.22 MPa and 31.69 Mpa respectively.

On 28th day, other than the 30FA 15ESP concrete cube, all other concrete cube mix are able to achieve compressive strength more than 45MPa. The compressive strength of 0FA 0ESP, 30FA 5ESP, and 30FA 15ESP are 61.35 MPa, 48.58 MPa, and 45.02 MPa respectively. The concrete cube of 30FA 15ESP had recorded the lowest comprssive strength of 36.52 MPa only at age of 28 days.

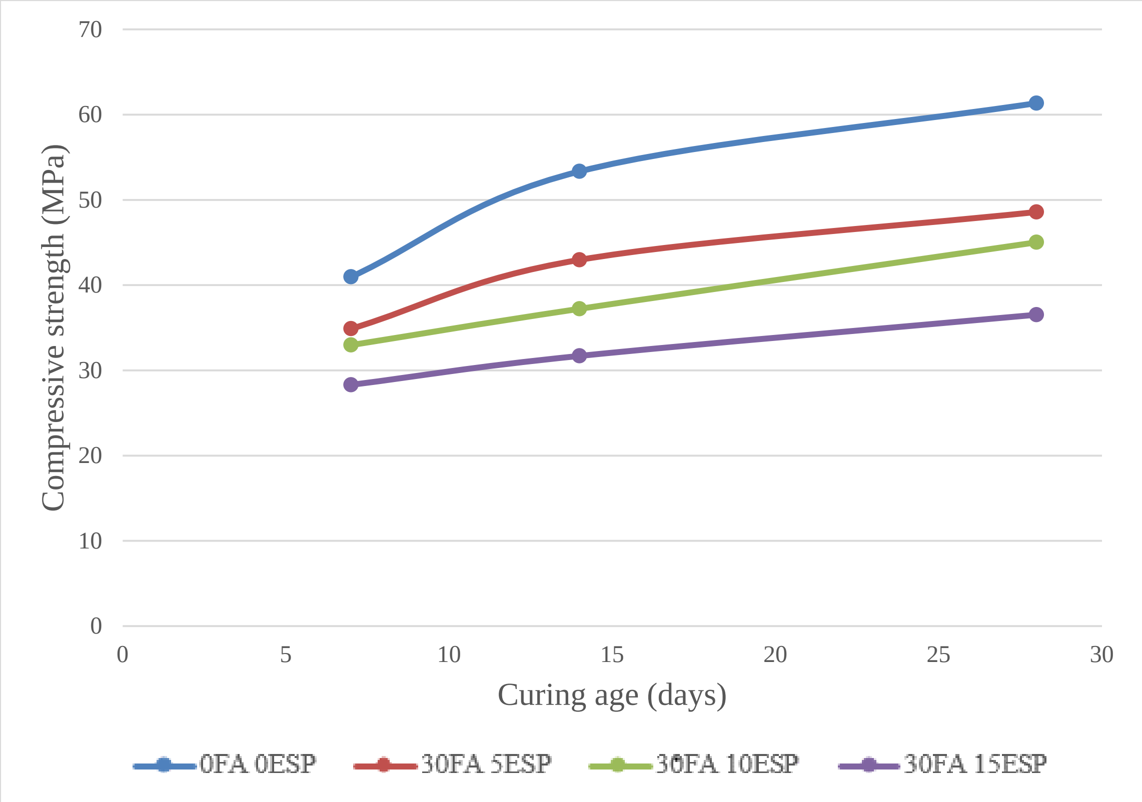

Figure 4.1 Compressive strength against curing age

According to Figure 4.1, 0FA 0ESP (the normal concrete) shows the highest compressive strength for day 7, day 14 and day 28. In this line graph, it clearly shows that the optimum cement replacement is 35%, which made up of 30% of fly ash and 5% of eggshell powder. When further increased of the percentage of cement replacement, the compressive strength reduced.

According to the research by Upadhyaya (2014), he also had almost similar trend for the cube compressive strength. Normal concrete had recorded a compressive strength of 67MPa and the strength become 46MPa when the cement is replaced by fly ash up to 30% at 28 days. Yerramala (2014) got similar result and concluded that addition of ESP to cement concrete shows the reduction in compressive strength compared to control concrete. Jayasankar *et al*. (2010) conducted experiments on ESP by altering it from 0% to 20% in steps of 5% and concluded that the maximum compressive strength was at 5% replacement to cement.

4.3 DURABILITY TEST

4.3.1 WATER ABSORPTION TEST

Water absorption test was used to test the ability of concrete specimens to absorb water at specific time. The test was only conducted on concrete after 28 days of water curing. The result of rate of water absorption of concrete with different percentage of cement replacement was tabulated in table 4.3.

Table 4.3 Summary result of water absorption

Concrete Cube	Percentage of Water absorption (%)		
	24 hours	48 hours	72 hours
0% FA 0% ESP	1.60	1.88	1.90
30% FA 5% ESP	1.60	1.87	1.88
30% FA 10% ESP	1.54	1.82	1.83
30% FA 15% ESP	1.76	2.05	2.06

The rate of water absorption is examined after 24 hours, 48 hours and 72 hours immersed in water. From the data collected, the rate of water absorption of concrete specimens is decreased after replacing by fly ash and eggshell powder from 0% to 40% and increased back again for 45% of cement replacement. Concrete cube 30FA 10ESP recorded the lowest percentage of water absorption for 1.54% in 24 hours, 1.82% in 48 hours and 1.83% in 72 hours. 45% of cement replacement will cause the rate of water absorption increased and the rate of water absorption will also be higher than that of normal concrete. After 72 hours of immersion, the percentage of water absorption of concrete cube 0FA 0ESP is 1.90% while 30FA 15ESP concrete cube is 2.06%.

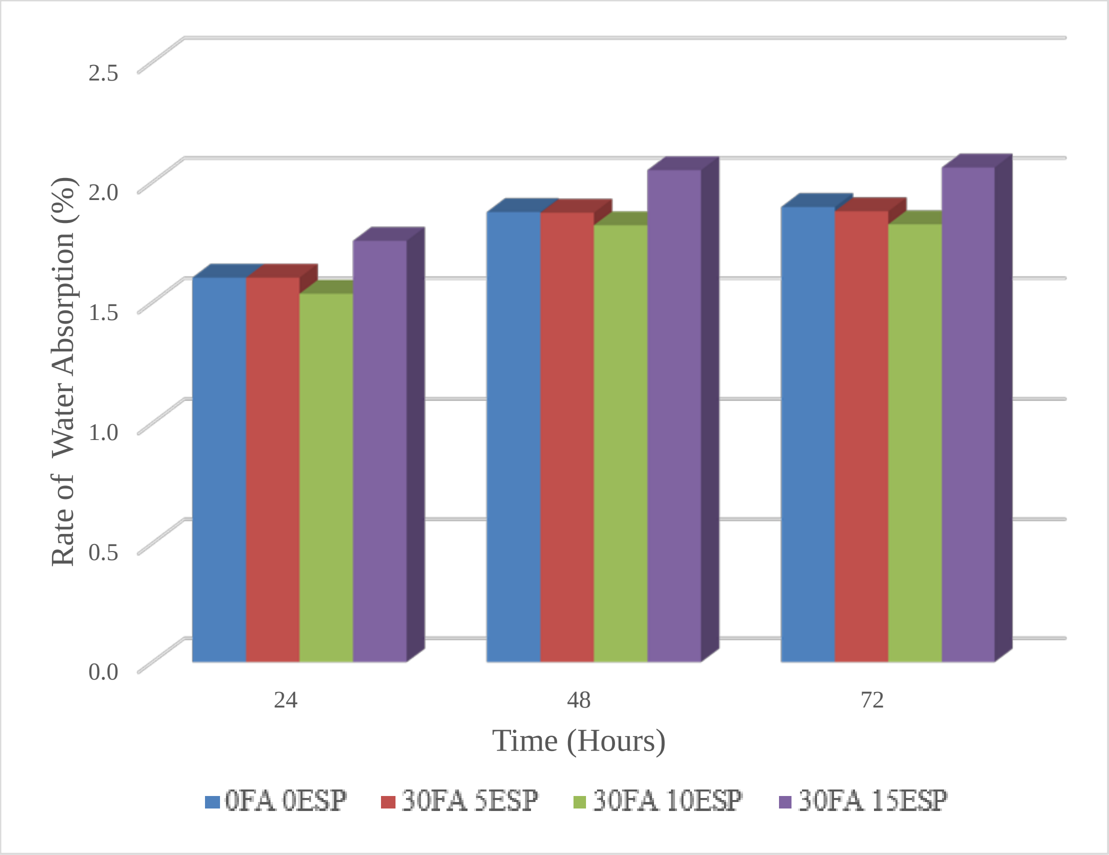

Figure 4.2 Percentage of water absorption (%) against type of concrete cube

30FA 5ESP and 30FA 10ESP mixture will have a higher durability than control as the mixture's rate of water absorption is lower than the control. 30FA 15ESP possess the lowest durability because the rate of water absorption is the highest among the mixture.

Sahoo *et al*. (2015) concluded that blending fly ash into concrete will reduce concrete permeability and brings the diffusion rate down.

4.3.2 WATER PENETRATION

Water penetration test is conducted according to BS EN-11390. It is used to determine the permeability and durability of concrete. The test is conducted on concrete specimens with 28 days of water curing by examining the depth penetrated. The depth is indicated as the water penetration. Table 4.4 shows the average depth of water penetration of different mix of concrete.

Table 4.4 Summary result of water penetration

Concrete Cube	Average depth of water penetration (mm)
0% FA 0% ESP	8.0
30% FA 5% ESP	7.0
30% FA 10% ESP	6.5
30% FA 15% ESP	8.0

From table 4.4, it is observed that the 0FA 0ESP and 30FA 15ESP concrete cubes have the same depth of water penetration, which is 8mm. It is recorded as the highest average depth of water penetration. Figure 4.3 shows a reducing trend of water penetration with the increase of fly ash and eggshell powder in the concrete from 0% till total 40% of cement replacement. The depth of penetration drop from 8mm to 6.5mm. However, when further increase replacement of cement by eggshell, the depth of penetration has increased to 8mm again.

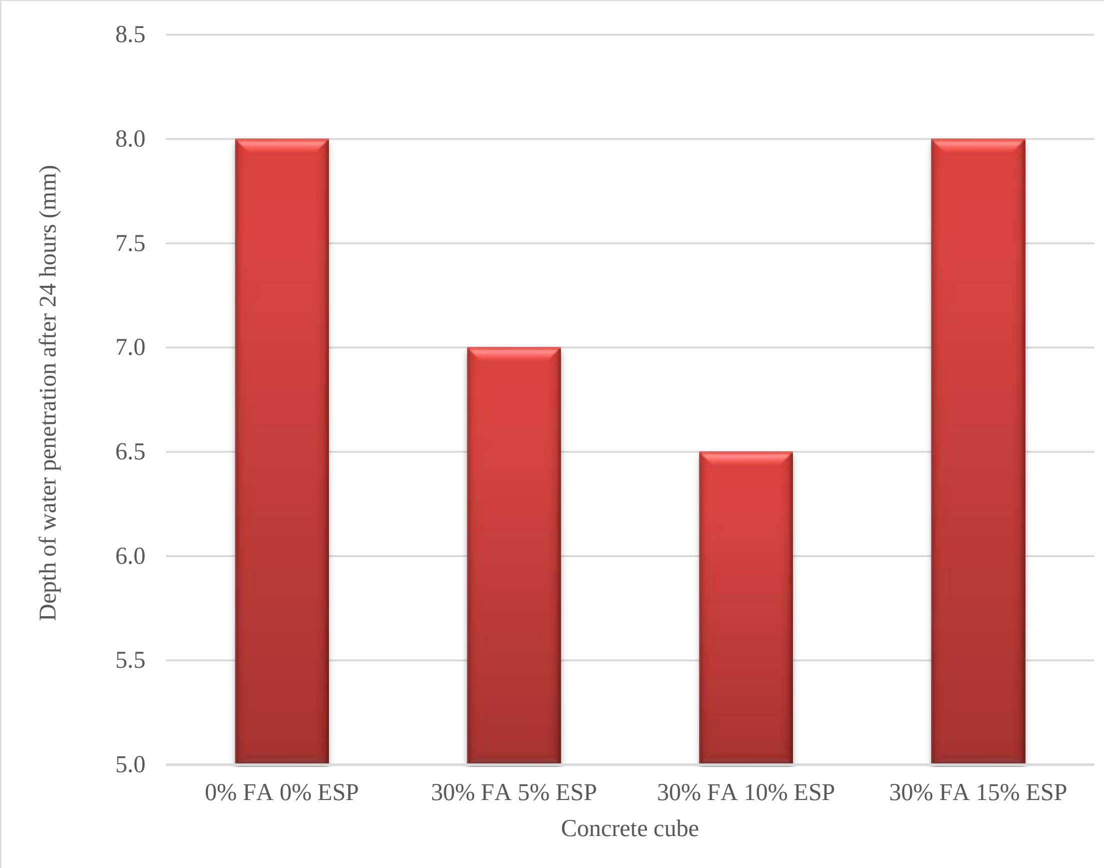

Figure 4.3 Depth of water penetration after 24 hours immersion (mm)

According to Islam *et al.* (2013), they concluded that the incorporation of fly ash in concrete will decrease the water permeability of concrete. The optimum amount of cement replacement by fly ash is 30%. The decrease in permeability is due to the reduction in pore sizes and thus loss of pore connectivity.

4.3.3 ACID ATTACK TEST

The concrete resistance towards acid attack was determined by the loss of compressive strength. It is done by comparing the strength of concrete which are not soaked in sulphuric acid solution and those concrete cubes which immersed in sulphate solution. The sulphuric acid is prepared by having 3% of sulphuric acid by weight of water. The concrete cubes of sizing 150mm were immersed in sulphate solution for 90 days after 28 days of water curing. The solution was added from time to time to ensure all the cubes were fully immersed in the solution. After 90 days of immersion, the concrete cubes were removed from the sulphate solution. Then wipe the girt and water from cube surface before it undergo compressive strength test. The weights of concrete cube specimen were taken. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water.

Table 4.5 Summarise the % of loss of weight and concrete strength due to acid attack

Concrete Cube	Initial weight of cubes after 28 days curing (grams)	Final weight of cubes after 90 days curing (grams)	Loss of weight due to acid attack (%)	Compressive strength of cube after 28 days curing (MPa)	Compressive strength of cube after 90 days curing (MPa)	Loss of compressive strength due to acid attack (%)
0% FA 0% ESP	7987.333	7921.200	0.83	61.35	42.91	30.06
30% FA 5% ESP	7859.667	7816.467	0.55	48.58	44.32	8.76
30% FA 10% ESP	7673.233	7630.933	0.55	45.02	40.91	9.13
30% FA 15% ESP	7652.533	7609.400	0.56	36.52	32.07	12.20

Figure 4.4 shows the percentage loss in compressive strength of concrete cubes due to sulphuric acid attack for different concrete mix. For acid attack test, 0FA 0ESP recorded the highest percentage loss of compressive strength which is 30.06%. While 30FA 5ESP shows the lowest percentage loss of compressive strength which is only 8.76%. There is a difference of 21.3% between the highest and lowest percentage loss of compressive strength. However, the percentage loss of compressive strength increased when further increase the percentage of eggshell powder. 30FA 10ESP and 30FA 15ESP mix recorded 9.13% and 12.2% loss of compressive strength due to acid attack respectively.

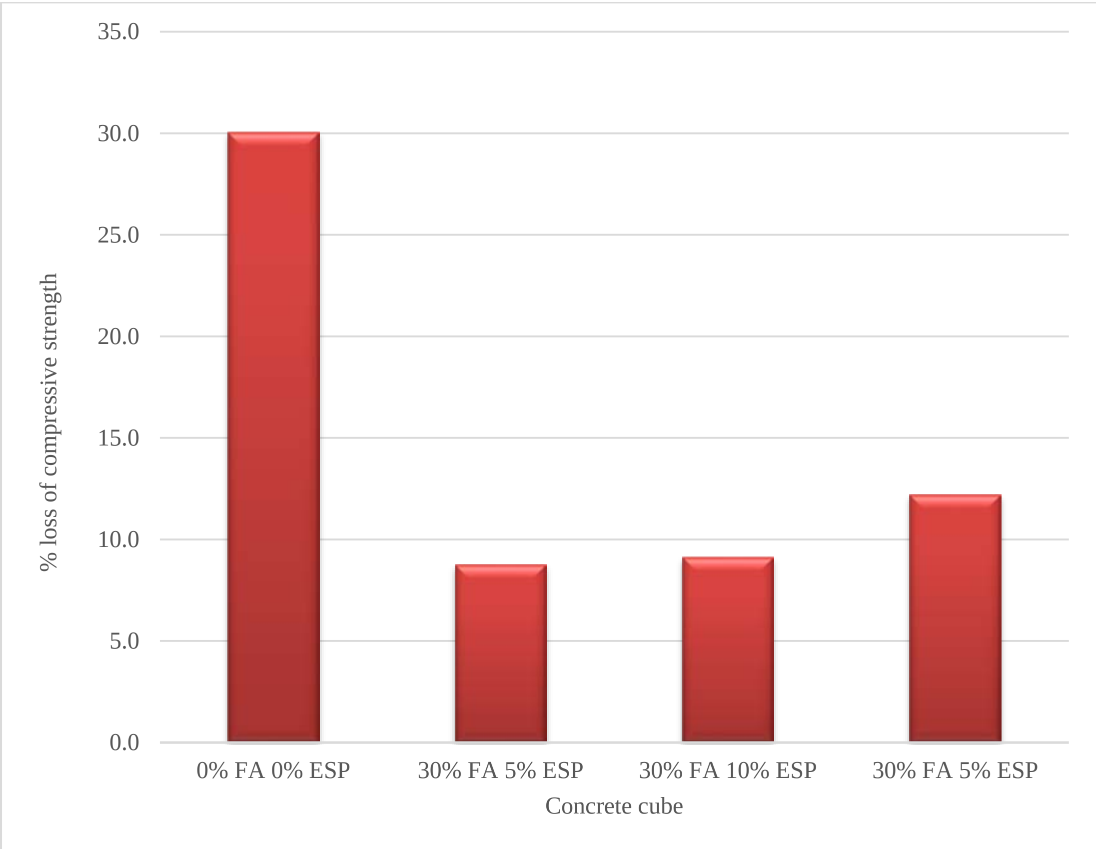

Figure 4.4 Percentage loss of compressive strength due to acid attack

Figure 4.5 shows the percentage loss of weight of concrete cubes due to acid attack for different concrete mix. For acid attack test, 0FA 0ESP has the highest percentage loss of weight, which is 0.83%. 30FA 5ESP and 30FA 10ESP mix have the same percentage loss of weight of 0.55%. The percentage loss of weight of 30FA 15ESP mix is 0.56%, which is almost similar to a total of 35% and 40% cement replacement.

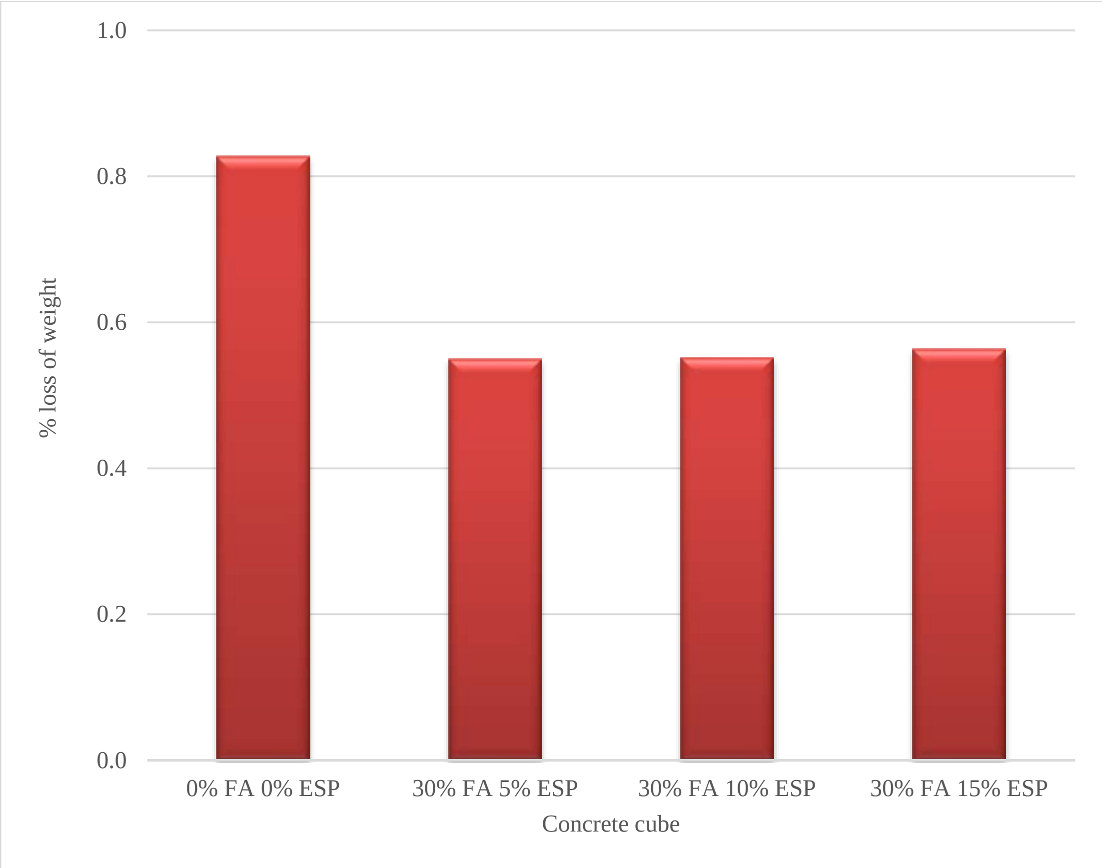

Figure 4.5 Percentage loss of weight due to acid attack

The acid diffuses into concrete structure destroys the cement gel binder and forming soft and soluble gypsum (calcium sulphate hydrate), which reacts with C_4A to form ettringite. The formation of secondary ettringite results in a substantial expansion of specimens and leads to increase the degree of acid attack. Sahoo et al. concluded that the strength loss of concrete with partial replacement of cement by fly ash in acid solution was the highest compared to salt and sulphate solution (Sahoo *et al.*, 2015).

Figure 4.6 Cube specimens for 0FA 0ESP (left side) and 30FA 5ESP (right side) after immersed in acid solution for 90 days

An obvious surface deterioration were found in a visual inspection of the normal concrete cube specimens after immersion of the specimens in the acid solution. Figure 4.6 shows the dissolution of cement from the cube specimens for 0FA 0ESP (left side) and no sign of surface deterioration was found for 30FA 5ESP specimens (right side) after immersed in acid solution for 90 days.

4.3.4 SULPHATE ATTACK TEST

The concrete resistance towards sulpahte attack was determined by the loss of compressive strength. It is done by comparing the strength of concrete which are not soaked in sulphate solution and those concrete cubes which immersed in sulphate solution. The sulphate solution is prepared by having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$) by weight of water. The concrete cubes of sizing 150mm were immersed in sulphate solution for 90 days after 28 days of water curing. The solution was added from time to time to ensure all the cubes were fully immersed in the solution. After 90 days of immersion, the concrete cubes were removed from the sulphate solution. Then wipe the girt and water from cube surface before it undergo compressive strength test. This is type of accelerated test of finding out the loss of compressive strength for accessing sulphate resistance of concrete (Reddy *et al.*, 2013). Table 4.6 summarise the % of loss compressive strength due to sulphate attack.

Table 4.6 Summarise the % of loss compressive strength due to sulphate attack

Concrete Cube	Compressive strength of cube after 28 days curing (MPa)	Compressive strength of cube after 90 days curing (MPa)	Loss of compressive strength due to sulphate attack (%)
0% FA 0% ESP	61.35	56.37	8.12
30% FA 5% ESP	48.58	45.13	7.10
30% FA 10% ESP	45.02	40.14	10.84
30% FA 15% ESP	36.52	30.41	16.73

Figure 4.7 shows the percentage loss in strength of concrete cubes due to sulphate attack for different concrete mix. For sulphate attack test, 35% of cement replacement by fly ash and eggshell powder has the lowest strength loss percentage which is 7.10% compared with normal concrete which has slightly higher percentage of strength loss of 8.12%. When further increase of the percentage of fly ash and eggshell powder in the concrete mix, the strength loss percentage also incraesed. For 40% of cement replacement, the strength loss percentage of the concrete is 10.84%. The strength loss increased 5.89% to 16.73% if further replace 5% of the cement with eggshell powder.

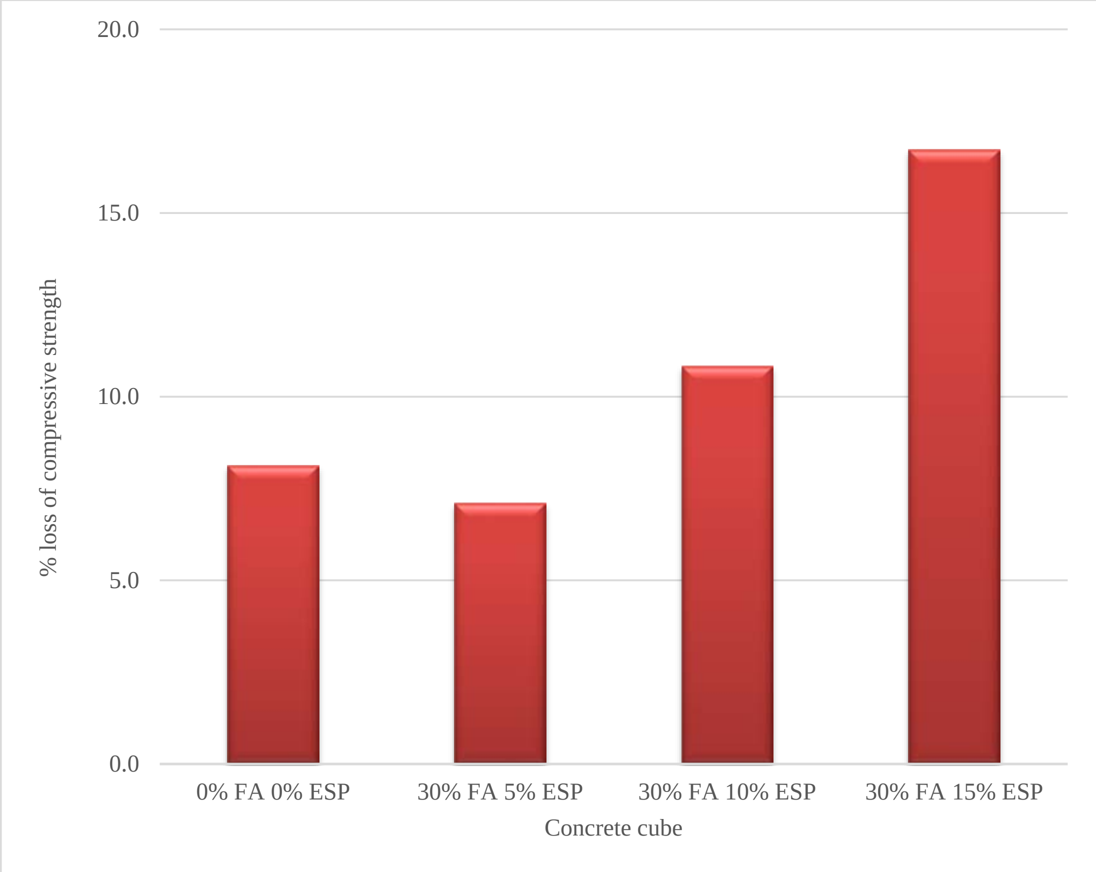

Figure 4.7 Percentage loss of compressive strength due to sulphate attack

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the conclusion of this research based on the objectives which has been set at the beginning stage of the research. The objectives of this research is to study the mechanical properties of concrete in term of compressive strength and durability properties in term of water absorption, water penetration, acid attack and sulphate attack test where the cement is partially replaced by fly ash and eggshell powder. The percentage of fly ash replacement is fixed at 30%, while the percentage of egg shell powder replacement is different, which are 5%, 10% and 15%.

5.2 CONCLUSION

Based on the results that are obtained, the objectives were achieved and several conclusion can be made:

i. The combination use of fly ash and eggshell powder for cement replacement will cause the deterioration of concrete strength. The normal concrete has the highest compressive strength among all the mix. All mix are able to achieve the concrete grade 30. 30FA 5ESP and 30FA 10ESP are able to achieve more than 45MPa concrete strength at the age of 28 day. 30FA 15ESP recorded the lowest compressive strength of 36.52MPa. However, all the mix are still suitable for structural use.

ii. Rate of water absorption of 30FA 10ESP is the least among others. The percentage of water absorption is only 1.83% which is slightly lower than the normal concrete. However when further increased the percentage of cement replacement, the percentage of water absortion will increased. 30FA 15ESP recorded the highest water absorption percentage of 2.06% which is 0.16% more than normal concrete.

iii. The average depth of water penetration of 30FA 10ESP is the least among others, which is 6.5mm only. When increase the percentage replacement of fly ash and eggshell powder in cement, the depth of water penetration decrease. However, the depth of water penetration increased back to 8mm again when a total of 45% cement is replaced by fly ash and eggshell powder.

iv. For sulphuric acid attack test, 35% of cement replacement by fly ash and eggshell powder has the lowest strength loss percentage which is 8.76% compared with normal concrete which has a dramatically higher percentage of strength loss of 30.06%. For 40% of cement replacement, the strength loss percentage of the concrete is 9.13%. The strength loss increased 3.07% to 12.20% if further replace 5% of the cement with eggshell powder. 0FA ESP has the highest percentage loss of weight, 0.83%. While other concrete mix has almost similar percentage loss of weight in the range of 0.55 and 0.56.

v. For sulphate attack test, 35% of cement replacement by fly ash and eggshell powder has the lowest strength loss percentage which is 7.10% compared with normal concrete which has slightly higher percentage of strength loss of 8.12%. For 40% of cement replacement, the strength loss percentage of the concrete is 10.839%. The strength loss increased 5.891% to 16.73% if further replace 5% of the cement with eggshell powder.

vi. The optimum percentage of cement replacement is 35% based on the overall concrete test performance.

5.3 RECOMMENDATIONS FOR FUTURE RESEARCH

In this research, the main focus is on the compressive strength, water absorption, water penetration, acid attack and sulphate attack test for the concrete where the cement is partially replaced by fly ash and eggshell powder. Through this research, several recommendations could be made to improve for this future research:

i. The study the effect of eggshell powder size to the strength of concrete.

ii. The thermal conductivity and fire resistance of blended concrete containing eggshell powder.

iii. The impact of superplasticiser toward the strength of concrete and provide good workability.

REFERENCES

Akmal, A. Z. M. N. Muthusamy, K. Yahaya, F. M. Hanafi, H. M. Azzimah, Z. N. (2017). Utilization of Fly Ash as Partial Sand Replacement in Oil Palm Shell Lightweight Aggregate Concrete. *IOP Conference Series: Materials Science and Engineering*, 271(1). doi: 10.1088/1757-899X/271/1/012003.

Al-Otaibi, S. (2008). Durability of Concrete Incorporating GGBS Activated by Water-glass. *Construction and Building Materials*, 22(10). pp. 2059–2067. doi: 10.1016/j.conbuildmat.2007.07.023.

Ali, N., Sobri, Josef, Samad, A.A.A., Mohamad. (2017). Potential Mixture of POFA and SCBA as Cement Replacement in Concrete – A Review. *MATEC Web of Conferences*, 1006. pp. 1–7. doi: 10.1051/matecconf/201710301006.

Amriou, A. and Bencheikh, M. (2017). New Experimental Method for Evaluating the Water Permeability of Concrete by A Lateral Flow Procedure on A Hollow Cylindrical Test Piece. *Construction and Building Materials*. Elsevier Ltd, 151. pp. 642–649. doi: 10.1016/j.conbuildmat.2017.06.126.

Amu O. O. and Salami B. A. (2010). Effect of Common Salt on Some Engineering Properties. *Electronic Journal of Geotechnical Engineering*, 3(5). pp. 49–56. doi: 10.5251/ajsir.2011.2.2.323.331.

Apostolopoulos, C. (2016). Special Issue on Durability of RC structures. *International Journal of Structural Integrity*, 7(2). p. IJSI-02-2016-0006. doi: 10.1108/IJSI-02-2016-0006.

Balakrishnan, B. and Awal, A. S. M. A. (2014). Durability Properties of Concrete Containing High Volume Malaysian Fly Ash. *International Journal of Research in Engineering and Technology*, 3(4). pp. 529–533.

Budiea, A, Hussin M.W., Muthusamy K and Ismail M.E. (2010). Performance of High Strength POFA Concrete in Acidic Environment. *Concrete research letters*, 1(1). pp. 14–18.

Chatveera, B. and Lertwattanaruk, P. (2011). Durability of Conventional Concretes Containing Black Rice Husk Ash. *Journal of Environmental Management*. Elsevier Ltd, 92(1). pp. 59–66. doi: 10.1016/j.jenvman.2010.08.007.

Chindaprasirt, P., Homwuttiwong, S. and Sirivivatnanon, V. (2004). Influence of Fly Ash Fineness on Strength, Drying Shrinkage and Sulfate Resistance of Blended Cement Mortar. *Cement and Concrete Research*, 34 (7). pp. 1087–1092. doi:

10.1016/j.cemconres.2003.11.021.

Chindaprasirt, P., Jaturapitakkul, C. and Sinsiri, T. (2007). Effect of Fly Ash Fineness on Microstructure of Blended Cement Paste. *Construction and Building Materials*, 21(7). pp. 1534–1541. doi: 10.1016/j.conbuildmat.2005.12.024.

Chong, C. (2015). *Teo Seng : Malaysia ' s Egg Consumption to Grow at 3 % to 5 %*. Available at: http://www.theedgemarkets.com/article/teo-seng-malaysia's-egg-consumption-grow-3-5.

Cordeiro, G. C., Toledo Filho, R. D. and De Moraes Rego Fairbairn, E. (2009). Use of Ultrafine Rice Husk Ash with High-Carbon Content as Pozzolan in High Performance Concrete. *Materials and Structures/Materiaux et Constructions*, 42(7). pp. 983–992. doi: 10.1617/s11527-008-9437-z.

Dabai M.U, Muhammad C., Bagudo B.U. and Musa A. (2009). Studies on the Effect of Rice Husk Ash as Cement Admixture. *Nigerian Journal of Basic and Applied Science*, 17(2). pp. 252–256. doi: 10.4314/njbas.v17i2.49917.

Deepika, T., Gobinath, N. and Tigerprabakaran, M. (2017). Durability Study on Concrete with Egg Shell Powder Introduction : Materials : Egg Shell Powder. *International Journal of Advanced Science and Engineering Research* 2 (2). pp. 94–98.

Dhanalakshmi, M., J., D. S. N. and A., D. C. (2015). A Comparative Study on Egg Shell Concrete with Partial Replacement of Cement by Fly Ash. *International Journal of Engineering Research & Technology (IJERT)*, 4(May). pp. 1532–1538.

Dinakar, P., Babu, K. G. and Santhanam, M. (2008). Durability Properties of High Volume Fly Ash Self Compacting Concretes. *Cement and Concrete Composites*. Elsevier Ltd, 30(10). pp. 880–886. doi: 10.1016/j.cemconcomp.2008.06.011.

Doh, S. I. and Chin, S. C. (2014). Eggshell Powder : Potential Filler in Concrete. *Malaysian Technical Universities Conference on Engineering & Technology*, (November), pp. 10–11.

Duan, P. Shui, Z. Chen, W. Shen, C. (2013). Enhancing Microstructure and Durability of Concrete from Ground Granulated Blast Furnace Slag and Metakaolin as Cement Replacement Materials. *Journal of Materials Research and Technology*. Korea Institute of Oriental Medicine, 2(1). pp. 52–59. doi: 10.1016/j.jmrt.2013.03.010.

Folic, R. (2009). Durability Design of Concrete Structures, Part 1: Analysis Fundamentals. *Facta universitatis - series: Architecture and Civil Engineering*, 7(1). pp. 1–18. doi: 10.2298/FUACE0901001F.

Gajera D. S. K. (2015). A review of Utilization of Eggshell Waste in Concrete and Soil Stabilization. *Medical Science* 67–69.

Girard, J. (2011). The Importance of Water / Cement Ratio in Concrete Countertop Mix Design. p. 2018. Available at: http://www.concretecountertopinstitute.com/blog/2011/07/the-importance-of-watercement-ratio-in-concrete-countertop-mix-design/.

Gowsika, D., Sarankokila, S. and Sargunan, K. (2014). Experimental Investigation of Eggshell Powder as Partial Replacement with Cement in Concrete. *International Journal of Engineering Trends and Technology*, 14 (2)(August). pp. 65–68.

Guades, E. J. (2017). Effect of Coarse Aggregate Size on the Compressive Behaviour of Geopolymer Concrete. *European Journal of Environmental and Civil Engineering*. Taylor & Francis, 8189. pp. 1–17. doi: 10.1080/19648189.2017.1304276.

Habeeb, G. A. and Mahmud, H. Bin. (2010). Study on Properties of Rice Husk Ash and its Use as Cement Replacement Material. *Materials Research*, 13(2). pp. 185–190. doi: 10.1590/S1516-14392010000200011.

Hassan, N., & Mohammed, A. B. (2014). Effect and Composition of Maximum Particle Size of Coarse Aggregates on the Compressive Strength of Normal Concrete. *Journal of Engineering and Applied Scientific Research*(6). pp. 46–56.

Hemalatha, T. Mapa, M. George, N. Sasmal, S. (2016). Physico-chemical and Mechanical Characterization of High Volume Fly Ash Incorporated and Engineered Cement System Towards Developing Greener Cement. *Journal of Cleaner Production*. Elsevier Ltd, 125, pp. 268–281. doi: 10.1016/j.jclepro.2016.03.118.

Islam, M. and Islam, M. (2013). Strength and Durability Characteristics of Concrete Made with Fly Ash Blended Cement. *Australian Journal of Structural Engineering*, 14(3). pp. 4–5. doi: 10.7158/13287982.2013.11465140.

Jayasankar, R., Mahindran, N. and Ilangovan, R. (2010). Studies on Concrete using Fly Ash, Rice Husk Ash and Eggshell Powder. *International Journal of Civil and Structural Engineering*, 1(3). pp. 362–372.

Jimoh, A. A., Awe, S. S. (2013). A Study on the Influence of Aggregate Size and Type on the Compressive Strength of Concrete. *Journal of Research Information in Civil Engineering* (4). pp. 157–168.

King`ori A.M. (2011). A Review of the Uses of Poultry Eggshells and Shell Membranes. *International Journal of Poultry Science* 10 (11).

Kumar, P., Viswakarma, A. and Soni, K. (2016). Laboratory Analysis of Cement Concrete Prepared with Eggshell Ash. *International Journal of Advanced Technology for Science & Engineering Research* 1(6). pp. 16–23.

Kupaei, R. H. Alengaram, U. J. Jumaat, M. Z. B. Nikraz, H. (2013). Mix Design for Fly Ash Based Oil Palm Shell Geopolymer Lightweight Concrete. *Construction and Building Materials*. Elsevier Ltd, 43. pp. 490–496. doi: 10.1016/j.conbuildmat.2013.02.071.

Lee, B. Y. R. (2011). Malaysians Consume 20 Million Eggs Daily. *The Star online*. pp. 1–6. Available at: http://www.thestar.com.my/news/community/2011/10/15/malaysians-consume-20-million-eggs-daily/.

Li, K., Chen, Z. and Lian, H. (2008). Concepts and Requirements of Durability Design For Concrete Structures: An Extensive Review of CCES01. *Materials and Structures/Materiaux et Constructions*, 41(4). pp. 717–731. doi: 10.1617/s11527-007-9276-3.

Lye, C. Q., Dhir, R. K. and Ghataora, G. S. (2016). Carbonation Resistance of GGBS Concrete. *Magazine of Concrete Research*, 68(18). pp. 936–969. doi: 10.1680/jmacr.15.00449.

Madeleine, B. Y. and May, R. (2016). Emissions from the Cement Industry. pp. 7–10. Available at: http://blogs.ei.columbia.edu/2012/05/09/emissions-from-the-cement-industry/.

Mehta, P. K. and Monteiro, P. J. M. (2006). *Concrete: Microstructure, Properties, and Materials*, *Concrete*. doi: 10.1036/0071462899.

Mohamed, M. A. Dinesh, K. M. Milan C. J. Vani, G. (2016). Replacement of Cement using Eggshell Powder. *SSRG International Journal of Cvil Engineering*, 3(3). pp. 2–3.

Muhardi, A. Marto, A. Kassim, K. A. Makhtar, A. M. Lee, F. W. Yap, S. L. (2010). Engineering Characteristics of Tanjung Bin Coal Ash. *Electronic Journal of Geotechnical Engineering*, 15 K. pp. 1117–1129.

Namagga, C., Atadero, R. A. and Ash, F. (2009). 'Optimization of Fly Ash in Concrete:High Lime Fly Ash as a Replacement for Cement and Filler Material Materials and Testing. *2009 World of Coal Ash (WOCA) Conference - May 4-7,* *2009 in Lexington, KY, USA*. pp. 1–6.

Nogrady, B. B. (2016) *Concrete Products Reabsorb Nearly Half CO2 Released in Cement Manufacture Key Points the Paris Climate Deal at Home Where is All Our Carbon ?* Available at: http://www.abc.net.au/news/science/2016-11-22/concrete-is-a-carbon-sink/8043174 (Accessed: 17 December 2017).

Olarewaju, A. J, Balogun, M. O. & Akinlolu, S. O. (2011). Suitability of Eggshell Stabilized Lateritic Soil as Subgrade Material for Road Construction. *EJGE* (16). pp. 899-908.

Özbay, E., Erdemir, M. and Durmuş, H. I. (2016). Utilization and Efficiency of Ground Granulated Blast Furnace Slag on Concrete Properties - A review, *Construction and Building Materials*, 105. pp. 423–434. doi: 10.1016/j.conbuildmat.2015.12.153.

Parkash, A. (2017). Behaviour of Concrete Containing Egg Shell Powder As Cement Replacing Material. *International Journal of Latest Research In Engineering and Computing (IJLREC)*, 5(4). pp. 4–8.

Pliya, P. and Cree, D. (2015). Limestone Derived Eggshell Powder as A Replacement in Portland Cement Mortar. *Construction and Building Materials*. Elsevier Ltd, 95. pp. 1–9. doi: 10.1016/j.conbuildmat.2015.07.103.

Portland Cement Association. (2002). Types and Causes of Concrete Deterioration. *PCA R&D Special N. 2617*. pp. 1–16. doi: IS536.01.

Praveen, K. R. Vijaya, S. R. Jose, R. B. (2015). Experimental Study on Partial Replacement of Cement with Eggshell Powder. *International Journal of Innovations in Engineering and Technology* 5(2). pp. 334-341.

Ranjbar, N. Behnia, A. Alsubari, B. Birgani, P. M. (2016). Durability and Mechanical Properties of Self-Compacting Concrete Incorporating Palm Oil Fuel Ash. *Journal of Cleaner Production*. Elsevier Ltd, 112. pp. 723–730. doi: 10.1016/j.jclepro.2015.07.033.

Reddy, M. V. S. Reddy, I. V. R. Reddy, K. M. M. Kumar, C. M. R. (2013). Durability Aspects of Standard Concrete. *Internation Journal of Structural and Civil Engineering Research*, 2(1). pp. 40–46.

Rivera, E. M. Araiza, M. Brostow, W. Castano, V. M. Estrada, J. R. D. Hernandez, R. Rodriguea, J. R. (1999). Synthesis of Hydroxyapatite from Eggshells. *Materials Letters*, 41(3). pp. 128–134. doi: 10.1016/S0167-577X(99)00118-4.

Rodríguez De Sensale, G. (2010). Effect of Rice-Husk Ash on Durability of

Cementitious Materials. *Cement and Concrete Composites*, 32(9). pp. 718–725. doi: 10.1016/j.cemconcomp.2010.07.008.

Saha, A. Pan, S. Pan, S. (2014). Strength Development Characteristics of High Strength Concrete Incorporating an Indian Fly Ash. *Journal of Technology Enhancements and Emerging Engineering Research*, 2(6). pp. 101–107.

Sahoo, S. Das, B. B. Rath, A. K. KAr, B. B. (2015). Acid, Alkali and Chloride Resistance of High Volume Fly Ash Concrete. *Indian Journal of Science and Technology*, 8(19). doi: 10.17485/ijst/2015/v8i19/72266.

Sivakumar, S. and Kameshwari, B. (2015). Influence of Fly Ash, Bottom Ash, and Light Expanded Clay Aggregate on Concrete. *Advances in Materials Science and Engineering*, 2015. doi: 10.1155/2015/849274.

Sofri, L. A. Zahid, M. Z. A. M. Isa, N. F. Azizan, M. A. Ahmad, M. M. Manaf, M. B. H. A. Rahim, M. A. Ghazaly, Z. M. Bakar, J. A. Ahmran, M. S. A. (2015). Performance of Concrete by Using Palm Oil Fuel Ash (POFA) as a Cement Replacement Material. *Applied Mechanics and Materials*, 815(June). pp. 29–33. doi: 10.4028/www.scientific.net/AMM.815.29.

Swaroop, A. H. L., Venkateswararao, K. and Kodandaramarao, P. P. (2013). Durability Studies On Concrete With Fly Ash & GGBS. *International Journal of Engineering Research and Applications (IJERA)*, 3(4). pp. 285–289.

Tan, Y. Y. Doh, S. I. Chin, S. C. Aizat, M. (2017). Natural Lime Treated as Partial Cement Replacement to Produce Concrete. *International Journal on Advanced Science, Engineering and Information Technology*, 7(5). p. 1798. doi: 10.18517/ijaseit.7.5.2559.

Tang, S. W. Yao, Y. Andrade, C. Li, Z. J. (2015). Recent Durability Studies on Concrete Structure. *Cement and Concrete Research*, 78. pp. 143–154. doi: 10.1016/j.cemconres.2015.05.021.

Tangchirapat, W., Jaturapitakkul, C. and Chindaprasirt, P. (2009). Use of Palm Oil Fuel Ash as a Supplementary Cementitious Material for Producing High-Strength Concrete. *Construction and Building Materials*. Elsevier Ltd, 23(7). pp. 2641–2646. doi: 10.1016/j.conbuildmat.2009.01.008.

Tangchirapat, W., Khamklai, S. and Jaturapitakkul, C. (2012). Use of Ground Palm Oil Fuel Ash to Improve Strength, Sulfate Resistance, and Water Permeability of Concrete Containing High Amount of Recycled Concrete Aggregates. *Materials and Design*. Elsevier Ltd, 41. pp. 150–157. doi: 10.1016/j.matdes.2012.04.054.

Teng, S., Lim, T. Y. D. and Sabet Divsholi, B. (2013). Durability and Mechanical Properties of High Strength Concrete Incorporating Ultra Fine Ground Granulated Blast-Furnace Slag. *Construction and Building Materials*. Elsevier Ltd, 40. pp. 875–881. doi: 10.1016/j.conbuildmat.2012.11.052.

Upadhyaya, S. (2014). Effects of Fly Ash on Compressive Strength of M20 Mix Design Concrete. *International Journal of Advancements in Research & Technology*, 3(9). pp. 19–23.

Usman, J. and Sam, A. R. M. (2017). Acid Resistance of Palm Oil Fuel Ash and Metakaolin Ternary Blend Cement Mortar. *Sustainable Environment Research*. Elsevier Ltd, 27(4). pp. 181–187. doi: 10.1016/j.serj.2017.02.003.

Venkateswara, S. R. Seshagiri, M. V. R. D Ramaseshu (2012). Strength and Durability Studies of Conventional Concrete and Self Compacting Concrete (Cc). *Magazine of Concrete Research* 2012 64:11. pp. 1005-1013.

Yerramala, A. (2014). Properties of Concrete with Eggshell Powder as Cement Replacement. *Indian Concrete Journal*, 88(10). pp. 94–102.

Zhang, J. Liu, G. Y. Chen, B. Song, D. Qi, J. Liu, X. Y. (2014). Analysis of CO_2 Emission for the Cement Manufacturing with Alternative Raw Materials: A LCA-Based Framework. *Energy Procedia*. Elsevier B.V., 61. pp. 2541–2545. doi: 10.1016/j.egypro.2014.12.041.

APPENDIX A
DELIVERY ORDER OF EGG SHELL

EGGTECH MANUFACTURING SDN BHD 509203-T
NO 10 JLN TIAJ 2/6, TAMAN INDUSTRI ALAM JAYA
BANDAR PUNCAK ALAM, MUKIM IJOK 42300, KUALA SELANGOR
TEL : 03-60389110 / 03-60389210 FAX : 03-60389310

UNI STUDENT **SAMPLE**
(SOHNG UNIVERSITY PAHANG)

DATE : 7/10/2017

ATTN :

ITEM NO	DESCRIPTION	QTY KG
EG-SHELL	EGG SHELL 150 KG	150

TOTAL	150

EGGTECH MANUFACTURING SDN BHD

Authorised Signature (S)

Received By