EXPERIMENTAL STUDY ON CONCRETE OF BLENDED CEMENT WITH EGGSHELL POWDER AND FLY ASH

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ABSTRACT

Cement as a vital material of concrete production plays an important role in construction field. However, production of cement had brought severe negative impact to environment. Research found that there is approximately 780 kg of carbon dioxide (CO_2) is emitted to atmosphere for every ton of cement produced. In order to minimize the negative effect of cement production, alternative environmental friendly material should be determined. In the past decade, consumer waste and industrial by-product handling method always become an environmental issue. Disposal of egg shells through landfilling might detrimental to human health as it may become the habitat for vermin. Fly ash as industrial by product had led to severe disposal and leachate problem also. Recent researches have proposed that these waste materials can be recycled and added to concrete as an effort to minimize post-consumer wastes and industrial by-products entering the landfills. Egg shells riches in pure form of calcium carbonate ($CaCO_3$) which is nearly similar as composition of limestone. The composition of fly ash includes substantial amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and calcium oxide (CaO). When they mix with Portland cement and water, it will result in production of calcium-silicates hydrates (C-S-H) which primarily responsible for the strength of concrete. As there is potential of developing these waste product as construction material, investigation is conducted to determine the mechanical properties and optimum mix design of blended cement with egg shells powder and fly ash. In this investigation, a combination of 30% of fly ash and four different percentages of eggshell powder with respect to cement were added into the concrete mix of Grade M30. The materials used in this experimental study involved non-composite Portland cement, coarse aggregate, fine aggregate, sand, Class C fly ash and eggshell powder. From the investigation, all the casted concrete has achieved the designated compressive strength of 30MPa. 30% of fly ash and 5% of eggshell powder is the optimum dosage for concrete to achieve higher flexural strength. Besides, the splitting tensile strength of concrete decrease with the further increase in proportion of fly ash and eggshell powder.

ABSTRAK

Simen merupakan bahan penting dalam pembuatan konkrit. Walau bagaimanapun, penghasilan simen telah membawa impak negatif yang berterusan kepada alam sekitar. Kajian mendapati bahawa terdapat kira-kira 780 kg karbon dioksida (CO_2) akan dibebaskan ke atmosfera bagi penghasilan setiap tan simen. Untuk mengurangkan kesan negatif penggunaan simen, bahan mesra alam sekitar harus dikenalpasti. Kebelakangan ini, produk sampingan industri telah menjadi isu alam sekitar. Pelupusan sisa kulit telur melalui kaedah pelupusan telah menjejaskan kesihatan manusia kerana ia mungkin menjadi habitat untuk vermin. Serbuk abu terbang sebagai hasil sampingan industri penjanaan elektrik telah menyebabkan isu pelupusan yang teruk dan masalah larut resapan juga. Penyelidikan baru-baru ini telah mencadangkan bahawa bahan buangan ini dapat dikitar semula dan ditambahkan dalam konkrit sebagai usaha untuk mengurangkan sisa pasca-pengguna dan produk sampingan industri yang memasuki tapak pelupusan sampah. Kulit telur mengandungi kalsium karbonat ($CaCO_3$) yang hampir sama dengan komposisi batu kapur. Komposisi serbuk abu terbang terdiri daripada silikon dioksida (SiO_2), aluminium oksida (Al_2O_3) dan kalsium oksida (CaO). Apabila mereka bercampur dengan simen dan air, ia akan menghasilkan hidrat kalsium-silikat (C-S-H) yang terutamanya bertanggungjawab terhadap kekuatan konkrit. Oleh sebab potensi produk sisa ini sebagai bahan binaan, penyiasatan turut dijalankan untuk menentukan sifat mekanik dan reka bentuk campuran optimum simen campuran dengan serbuk kulit telur dan serbuk abu terbang. Dalam penyiasatan ini, gabungan 30% serbuk abu terbang dan empat jenis percent serbuk kulit telur yang berbeza merujuk kepada kandungan simen telah dimasukkan ke dalam campuran konkrit Gred M30. Bahan-bahan yang digunakan dalam kajian eksperimen ini meliputi Portland simen yang tidak komposit, agregat kasar, agregat halus, pasir, serbuk abu terbang kelas C dan serbuk kulit telur. Daripada hasil penyiasatan, didapati bahawa semua konkrit telah mencapai kekuatan mampatan yang ditetapkan sebanyak 30MPa. 30% serbuk abu terbang dan 5% serbuk kulit telur adalah dosis optimum bagi konkrit untuk mencapai kekuatan lenturan yang lebih tinggi. Selain itu, kekuatan tegangan pemecahan konkrit berkurang dengan peningkatan kandungan serbuk 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
μm	Micro meter
wt%	Weight percent

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
i.e.	That is
MS	Malaysian standard
OPC	Ordinary Portland cement

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Cement as a vital material of concrete production plays an important role in construction field. Cement mainly consists of compounds including lime (calcium oxide, CaO) mixed with silica (silicon dioxide, SiO_2) and alumina (aluminum oxide, Al_2O_3). However, production of cement had brought severe negative impact to environment. Carbon dioxide (CO_2) is released during the calcination process of cement production whereby the calcium carbonate undergoes thermal decomposition to produce cement clinker. This greenhouse gas emission will gradually lead to global warming and other environmental issue that will endanger living organisms on earth. In order to minimize the negative effect of cement production, alternative environmental friendly material should be determined.

In the past decade, consumer waste and industrial by-product handling method always become an environmental issue. For instance, disposal of egg shells through landfilling might detrimental to human health as it may become the habitat for vermin. Furthermore, rotting egg shells allows methane and carbon dioxide to seep out of the ground and up into the air which indirectly causes global warming. Fly ash as industrial by product is generated by coal-fired electric and steam generating plants. Although it can be disposed through dry landfill, the Environmental Protection Agency (EPA) had discovered that there is a higher risk of getting cancer or other diseases if living next to a fly ash disposal site. Recent researches had proposed that these renewable waste materials have shown a potential to be recycled and added to concrete as an effort to minimize post-consumer wastes and industrial by-products entering the landfills. According to Bandhavya et al., (2017), compressive strength of concrete with 5 % and 10% egg shell powder replacement was higher than conventional concrete at 3, 7 and 28 days of curing ages. Research from Doh and Chin (2014) had shown that the inclusion of eggshell powder as filler into concrete had improved the flexural behavior of concrete up to 22.9% compared to the control concrete. The blending of pumice powder and fly ash in cement decreased the early age compressive and splitting tensile strength of concretes, however at later ages (28, 90 and 180 days) the strength values were comparable with that of the reference concrete (Nihat Kabay et al., 2015). As there is potential of developing these waste product as construction material, investigation is conducted to determine the mechanical properties and optimum mix design of blended cement with egg shells powder and fly ash.

1.2 PROBLEM STATEMENT

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. It is considered as a chemically combined mass where the inert material acts as a filler and the binding materials act as a binder. The most important binding materials are cement and lime while the inert materials used in concrete are aggregates. Despite of its contribution in construction industry, cement production had led to relentless impact towards our earth in terms of environmental pollution.

The production of cement involves the consumption of large quantities of raw materials, energy, and heat. Cement production also results in the release of a significant amount of solid waste materials and greenhouse gaseous emissions including carbon dioxide (CO_2). The CO_2 emission from the concrete production is directly proportional to the cement content used in the concrete mix. 900 kg of CO_2 are emitted for the fabrication of every ton of cement, accounting for 88% of the emissions associated with the average concrete mix (Michael et al., 2002). It has long been known that carbon dioxide emissions contribute to climate change. Constantly increasing CO_2 emissions are responsible for an increase in temperatures, which is expected to continue over the coming decades reaching up to +1.4˚ to +5.8˚C globally by the year 2100. Increasing temperature can cause severe droughts in some parts of the world, extreme weather conditions, the loss of ecosystems and potentially hazardous health effects for people (Shraddha Mishra et al., 2014). In addition to the generation of CO_2 the cement manufacturing process produces millions of tons of the waste product cement kiln dust each year contributing to respiratory and pollution health risks. Although the cement industry has made significant progress in reducing CO_2 emissions through improvements in process and efficiency, but further improvements are limited because CO_2 production is inherent to the basic process of calcination limestone (Stajanča and Eštoková, 2012).

As one of the potential alternative construction material in replacing cement, egg shells riches in pure form of calcium carbonate ($CaCO_3$) which is nearly similar as composition of limestone. $CaCO_3$ will further undergo thermal decomposition and hydration with water to form calcium silicate (C_2S, C_3S) which contributes to strength of concrete during mixing. Malaysia has been ranked 14^{th} in terms of egg consumption per capita within the group of 159 countries, which almost 14.0 kg egg consumption per capita in year of 2013 (Teo Seng Capital Bhd, 2015). Majority sources of egg shells can be easily obtained from egg breaking plants which produces liquid eggs for food and non-food products usage. While the minor source of egg shells can be found from restaurant and household in term form of food waste. However, most of the eggshell waste is deposited as landfills. Eggshell waste in landfills attracts vermin due to attached membrane and causes problems associated with human health and environment.

Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. One of the major problems of all coal combustion power plants is the unused fly ash and bottom ash that bring environmental problems, such as air pollution and groundwater contamination, due to the leaching of metals from the ashes, especially the accumulation of the very fine particles of fly ash. In Malaysia, fly ash is an industrial waste material commonly deposited in landfills. This brings no benefits, but rather environmental nuisance. The production of fly ash in Malaysia is believed to be approaching two million tons annually. Tanjung Bin power station produce 180 tonnes per day of bottom ash and 1,620 tonnes per day of fly ash from 18,000 tonnes per day of coal burning alone (Abdulhameed et al., 2012) . The disposal of fly ash has reached an alarming proportion such that its application in construction is a necessity than a desire and if applied on a large scale, would revolutionize the construction industry by economizing the construction cost while benefit the environment. The composition of fly ash includes substantial amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and calcium oxide (CaO). When they mix with Portland cement and water, it will result in production of calcium-silicates hydrates (C-S-H) which primarily responsible for the strength of concrete. Fly ash is classified into two categories, which are Class C and Class F ash based on its chemical composition. Class C ashes are generally derived from sub-bituminous coals and consist primarily of calcium alumino-sulfate glass, as well as quartz, tricalcium aluminate, and free lime (CaO). Class C ash is also referred to as high calcium fly ash because it typically contains more than 20 percent CaO. Class F ashes are typically derived from bituminous and anthracite coals and consist primarily of an alumino-silicate glass, with quartz, mullite, and magnetite also present. Class F, or low calcium fly ash has less than 10 percent CaO.

Thus, the incorporation of both egg shell powder and fly ash in concrete mixing has the potential to produce environmental friendly green concrete as it offer the solution to reduce and reuse industrial waste while minimizing the negative impact of cement usage by reducing its production.

1.3 OBJECTIVES

The objectives of the present research are as follows:

a) To investigate the compressive strength of concrete of blended cement with eggshell powder and fly ash.
b) To determine the flexural strength of concrete of blended cement with eggshell powder and fly ash.
c) To examine the splitting-tensile strength of concrete of blended cement with eggshell powder and fly ash.
d) To determine the optimum mix design of of concrete of blended cement with eggshell powder and fly ash.

1.4 SCOPE OF RESEARCH

This research concentrates on investigation of mechanical properties of concrete of blended cement with eggshell powder and fly ash including compressive strength, flexural strength and splitting-tensile strength. A control mix of concrete with grade M30 is firstly determined by mixing cement, sand, aggregate and water without blending any eggshell powder and fly ash as partial cement replacement.

After obtaining the best control mixes, a series of blended concrete with 30% of fly ash (FA) and four different percentages of eggshell powder (ESP) including 0%, 5%, 10% and 15% with respect to cement quantity in terms of weight per unit volume were prepared. The concrete was casted and poured into mould and the hardened concrete was taken out from the mould after 24 hours. Then, the hardened concrete was cured in water to enhance its strength development based on three aging stage, which is 3 days, 7 days and 28 days. Three test will be conducted to determine the compressive strength, flexural strength and splitting-tensile strength of casted concrete.

1.5 RESEARCH SIGNIFICANCE

Discovery from this research would provide information on the effectiveness of eggshell powder and fly ash content as partial cement replacement towards the mechanical properties of concrete of blended cement with eggshell powder and fly ash. Based on the result obtained from mechanical properties testing, the optimum mix design of concrete of blended cement with eggshell powder and fly ash will be determined. As professional engineer, we not only focus on construction development, at the same time we have to take the initiative to save our environment from pollution. Based on Malaysia Construction Industry Transformation Program from 2016 to 2020, it is targeted that 100% of large infrastructure projects should exceed sustainability requirements with 4 Mega tonnes of CO_2 reduction per year. In line with Green Technology Master Plan Malaysia from 2017-2030 which encourage the usage of green building materials, utilization of eggshell powder and fly ash as partial cement replacement in concrete production has the capability to reduce construction industry's reliability on cement, thus minimise cement usage. In other words, the cement production can be minimised and at the same time the negative environmental impact due to cement production such as greenhouse gases emission can be reduced.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the review of previous research paper related to this study will be discussed. The content of literature review is elaborated based on the objectives and scope of study that had finalized which is the literature review of concrete, cement, eggshell, fly ash, compressive strength, flexural strength and splitting tensile strength. All these reviews will help to improve the understanding and possibility of using concrete of blended cement with eggshell powder and fly ash.

2.2 CONCRETE

Concrete is a mixture of paste and aggregates in a simple form. The paste that composed of Portland cement and water will coat the surface of the fine and coarse aggregates. The paste will then hardens and gains strength to form the rock-like mass known as concrete through a chemical reaction called hydration (Portland Cement Association, 2012). The crushed aggregate and sand in cement paste and unhydrated cement grains make up the elastic skeleton of concrete body to support external loads. Under application of external loads, micro voids and the Calcium-Silica-Hydrate(C-S-H) gel at transition zone between cement mortar and aggregates allow concrete to have plastic deformation. Micro defects such as voids and cracks will initiate the process of concrete failure therefore the propagation of cracks and voids can severely affect the mechanical properties of concrete (Gu. et al., 2016). By proper adjusting the proportions of various materials, concrete with sufficient compressive strength for various uses can be developed. The strength of concrete depends mainly on its materials, their relative quantities and the manner in which they are mixed and placed.

Concrete is used worldwide as a building construction material and is the second-most consumed substance on earth after water. Statistic from research study had found that global concrete production is approximately 5.3 billion cubic meters per year (Roskos et al., 2011). Conventional concrete is best renowned for its favorable advantages such as low cost of materials and simple application (Golestaneh et al., 2010). As the main construction material, conventional concrete possesses high durability, high temperature and water resistance, high compressive strength, and low maintenance requirement. However, there is some limitation and weakness for conventional concrete too. For instance, conventional concrete possesses low tensile strength, weak flexural strength, low resistance towards sulphate and acid attack (Suryakanta, 2015). Unfortunately, conventional concrete production involves large amount of greenhouse gases emission and greatly disrupts our virgin lands (Roskos et al., 2011).

2.3 ORDINARY PORTLAND CEMENT

Cement is an extremely important construction material used for housing and infrastructure development. Cement demand is directly associated to economic growth and many growing economies country are striving for rapid infrastructure development which underlines the tremendous growth in cement production (World Business Council for Sustainable Development, 2014).

Portland cement is finely ground powder which produces a very strong binding medium for aggregate particles when mix with water. The chemical reaction between cement and water to produce cement paste is known as hydration process. The raw materials used in the manufacture of Portland cement mainly consist of lime, silica, alumina and iron oxide. The oxides account for over 90% of the cement. The oxide composition of (ordinary) Portland cement may be expressed as follows:

Table 2.1: Chemical composition of ORANG KUAT branded OPC

CHEMICAL COMPOSITION	PERCENTAGE (%)
CAO	65
SIO_2	21
AL_2O_3	6
FE_2O_3	3.5
MGO	0.7
SO3	1.5
FREE LIME	2

Source: Ali et al. (2008)

Despite its popularity and profitability, the cement industry faces many challenges due to environmental concerns and sustainability issues. Cement industry is an energy intensive and significant contributor to climate change. The major environment health and safety issues due to cement production are emissions of greenhouse gases and energy consumption. Cement manufacturing requires huge amount of non-renewable resources like raw material and fossil fuels. It is estimated that 5-6% of all carbon dioxide greenhouse gases generated by human activities originates from cement production (Potgieter, 2012). Raw material and energy consumption result in emissions of greenhouse gases and dust. The exhaust gases from a cement kiln contains are nitrogen oxides (NOx), carbon dioxide, water, oxygen and small quantities of dust, chlorides, fluorides, sulfur dioxide, carbon monoxide , and some smaller quantities of organic compounds and heavy metals (Shraddha Mishra et al., 2014). Toxic metals and organic compounds are released when industrial waste is burnt in cement kiln. Other sources of dust emissions include the clinker cooler, crushers, grinders, and materials-handling equipment. These emissions are not only deteriorating air quality but also degrading human health. Emissions have local and global environment impact resulting in global warming, ozone depletion, acid rain, biodiversity loss, and reduced crop productivity (Suman et al., 2013). Scientific evidence indicates that air pollution from the combustion of fossil fuels causes a spectrum of health effects from allergy to death (Marchwinska-Wyrwal et al., 2011).

2.4 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 had 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.

Eggshell consists of several mutually growing layers of $CaCO_3$. The innermost layer-maxillary 3 layer grows on the outermost egg membrane and creates the base on which palisade layer constitutes the thickest part of the eggshell. The top layer is a vertical layer covered by the organic cuticle (Karthick et al., 2014). In general eggshell quality can be affected by several factors such as type of genetics, age, nutritional diet, and stress related to population density. Brown eggs are larger, heavier and have thicker shells than white eggs. However, the shell color is not an indication of the internal quality of an egg since brown eggs are not healthier than white eggs (Pliya and Cree, 2015). In addition, the quality of lime in eggshell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions.

The main ingredient in eggshells is calcium carbonate ($CaCO_3$). The shell itself is about 95% $CaCO_3$ (which is also the main ingredient in sea shells). The remaining 5% includes Magnesium, Aluminum, Phosphorous, Sodium, Potassium, Zinc, Iron, Copper, Ironic acid and Silica acid. Eggshell has a cellulosic structure and contains amino acids. Thus, it is expected to be a good bio-sorbent (Karthick et al., 2014). Table 2.2 shows the chemical composition of eggshell.

Table 2.2: Chemical composition of eggshell

OXIDE CONTENTS	PERCENTAGE (%)
CAO	50.7
SIO_2	0.09
AL_2O_3	0.03
MGO	0.01
FE_2O_3	0.02
NA_2O	0.19
P_2O_5	0.24
SRO	0.13
NIO	0.001
SO_3	0.57
CL	0.219

Source: Parthasarathi et al., (2017)

The research study show that the percentage of calcium carbonate in brown eggs was found to be 96–97 wt.% and 3–4 wt.% organic matter. While in other investigations, white eggs were found to have 94 wt.% calcium carbonate content with 6 wt.% organic matter and other minor compounds (Intharapat et al., 2013).

Re-use of limestone based eggshells would promote recycling of farm waste and prevent its diversion to landfills. Consumption of eggs in restaurants and households are minor compared to the majority of eggs utilized in egg breaking plants which involve mass production of liquid eggs for use in food and non-food related products. The weight of an average egg is about 60 g, while the empty shell corresponds to 11 wt.% (Pliya and Cree, 2015). Correspondingly, 1 billion eggs would produce 6600 tonnes of limestone powder. Although these amounts would not support the concrete industry in total, it could be used as partial supplements or replacement of cement.

2.5 FLY ASH (FA)

Fly ash (FA) is a principal byproduct of coal combustion in thermal power plants. It is comprised of the non-combustible mineral portion of coal. When coal is consumed in the power plant, it is first ground to the fineness of powder. After being blown into the power plants boiler, the carbon is consumed, leaving molten particles rich in silica alumina and calcium. These particles solidify as microscopic, glassy spheres that are collected from the power plants exhaust before they can fly away- hence the products name fly ash. There are two basic types of fly ash which are Class F and Class C. According to ASTM C618, fly ash belongs to Class F if (SiO_2+Al_2O_3+Fe_2O_3) > 70% and belongs to Class C if 70% > (SiO_2+Al_2O_3+Fe_2O_3) > 50% (Islam & Islam, 2010). Both these fly ashes can undergo pozzolanic reaction with lime (Calcium hydroxide) created by hydration of cement and water to form calcium silicate hydrate like cement. In addition, some Class C fly ashes may possess enough lime to be self-cementing in addition to the pozzolanic reaction with lime from cement hydration. According to ASTM C125, pozzolan is a siliceous or siliceous and aluminous material which itself possesses little or no cementitious value but will in finely divided form. In the presence of moisture, pozzolan will chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. Due to this series of chemical reaction, rate of strength gain for fly ash concrete is relatively slower at early ages of curing.

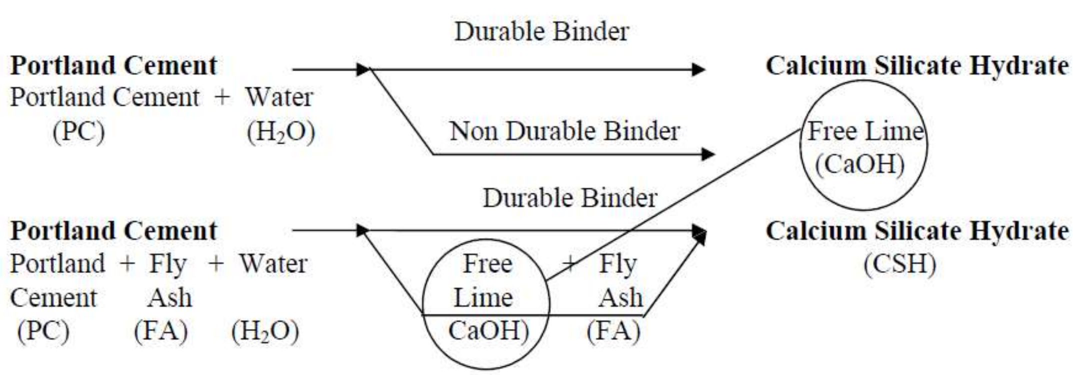

Figure 2.1: Hydration products of cementing binders

It is estimated that FA constitutes up to 75% of the total ash content in coal. The composition of FA mainly consists of silicate compounds with a small fraction of unburnt carbon (Ebrahimi et al., 2017). Table 2.3 show the chemical composition of fly ash.

Table 2.3: Chemical composition of fly ash

MATERIALS	**CLASS C (%)**	**CLASS F (%)**
SIO_2	38.29	49.83
AL_2O_3	15.49	18.94
FE_2O_3	14.44	11.43
CAO	18.47	9.27
MGO	7.76	3.57
SO_3	2.49	2.13
NA_2O	0.03	1.55
K_2O	1.38	1.80
ACTIVE SIO_2	75%	70%

Source: Jing Yu et al., (2017)

Substituting cement with fly ash in the mix design of concrete brings a number of benefits. Firstly, replacement of cement by fly ash increases the environmental greenness and decreases the hydration heat as well as the material cost. Secondly, the addition of fly ash can enhance durability and reduce drying shrinkage. Thirdly, the morphological and micro-aggregate effects of un-hydrated fly ash particles with small particle size and smooth spherical shape, result in better workability, higher compactness in the interfacial transition zone and a finer pore structure in the system (Yu et al., 2017).

Therefore, the utilization of FA as a raw material in cement manufacturing and as a partial replacement for cement in concrete has been the subject of great interest in an attempt to develop more sustainable cementitious materials, (Korpa et al., 2012).

However, despite the increasing global production of FA, only 15-30% of the total production is utilized as cement replacement materials (Ishak & Hashim, 2015). Although some cement companies have started using fly ash in manufacturing cement, which is known as "Pozzolana Portland Cement," but the overall percentage utilization remains very low and most of the fly ash is dumped at landfills (Islam & Islam, 2010). The disposal of fly ash through landfills will increase the potential risks of air pollution and contamination of water due to leaching (Rashad, 2015).

2.6 EGGSHELL POWDER CONCRETE MECHANICAL PROPERTIES

Parthasarathi et al., (2017) had done a research to determine the effect of utilization of eggshell powder as cement replacement material by making concrete cubes and prisms. The research indicated that the compressive strength of the concrete with eggshell powder as cement replacement material increases up to 15% without silica fume proportion. The flexural strength of the egg shell concrete increased with the addition of eggshell powder up to 15% of cement replacement. At the same time, the research also found that the split tensile strength of the egg shell powder concrete decreases with the addition of egg shell powder.

An experimental study on partial replacement of cement with egg shell powder in concrete were done by Bandhavya et al., (2017). Based on the result obtained, it can be found that the compressive strength of concretes with 5% and 10% eggshell powder as cement replacement were higher than conventional concrete at 3, 7 and 28 days of curing ages. However, concrete with eggshell powder replacements greater than 10 % had possessed lower compressive strength than conventional concrete. Besides, the splitting-tensile strength of eggshell powder concretes were comparable with conventional concrete up to 15 % eggshell powder replacement.

Research done by Ansari et al., (2016) shows that the 10-15% replacement of cement with eggshell powder is effective improving the compressive strength of concrete. However, the research also indicated that the compressive strength will decrease with the further increase in the percentage of eggshell powder as cement replacement.

A comparative study on eggshell concrete with partial replacement of cement by fly ash had done by Dhanalakshmi et al., (2015) to determine the potential use of using these industrial wastes as cementing material for concrete. The research had shown that the compressive strength of eggshell concrete was lower than control concrete mix (M40). In addition, the combination of eggshell powder and fly ash as cement replacement has contributed to the reduction in compressive strength when compared with control concrete and egg shell powder concrete.

Apart from this, Pliya and Cree (2015) had carried out a research by using limestone derived eggshell powder 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.

Karthick et al., (2014) had investigated the effect of egg shells on mechanical and physical properties of concrete. Based on the analysis in the present experimental work, it was discovered that the compressive strength of the concrete able to meet the required strength of 25MPa with 20% of the eggshell powder as cement replacement and the weight of the cubes are reduced from 2.8kg to 2.0kg. Whilst, the research also recorded that the tensile strength and flexural strength was decreased with increasing eggshell powder percentage as cement replacement. The tensile strength decreased from 2.36N/mm^2 to 0.21 N/mm^2 with increasing eggshell proportion from 0wt% to 50wt%.

Gowsika et al., (2014) had conducted an experimental investigation of eggshell powder as partial replacement of cement in concrete. Eggshell powder obtained from industrial wastes was added in various ratios for cement replacement and it was found that replacement of 5% Egg shell powder and 20 % microsilica can be conducted without any reduction in compressive strength properties of conventional cement. Meanwhile, replacement of 5% eggshell powder and 10% microsilica in cement yields similar flexural strength as in conventional concrete. The research also found that replacement of 5% eggshell powder and 10% microsilica in cement yields higher splitting-tensile strength as compared to other compositions.

Research regarding to the investigation of eggshell powder as potential filler in concrete had done by Doh and Chin (2014). Based on the result of experimental work, it can be concluded that the inclusion of eggshell powder as filler in concrete had improved the compressive strength of concrete. Concrete with addition of 10% eggshell powder as filler showed the highest compressive strength of 42.82 N/mm^2. Meanwhile, the incorporation of eggshell powder as filler into concrete had also improve the flexural behavior of concrete up to 22.9% compared to the control concrete. In other words, the addition of eggshell powder as filler in concrete had improved the resistance of failure in bending.

2.7 FLY ASH CONCRETE MECHANICAL PROPERTIES

Yu et al., (2017) had carried out an investigation to determine the mechanical properties of green structural concrete with ultrahigh volume fly ash. In this study, the mechanical properties of green structural concrete with ultrahigh-volume fly ash (UHVFA) were experimentally explored. By lowering the water/binder ratio to 0.2 and properly combining the raw materials, a type of UHVFA concrete with adequate strength and workability for structural use was developed when 80% of the cement is replaced by fly ash. The compressive strength of both mortar and concrete can reach over 40MPa at 7-day age of curing, and over 60MPa at 28 days age of curing. However, when the fly ash content is further increased, the cementing efficiency of the fly ash decreases significantly.

Shehab et al., (2016) had conducted the research to examine the mechanical properties of fly ash based geopolymer concrete with full and partial cement replacement. Throughout the research, a constant w/c ratio of 0.5 was used for all test specimens. Sand with grain size smaller than 5.0 mm was used. Uncrushed natural gravel graded from 4.76 mm to 15.0 mm was used as a coarse aggregate. Fly ash (FA) used in this study in conformance with ASTM C-618. Based on the result of experimental work, it was observed that the values of compressive strength, bond strength, splitting tensile strength and flexural strength at 28- days are the highest at 50% cement replacement as compared to mixtures produced from 0%, 25%, 75% and 100% replacement ratio.

Research regarding to properties of concrete with pumice powder and fly ash as cement replacement materials had conducted by Nihat et al., (2015). Based on the experimental result, it showed that the addition of pumice powder, fly ash as replacement of cement decreased the early age compressive and splitting tensile strength of concretes. However at later ages of curing age including 28 days, 90 days and 180 days, the value of strength were comparable or similar with the strength of control concrete.

A research regarding to the mechanical properties, durability, and life-cycle analysis of self-consolidating concrete mixtures made with blended Portland cements containing fly ash and limestone powder had carried out by Celik et al., (2014). The research concluded that a wide range of early and long term strengths were attainable depending on the selected mix proportion. The rate of strength gain increased with increasing fly ash content. In addition, it was observed that the mix with 20% fly ash exceeded the strength of the control mix that contains only 25% limestone powder by 28 days. The mix with 30% fly ash performed similarly but by 91 days. The results indicates that the synergistic effect between limestone powder and fly ash leads strength gain by the time of curing.

Based on the research of mechanical properties of high volume fly ash (HVFA) concrete subjected to elevated temperatures up to 120°C done by Kaur et al., (2013), the compressive strength of concrete decreased with the increase in cement replacement with Class F fly ash. However, at each replacement level of cement with fly ash, an increase in strength was observed with the increase in curing age. Splitting tensile strength and modulus of elasticity increased with increase in curing age at each replacement level of cement using fly ash up to 50% but they were decreased with increase in volume of fly ash.

Sivalingam et al., (2012) had conducted a research to determine the mechanical properties of concrete composites with replacement of class C fly ash and silica fume. The control concrete mix having compressive strength of 30MPa after 28 days was designed. According to result of research, concrete with mix of 50% fly ash and 20% silica fume of cement replacement had achieved maximum strength at 7 days, 56 days and 90 days of curing age, with maximum strength of 62.37MPa. Although the mix blended with fly ash had no appreciable early strength, it managed to gain the strength more than the target strength in later days. The mix 50% fly ash had gained a maximum strength of 55.92 MPa after 90 days.

Islam and Islam (2010) had investigated the strength behavior of cement mortar using fly ash as partial cement replacement. By using class F fly ash replacement, maximum compressive strength was obtained for 30% and 40% replaced mortar specimens with an increase in strength of 10% and 14% respectively as compared to Ordinary Portland cement (OPC) mortar after 90 days of curing age. Cement normally gains its maximum strength within 28 days. During that period, lime produced form cement hydration remains within the hydration product. Generally, this lime reacts with fly ash and results in more strength. For this reason, mortar made with fly ash will have slightly lower strength than cement mortar up to 28 days and substantially higher strength within 90 days. Fly ash retards the hydration of C_3S in the early stages but accelerates it at later stages. The optimum fly ash content is observed to be 40% of cement. Fly ash mortars with 40% cement replacement shows around 14% higher compressive strength than OPC mortar after 90 days curing. The corresponding increase in tensile strength is reported to be around 8%.

2.8 SUMMARY

The literature review had outlined that cement as the main reason contributed to construction pollution. In order to minimize the negative environmental impact due to cement usage, construction industry must embrace a comprehensive as well as integrated approach that involves the use of less concrete for new structures or consumption of less cement in concrete mixtures.

Though various alternative materials are available for several purposes in concrete construction industry, the present study is mainly focused on the usage of eggshell and fly ash as partial cement replacement material. Keeping in view of the study conducted by previous researchers, the objective of the present research is to determine the mechanical properties including compressive strength, flexural strength and splitting-tensile strength of concrete of blended cement with eggshell powder and fly ash at different age of curing.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss in detail regarding to the procedure in carrying out the experimental work and laboratory testing in order to accomplish the objective of this research. This chapter will be distributed into 4 parts. The first of this chapter will explain about the details of materials and preparation work of material used for the concrete mixing. Secondly, this chapter will briefly present about the explanation on trial mix method used to produce control concrete and concrete of blended cement with eggshell powder and fly ash. The third part of this chapter will be regarding to the detail of experimental work conducted including curing process and details of concrete specimen. Lastly, this chapter also will explain about the laboratory testing that we are going to conduct to determine the mechanical properties of concrete of blended cement with eggshell powder and fly ash including compressive strength, flexural strength and splitting tensile strength.

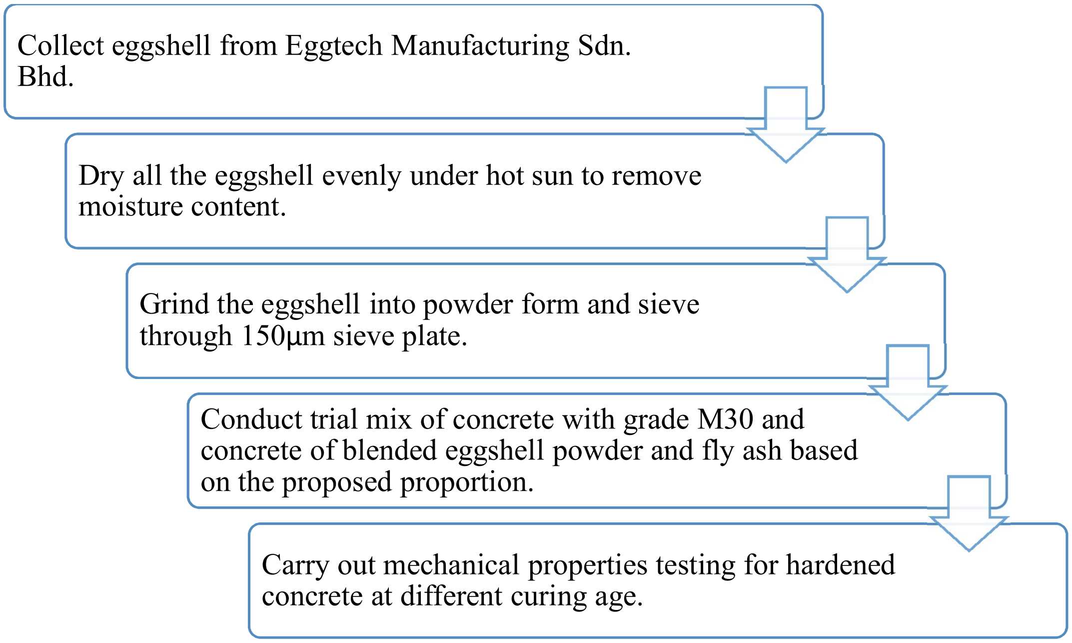

Figure 3.1: Flow chart of methodology

3.2 MIXING MATERIALS

There are total 7 materials will be used to produce concrete sample of blended cement with eggshell powder and fly ash including Ordinary Portland Cement (OPC), fly ash (FA), eggshell powder (ESP), 20mm coarse aggregate, 10mm fine aggregate, sand and water.

3.2.1 CEMENT

Cement is an adhesive substances which act as binding materials in construction industry. It is a kind of finely ground powders that will set to a hard mass when mixed with water. The setting and hardening results are due to hydration which is a chemical combination of the cement compounds with water that yields submicroscopic crystals or a gel-like material with a high surface area. This gel-like material will bind the coarse aggregate as well as fine aggregate to produce a quality concrete. Due to their hydrating properties, constructional cements will even set and harden under water. There is variety of Portland cement available in the market. In this research, ORANG KUAT Portland

Cement as shown in Figure 3.2 was chosen to use in producing concrete specimen. This brand of cement is certified to MS EN 197-1:2014, CEM I 42.5N / 52.5N which suitable to use for structural concreting, brickmaking and all general purpose applications. All the cement used were properly stored away from damp environment and stacked together closed together in well-aired, clean and dry place.

Figure 3.2: YTL ORANG KUAT Ordinary Portland Cement

3.2.2 EGGSHELL POWDER (ESP)

An eggshell is the outer covering of a hard-shelled egg. Waste chicken eggshells contain a very pure form of calcium carbonate or limestone frequently called calcite ($CaCO_3$). The eggshell was obtained from Eggtech Manufacturing Sdn. Bhd which located at Puncak Alam Selangor. Firstly, the eggshell is cleaned by water to remove the remaining egg yolk and egg white stick on the eggshell once we obtained from the factory. Then, the cleaned eggshells are distributed evenly on the surface of canvas and dried under hot sun to remove their surface moisture as shown in Figure 3.3. Next, the dried eggshells are grinded into powder form using the grinding machine as shown in Figure 3.4. After grinding process, the eggshell powder is passing through 150μm sieve plates and will be blended into concrete mix as partial cement replacement at 5%, 10% and 15%. The eggshell powder was kept in air-tight container to ensure it was in dry condition. Figure 3.5 shows the eggshell powder to be used in this research.

Figure 3.3: Drying of eggshell under sun

Figure 3.4: Grinding machine used for grinding eggshell

Figure 3.5: Eggshell powder

3.2.3 FLY ASH (FA)

Fly ash is most commonly used as pozzolans in construction applications. Pozzolans are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. There are two types of fly ash which is class F and class C. Class F fly ash contains less than 5% lime and class C fly ash contains more than 10% of lime. In this research, class C fly ash was used to blend into concrete mix as partial cement replacement at 30% based on cement quantity in terms of weight per unit volume produced. The fly ash was obtained from Rylan Tech Sdn. Bhd and the source of the fly ash is generated from a power plant located in Port Dickson. Figure 3.6 shows the fly ash used for this research.

Figure 3.6: Fly ash

3.2.4 AGGREGATE

Aggregate is a type of construction material used for mixing with cement, lime, gypsum, or other adhesive to form concrete or mortar. Aggregate contributes to volume, stability, strength resistance towards erosion and other desired physical properties to the finished product. In construction industry, aggregate can be classified into coarse aggregate and fine aggregate. Coarse aggregate with 20mm size commonly consists of gravel (pebbles) and fragments of broken stone. Fine aggregate with 10mm size usually consists of sand, crushed stone, or crushed slag screenings. The coarse aggregate and fine aggregate used in this research are obtained from Panching, Kuantan as shown in Figure 3.7.

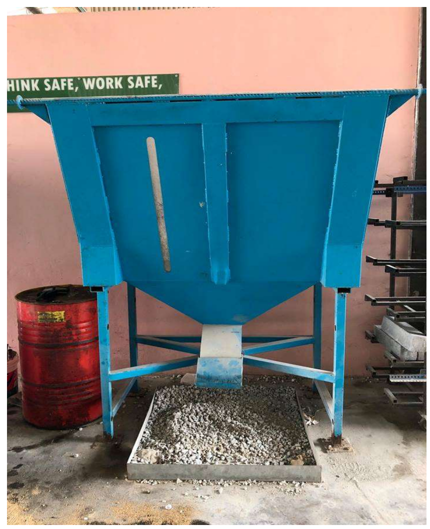

Figure 3.7: Aggregate

3.2.5 SAND

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent of sand is silica (silicon dioxide, or SiO2), usually in the form of quartz. Sand provides bulk and strength to construction materials like asphalt and concrete. In addition, sand also subdivides the paste of the binding material into a thin film and thus more surface area can be provided for its spreading and adhering. The sand used in this research was obtained from Panching, Kuantan as shown in Figure 3.8. Firstly, the sand will undergo air dry for at least for 24 hours to remove moisture content. Next, the sand will send for sieve analysis using the mechanical shaker as show in Figure 3.9. The size of sand particles are varied from 75 μm to 4.75 mm. During the sieve analysis, the sand will be sieved through No.4 (4.76mm) and retained on No.200 which comply with ASTM125. After completed sieving process, the sand was store properly in dry condition.

Figure 3.8: Sand

Figure 3.9: Shaker machine used to sieve sand

3.2.6 WATER

Water plays an important role in concrete mixing process. Water is needed to initiate the cohesive properties of the binder Portland cement through hydration process. The chemical reaction between water and cement is very significant to achieve a cementing property. Therefore, it is essential to ensure the water used in experimental work is not polluted or contains any impurities substance that may affect the reaction occurred during hydration process. In this research, tap water is used for the mixing of concrete of blended cement with eggshell powder and fly ash. This tap water throughout the study was supplied by Pengurusan Air Pahang Berhad (PAIP).

3.3 TRIAL MIX FOR CONCRETE GRADE M30

In this research, concrete specimens are produced using trial mix method. The experimental work is targeted to produce concrete with 30MPa strength. In order to determine the optimum percentage of fly ash and eggshell powder, there are total 5 set of mix design that are going to prepare. The first set is control specimen without any content of eggshell powder and fly ash. For the other 4 set of mix design, the specimens are prepared by blending eggshell powder at proportion of 5%, 10% and 15% respectively while the proportion of fly ash blended in the specimen is fixed at 30%. The percentage of replacement of cement is based on the cement quantity in terms of weight per unit volume concrete prepared. The quantity of coarse and fine aggregate, sand and water were fixed for each mix. Table shows the proportion of design concrete. The optimum mix design will be chosen based on the result of mechanical properties testing.

Table 3.1: Proportion of mix design for concrete

Mix Design	Cement, kg/m^3	Water, kg/m^3	ESP, kg/m^3	F, kg/m^3	20mm Ca, kg/m^3	10mm Fa, kg/m^3	Sand kg/m^3
0% FA + 0% ESP	468	186	0	0	820	400	500
30% FA + 5% ESP	304	186	140	24	820	400	500
30% FA + 10% ESP	281	186	140	47	820	400	500
30% FA + 15% ESP	258	186	140	70	820	400	500

*ESP = Eggshell Powder

*FA = Fly Ash

*Ca = Coarse Aggregate

*Fa = Fine Aggregate

3.4 EXPERIMENTAL PROGRAM

Three are three mechanical properties that we are going to determine including compressive strength, flexural strength and splitting-tensile strength. The details of concrete specimens are shown in Table 3.2.

Table 3.2: Details of specimen

Testing	Details of Specimen		
	Code of Practice	Type of Mould	Size of Mould (mm^3)
Compressive Strength Test	BS EN12390-3 (2009)	Cube	100 x 100 x 100
Split-tensile Strength Test	BS EN1881-117 (1983)	Cylinder	110 diameter x 200 height
Flexural Strength Test	BS EN12390-5 (2009)	Beam	100 x 100 x 500

3.5 ENGINEERING PROPERTIES MEASUREMENT

3.5.1 COMPRESSIVE STRENGTH TEST

Compressive strength test is conducted to determine the concrete compressive strength. The specimen of compressive strength test is prepared and tested according to BS EN 12390-3 (2009). 36 units of concrete cubes were produced with size of 100mm x100mm x 100mm and underwent curing process in water tank. The compressive strength test was conducted after the specimen was removed from water tank. The weight of specimen was measured to determine the wet density of concrete. All specimen were tested on 3, 7 and 28 days. During the testing, concrete specimen was subjected to increasing compression load in order to determine the maximum load that can be sustained by the concrete specimen. Before testing, the machine surfaces was wiped and clean to ensure no error happen while tested. Concrete sample placed at the center if the lower plate and the load was applied as shown in Figure. The maximum concrete strength was directly taken from the machine or can be calculated using Equation 3.1:

$$f_c = \frac{P}{W \times T}$$

Where,

f_c = Compressive strength (MPa)

P = Maximum load carried by specimen, (N)

W = Width of specimen, (mm)

T = Thickness of specimen, (mm)

Figure 3.10: Concrete cubes with size of 100mm x100mm x 100mm

Figure 3.11: Compressive Strength Testing Machine

3.5.2 FLEXURAL STRENGTH TEST

The purpose of conduct flexural strength test is to determine the flexural strength of concrete beam in resisting failure due to bending. 36 beams with size 100mm x 100mm x 500mm were prepared and used for flexural strength test. All the specimens were subjected to water curing, followed by testing at the age of 3, 7 and 28 days. The flexural strength of beam were tested using T-Machine Universal Testing Machine according to BS EN 12390-5 (2009). The machine consists of two supporting rollers and two applying rollers. Before testing, the rollers need to be wipe and clean in order to remove any loose sand and grit that can make contact with the specimen. Two point constant loading with the rate of 0.03 N/mm^2/sec was maintained for this test until the specimen break and the maximum load was recorded. The value of flexural strength was calculated by using Equation 3.2:

$$f_{cf} = \frac{F \times I}{d_1 \times d_2}$$

Where,

f_{cf} = Flexural strength (MPa)

F = Breaking Load (N)

d_1 and d_2 = Lateral dimensions of the cross section (mm)

I = Distance between the supporting rollers, (mm)

Figure 3.12: Concrete beams with size of 100mm x 100mm x 500mm

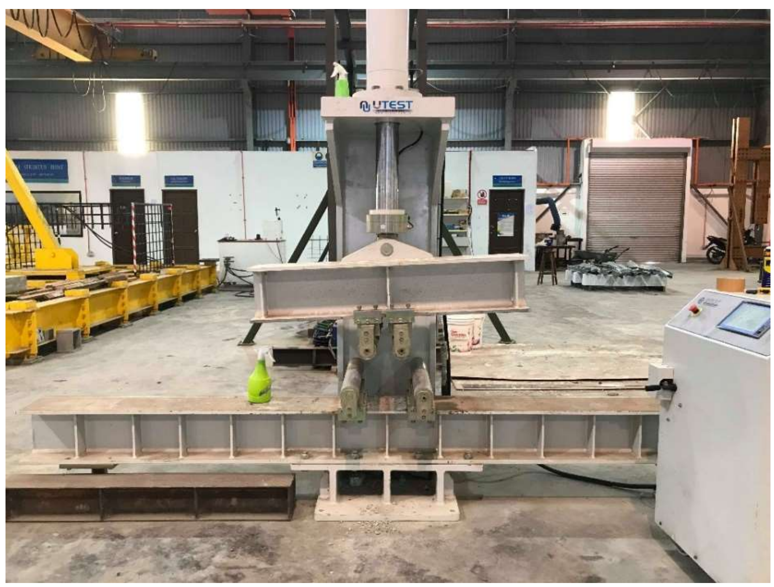

Figure 3.13: Flexural Strength Testing Machine

3.5.3 SPLITTING-TENSILE STRENGTH TEST

Splitting-tensile strength test is conducted to identify the tensile strength of concrete. Concrete is very weak in tension due to its brittle nature and it is not expected to resist the direct tension. Tensile failure occurs rather than compressive failure because of the areas of load application is in a state of triaxial compression. The splitting tensile strength of concrete is determined according to BS EN 1881-117 (1983). 36 units of cylinder specimen with size of 110mm diameter x 200mm height were casted and tested on 3, 7 and 28 days after water curing at each phase. The specimen was placed horizontally into a cylindrical loading mould. Compressive force with rate of 2.0 N/mm2/sec was applied along the length of specimen until split occur. The maximum applied load is recorded to calculate the splitting tensile strength. The splitting-tensile strength can be obtained by using Equation 3.3:

$$f_{ct} = \frac{2P}{P \times L \times D}$$

Where,

f_{ct} = Splitting-tensile strength

P = Total applied load

D = Diameter

L = Length

Figure 3.14: Cylinder specimen with size of 110mm diameter x 200mm height

Figure 3.15: Splitting-tensile strength testing machine

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss about the data recorded from laboratory testing based on the proposed methodology in chapter 3. All the data collected will be analysed and tabulated into table as well as presented in graph form. The results of mechanical properties laboratory testing including compressive strength, flexural strength and splitting-tensile strength with respect to different proportion of eggshell powder and fly ash as cement replacement will be discussed in detail in this chapter. The curing age for the samples can be categorized into 3rd day, 7th day, and 28th day. All laboratory testing are conducted once the sample is removed from the curing tank according to the curing age.

4.2 COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is the most common performance measure used by the engineer in designing buildings and other structures. Compressive strength test results are primarily used to determine the concrete mixture as delivered meets the requirements of the specified strength, f_c, in the job specification. The test results may be used for quality control, acceptance of concrete, or for estimating scheduling construction operations such as form removal or for evaluating the adequacy of curing and protection afforded to the structure.

The result of compressive strength for concrete with 30% of fly ash and different proportion of eggshell powder is tabulated in Table 1.0. Figure. 5.0 shows the effect of fly ash & eggshell powder on compressive strength of concrete. Generally, all the concrete samples show development trend in compressive strength from 3rd to 28th day. Based on our mix design calculation, the concrete strength of specimen should achieve 30MPa at 28th day of curing age. It can be observed that all the casted concrete had achieved more than the designated compressive strength of 30MPa. However, it is discovered that further inclusion of eggshell powder and fly ash in concrete had weaken the compressive strength of concrete.

From the table, it can be observed that concrete A1 with 0% of eggshell powder and fly ash shows the highest compressive strength at 3rd day of curing age, which is 38.384MPa while the compressive strength of concrete A4 is the lowest among the 4 type of sample, which is 24.725MPa. Concrete A1 and A4 show a contrast of 13.659MPa in compressive strength, which is about 35.6% reduction in strength. The compressive strengths of concrete A2 and A3 are slightly higher than concrete A4, which recorded as 31.657MPa and 28.045MPa respectively.

At 7th day of curing age, concrete A1 has recorded the highest compressive strength with 45.625MPa while concrete A4 has recorded the lowest compressive strength with 27.610 MPa, which is about 18MPa difference between concrete A1 and A4. The compressive strengths of concrete A2 and A3 are still lower than concrete A1 which are 35.962MPa and 32.239MPa respectively. Based on the theoretical study, the compressive strength of concrete at 7th day of curing age should achieve about 70% of its compressive strength at 28th day of curing age. Since our designated compressive strength is 30MPa, it is targeted that the compressive strength of all specimen should achieve at least 21MPa which is 70% of 30MPa at 7th day of curing age. Based on the tabulated result, all the concrete specimen had achieved more than 21MPa compressive strength at 7th day of curing age.

From table, it can be observed that concrete A1 still show the highest compressive strength with 61.969MPa while the lowest compressive strength is still recorded by concrete A4 with 37.866MPa at 28th day of curing age. The difference in compressive strength between concrete A1 and A4 is about 24.1MPa, which is 38.9% of declination in strength after blended with eggshell powder and fly ash. Meanwhile, the compressive strengths of concrete A2 and A3 are recorded as 48.171MPa and 43.149MPa respectively, whereby both are higher than the compressive strength of concrete A4 at 28th day of curing age.

Figure 5.0 indicates that concrete A1 shows the highest compressive strength at 3rd, 7th and 28th day of curing age when compare with concrete A2, A3 and A4. At the same time, it can be observed that the compressive strength of concrete decrease with the further increase in proportion of fly ash and eggshell powder. The difference in compressive strength between concrete A1 and concrete A4 has become gradually obvious with the development of curing age, from the initial 13.659MPa at 3rd day till 24.1MPa. Concrete A2 has shown a steady trend in compressive strength development as it maintained higher when compare to the compressive strength of concrete A3 and A4 throughout the 28 days of testing. In other words, 35% (5% ESP, 30% FA) of cement replacement of concrete A2 is the optimum mix design of concrete of blended cement with eggshell powder and fly ash.

As compare with the study done by previous researchers, concrete of blended cement with eggshell powder and fly ash possess the similar trend. Research done by Dhanalakshmi et al., (2015) had shown that the compressive strength of eggshell concrete was lower than control concrete mix (M40). Mohamed Ansari et al., (2016) who conducted the research of replacement of cement using eggshell powder also found that the compressive strength will decrease with the further incorporation of eggshell powder as cement replacement. As at present study, compressive strength of the control is the highest among all the mix design concrete. There is a similar trend that compressive strength of concrete decrease with the further increase in proportion of eggshell powder from 5% to 15%.

Table 4.1: Result of compressive strength test

Sample	ESP%	FA%	Compressive Strength (MPa)		
			Day 3	Day 7	Day 28
A1	0	0	38.384	45.625	61.969
A2	5	30	31.657	35.962	48.171
A3	10	30	28.045	32.239	43.149
A4	15	30	24.725	27.610	37.866

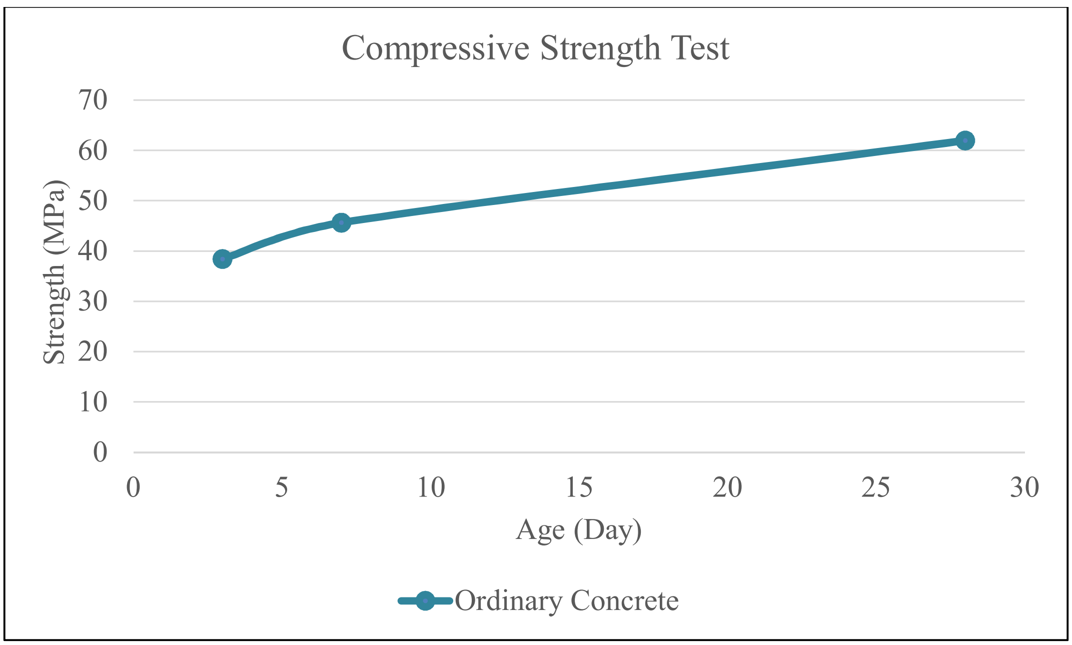

Figure 4.1: Compressive strength development of control concrete

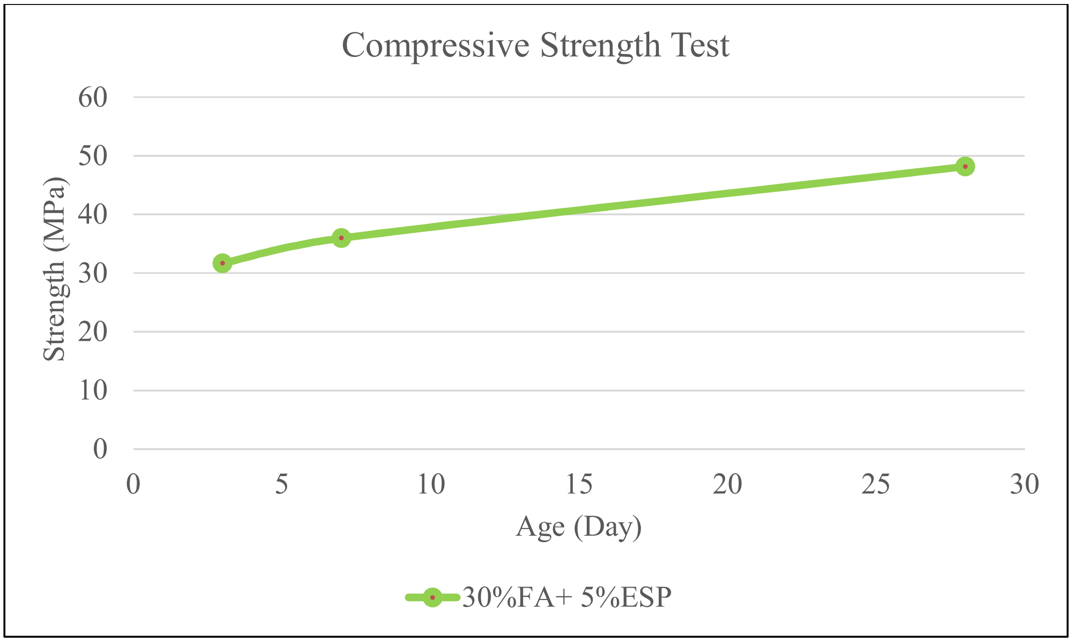

Figure 4.2: Compressive strength development of concrete of blended cement with 5% ESP and 30% FA

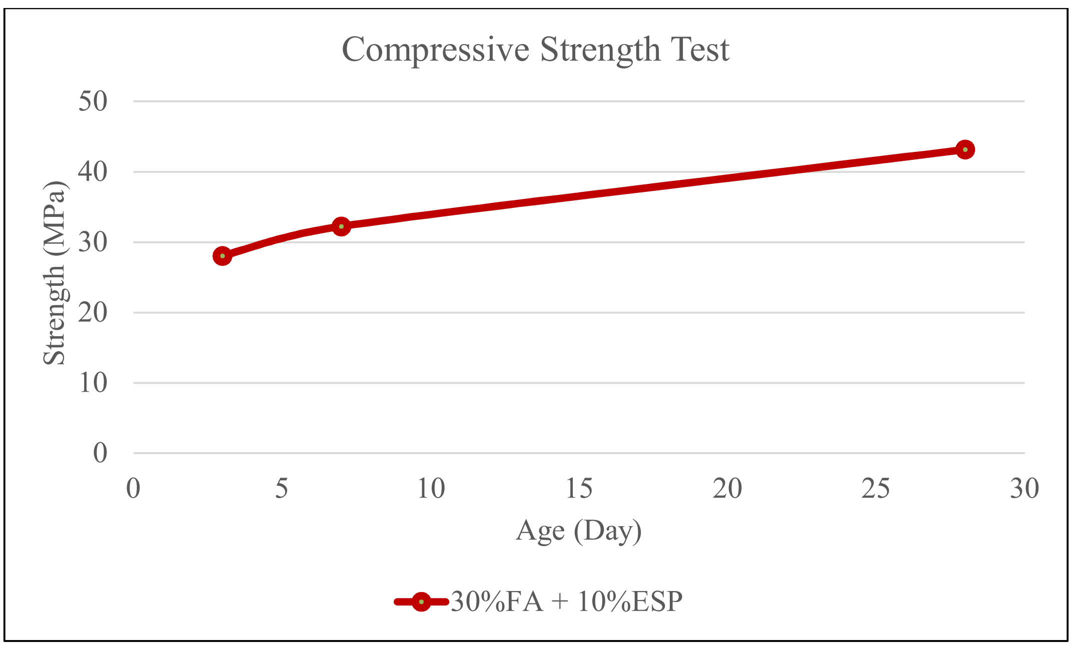

Figure 4.3: Compressive strength development of concrete of blended cement with 10% ESP and 30% FA

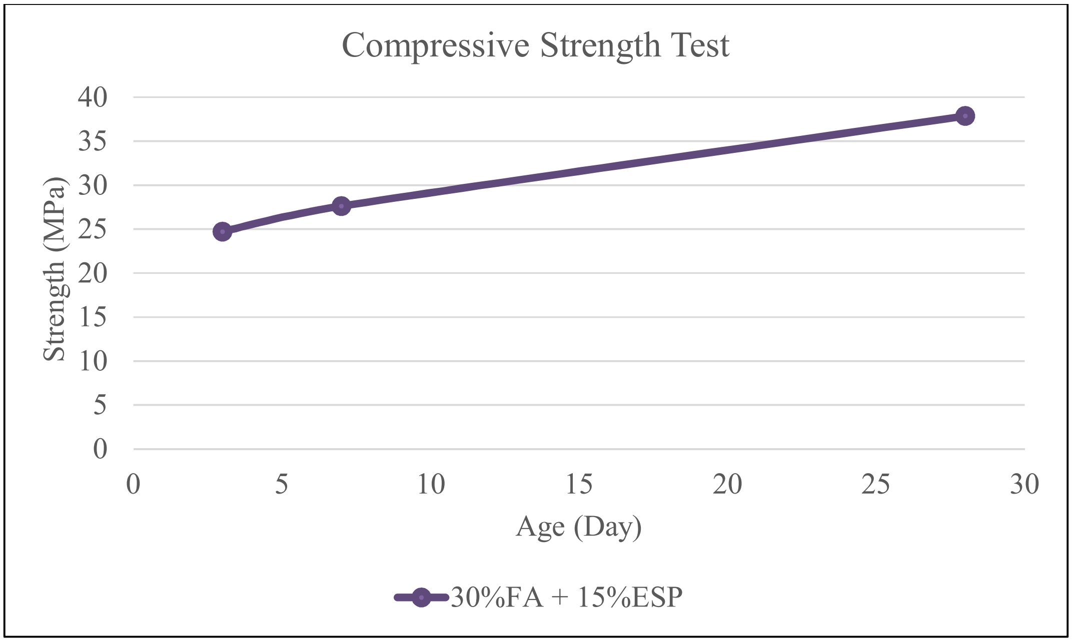

Figure 4.4: Compressive strength development of concrete of blended cement with 15% ESP and 30% FA

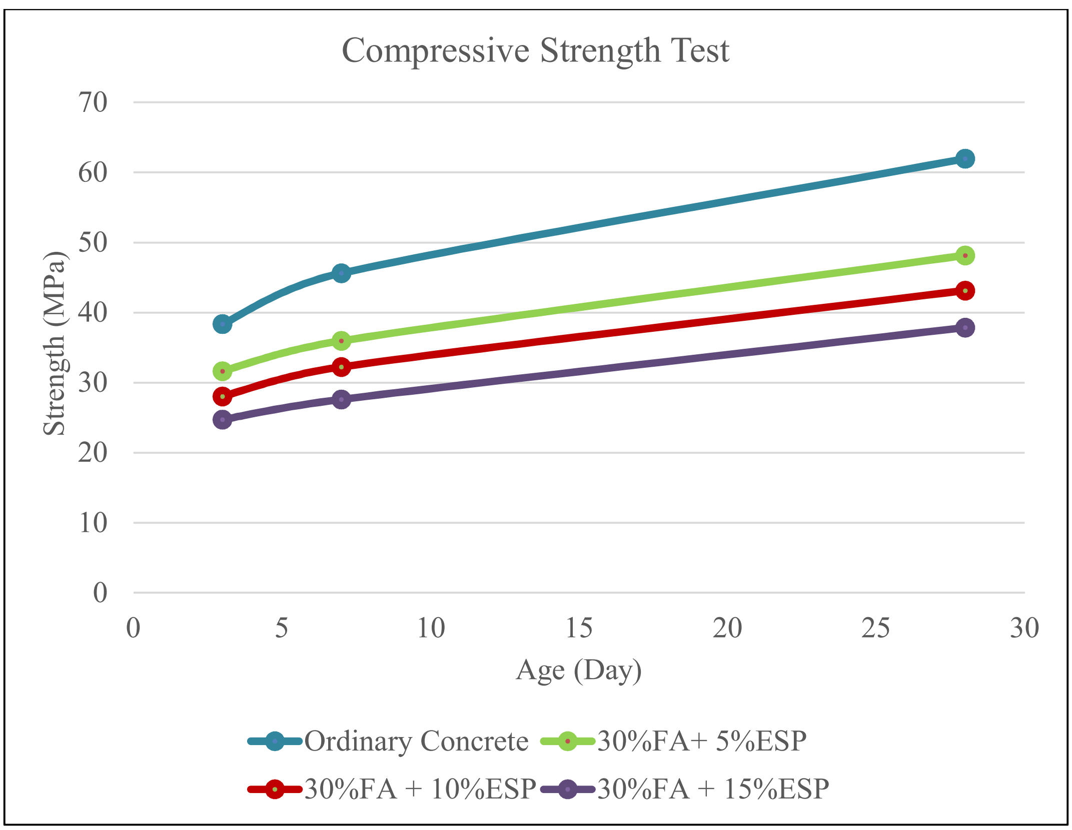

Figure 4.5: The effect of fly ash & eggshell powder on compressive strength development of concrete

4.3 FLEXURAL STRENGTH TEST

Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen. Flexural strength test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. Unlike a compression test or tensile test, flexure strength test does not measure fundamental material properties. When a specimen is placed under flexural loading, all three fundamental stresses are present including tensile, compressive and shear. Hence, the flexural properties of a specimen are the result of the combined effect of all three stresses as well as the geometry of the specimen and the rate of the load applied.

The result of flexural strength for concrete with 30% of fly ash and different percentage of eggshell powder is tabulated in Table 2.0. Figure. 6.0 shows the effect of fly ash & eggshell powder on flexural strength of concrete. Generally, all the concrete samples show increase trend in flexural strength development from 3rd to 28th day.

From the table, it can be observed that concrete B1 with 0% of eggshell powder and fly ash shows the highest flexural strength at 3rd day of curing age, which is 5.045MPa while the flexural strength of concrete B4 is the lowest among the 4 type of sample, which is 3.286MPa. Concrete B1 and B4 show a contrast of 1.759MPa in flexural strength, which is about 34.9% reduction in strength after blended with eggshell powder and fly ash. The flexural strengths of concrete B2 and B3 are slightly higher than concrete B4 at 3rd day of curing age, which recorded as 4.310MPa and 3.748MPa respectively.

At 7th day of curing age, concrete B2 has recorded the highest flexural strength with 6.291MPa while concrete B4 has recorded the lowest flexural strength with 5.096 MPa, which is about 1.195MPa difference between concrete B2 and B4. Unlike the result at 3rd day of curing age, concrete B1 has only the 2nd highest of flexural strength with 5.872MPa at 7th day of curing age. The flexural strength of concrete B3 is recorded as 5.577MPa, which is 0.481 higher than the flexural strength of concrete B4.

Based on the result obtained from table, it is clearly shown that concrete B2 shows the highest flexural strength with 8.388MPa while the lowest flexural strength is still recorded by concrete B4 with 6.795MPa at 28th day of curing age. The difference in flexural strength between concrete B2 and B4 is about 1.593MPa, which is 19% of decrease in strength. Meanwhile, the flexural strengths of concrete B1 and B3 are recorded as 7.830MPa and 7.436MPa respectively, whereby both are higher than the flexural strength of concrete B4 at 28th day of curing age.

From Figure. 6.0, generally the result indicates that the flexural strength of all concrete increases with the age of concrete curing. Although concrete B1 shows the highest earlier flexural strength at 3rd day of curing age, concrete B2 with 30% of fly ash and 5% of eggshell powder shows a better result in flexural strength compare among all concrete mix as it has the maximum flexural strength at the age of 7th day and 28th day of curing age. The trend also indicates that the usage of eggshell powder and fly ash as cement replacement at 35% has improve the late flexural strength development of concrete. However, there is a decline trend in flexural strength with further increase in fly ash and eggshell powder percentage. From the tabulated result, it can be concluded that 30% of fly ash and 5% of eggshell powder is the optimum dosage for concrete to achieve higher flexural strength.

Research done by Doh and Chin (2014) regarding to the investigation of eggshell powder as potential filler in concrete had proved that incorporation of eggshell powder as filler into concrete had improved the flexural behaviour of concrete up to 22.9% compared to the control concrete. Based on the present study, concrete with 30% of fly ash and 5% of eggshell powder as cement replacement had achieved slightly improvement in flexural strength with 7.1% better than control concrete.

Table 4.2: Result of flexural strength test

Sample	**ESP%**	**FA%**	**Flexural Strength (MPa)**		
			Day 3	Day 7	Day 28
A1	0	0	5.045	5.872	7.830
A2	5	30	4.310	6.291	8.388
A3	10	30	3.748	5.577	7.436
A4	15	30	3.286	5.096	6.795

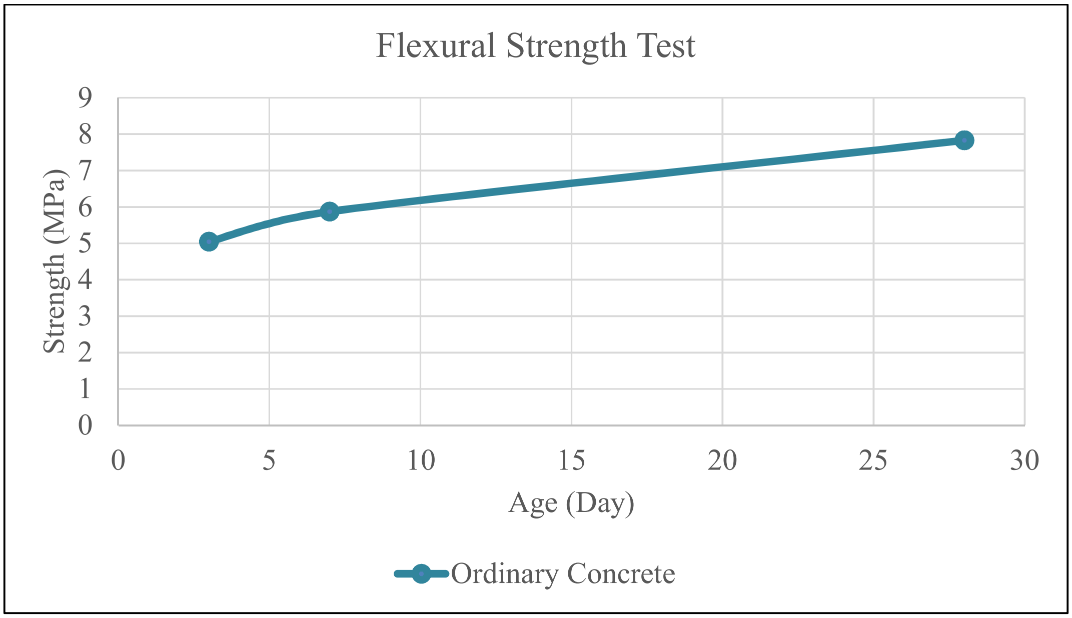

Figure 4.6: Flexural strength development of control concrete

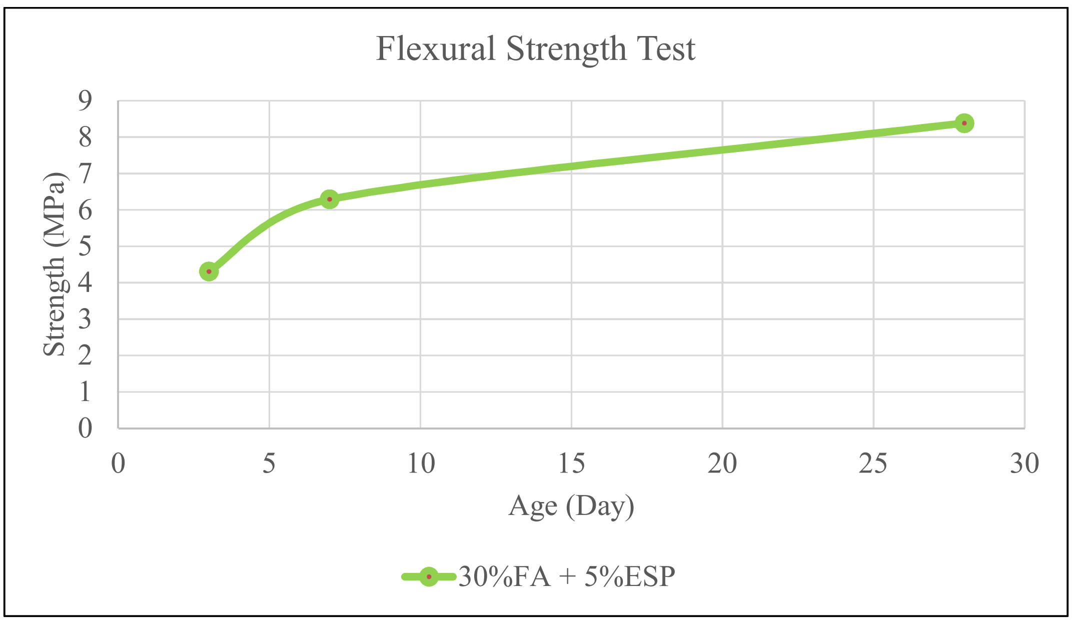

Figure 4.7: Flexural strength development of concrete of blended cement with 5% ESP and 30% FA

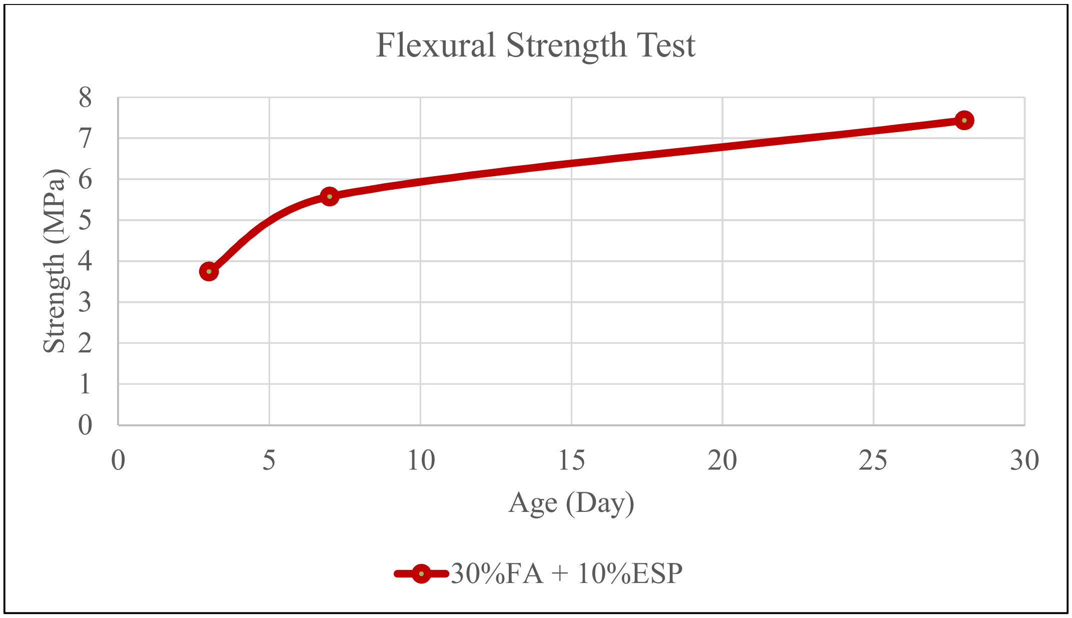

Figure 4.8: Flexural strength development of concrete of blended cement with 10% ESP and 30% FA

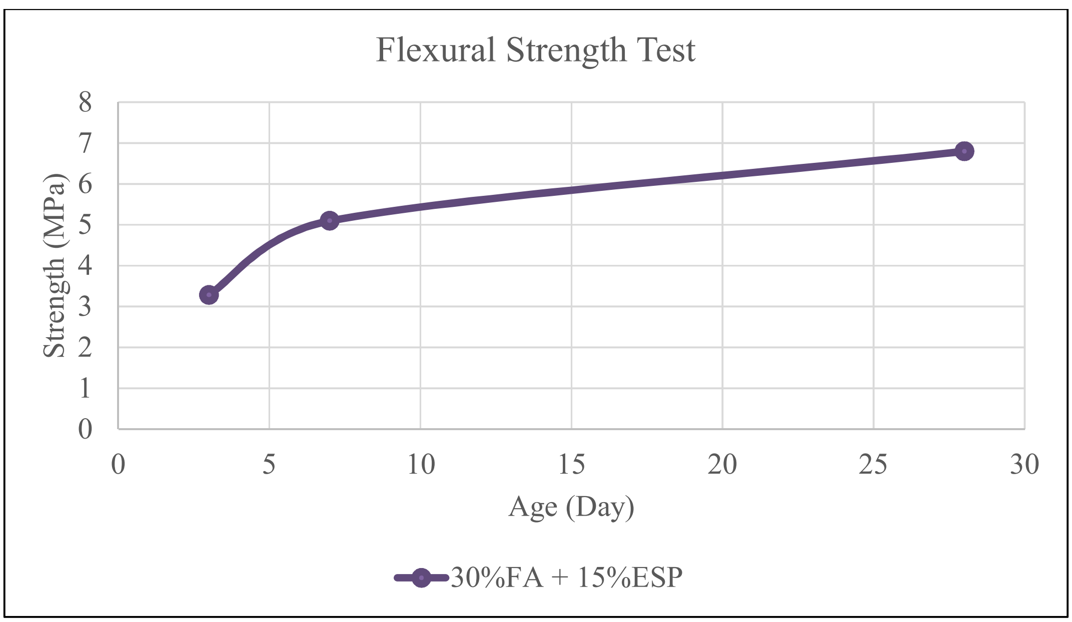

Figure 4.9: Flexural strength development of concrete of blended cement with 15% ESP and 30% FA

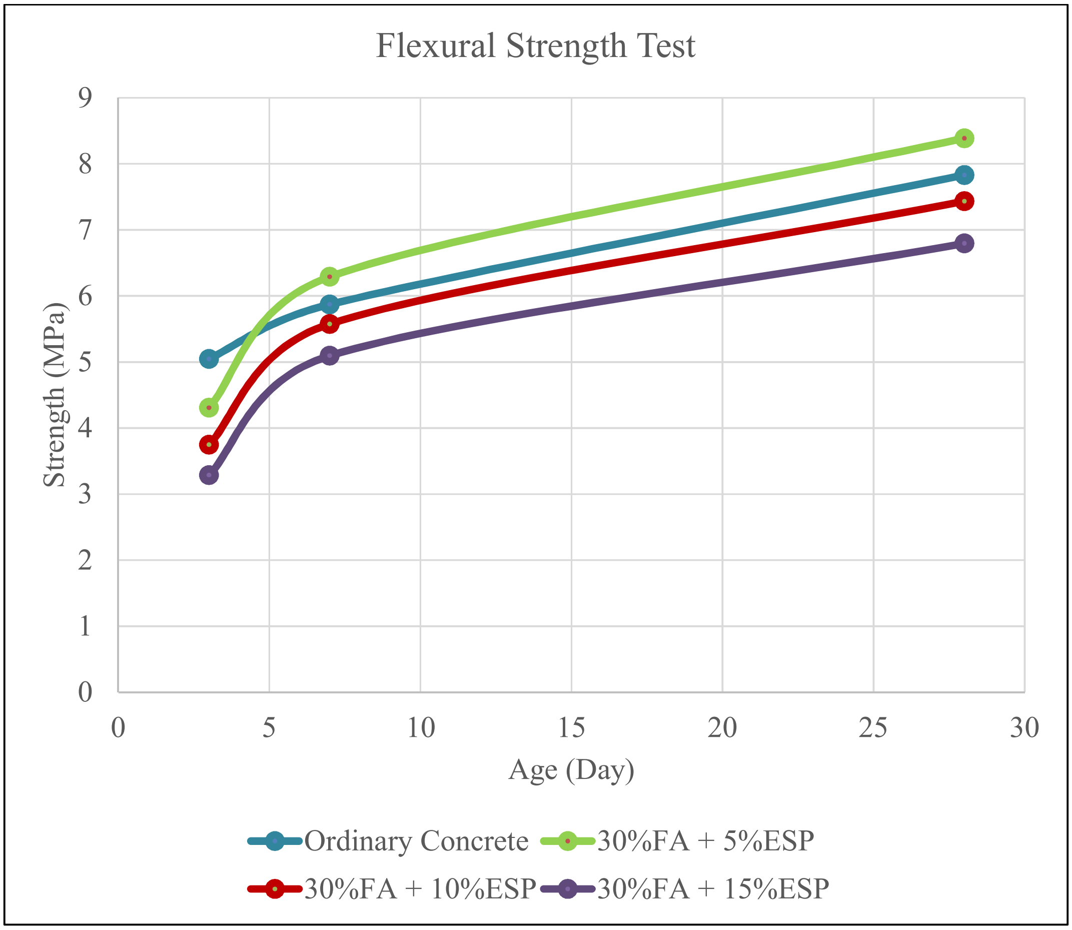

Figure 4.10: The effect of fly ash & eggshell powder on flexural strength development of concrete

4.4 SPLITTING TENSILE STRENGTH TEST

Tensile strength is a measure of the ability of material to resist a force that tends to pull it apart. Concrete has relatively high compressive strength, but significantly lower tensile strength. As a result, concrete would almost always fail from tensile stresses even when loaded in compression. In direct tensile strength test, it is impossible to apply true axial load as there will be always some eccentricity present. Hence, splitting-tensile test is conducted to determine the tensile strength of concrete at which the concrete members may crack when applied with load.

The result of splitting-tensile strength of concrete with 30% of fly ash and different proportion of eggshell powder is tabulated in Table 3.0. Figure. 5.0 shows the effect of fly ash & eggshell powder on splitting-tensile strength of concrete. Generally, all the concrete samples show increase trend in splitting-tensile strength development at the age of 3, 7 and 28 days of ambient curing. However, it is discovered that further inclusion of eggshell powder and fly ash in concrete has reduce the compressive strength of concrete.

At 3rd day of curing age, concrete C1 has recorded the highest splitting-tensile strength with 2.516MPa while concrete C4 has recorded the lowest splitting-tensile strength with 1.998MPa, which is about 0.518MPa difference between concrete C1 and C4. This result indicates that the concrete without any cement replacement by eggshell powder and fly ash is stronger in resisting early tensile stress at 3rd day of curing age. The compressive strengths of concrete C2 and C3 at 3rd day of curing age are slightly lower than concrete A1 which are 2.399MPa and 2.171MPa respectively.

From the table, it can be observed that concrete C1 with 0% of eggshell powder and fly ash shows the highest splitting-strength at 7th day of curing age, which is 2.680MPa while the splitting-strength of concrete C4 is the lowest among the 4 type of sample, which is 2.078MPa. Concrete C1 and C4 show a contrast of 0.602MPa in splitting-tensile strength, which is about 22.5% reduction in strength after blended with eggshell powder and fly ash. The splitting-tensile strengths of concrete C2 and C3 are marginally higher than concrete C4, which recorded as 2.536MPa and 2.241MPa respectively.

From table, it can be observed that concrete C1 still show the highest splitting-tensile strength with 3.373MPa while the lowest splitting-tensile strength is still recorded by concrete C4 with 2.224MPa at 28th day of curing age. The difference in splitting-tensile strength between concrete C1 and C4 is about 1.149MPa, which is 34.1% of declination in strength after blended with eggshell powder and fly ash. Meanwhile, the compressive strengths of concrete C2 and C3 are recorded as 2.981MPa and 2.411MPa respectively, whereby both are higher than the splitting-tensile strength of concrete A4 at 28th day of curing age.

Figure 5.0 indicates that concrete C1 shows the highest compressive strength at 3rd, 7th and 28th day of curing age when compare with concrete C2, C3 and C4. Meanwhile, it can be concluded that the splitting-tensile strength of concrete drop with the further increase in proportion of fly ash and eggshell powder. Concrete C1 shows an obvious rising trend in splitting-tensile strength development, which is about 34% increment from 3rd day till 28th day of curing age. While the development trends of splitting-tensile strength of concrete C3 and C4 are comparatively less obvious to an extent as they only increase about 11% from initial 3rd day till 28th day of curing age. Concrete C2 has shown a steady trend in compressive strength development as it maintained higher when compare to the splitting-tensile strength of concrete C3 and C4 throughout the 28 days of testing. In other words, 35% (5% ESP, 30% FA) of cement replacement of concrete C2 is the optimum mix design of concrete of blended cement with eggshell powder and fly ash. Besides, the results also demonstrated that irrespective of fly ash and eggshell powder percentage replacement, there is a good relationship between compressive strength and split tensile strength as both show similar trend in strength development.

Based on the research done by Karthick et al., (2014) to investigate the effect of eggshells on mechanical and physical properties of concrete, he discovered that the tensile strength was obviously decreased with increase in eggshell powder percentage as cement replacement, from 2.36MPa to 0.2MPa with increment of eggshell proportion from 0wt% to 50wt%. The current research also able to possess a similar trend as the the splitting-tensile strength of concrete decrease with the further increase in proportion of eggshell powder, which drop from 2.981MPa to 2.224MPa with the increase of eggshell powder percentage from 5% to 15%.

Table 4.3: Result of splitting-tensile strength test

Sample	**ESP%**	**FA%**	**Flexural Strength (MPa)**		
			Day 3	Day 7	Day 28
A1	0	0	2.516	2.680	3.373
A2	5	30	2.399	2.536	2.981
A3	10	30	2.171	2.241	2.411
A4	15	30	1.998	2.078	2.224

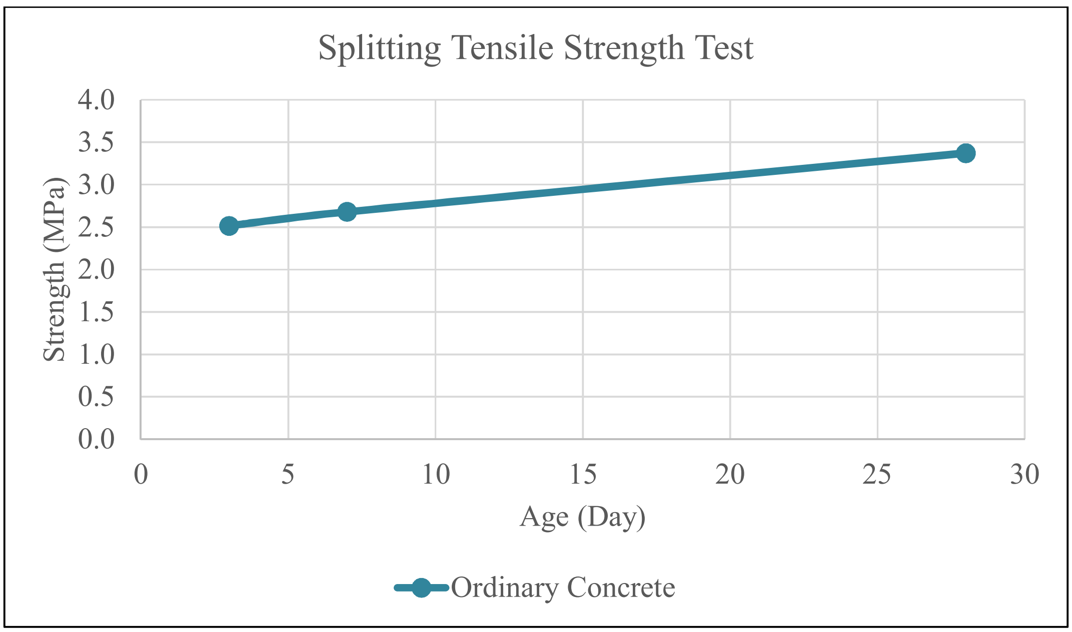

Figure 4.11: Splitting-tensile strength development of control concrete

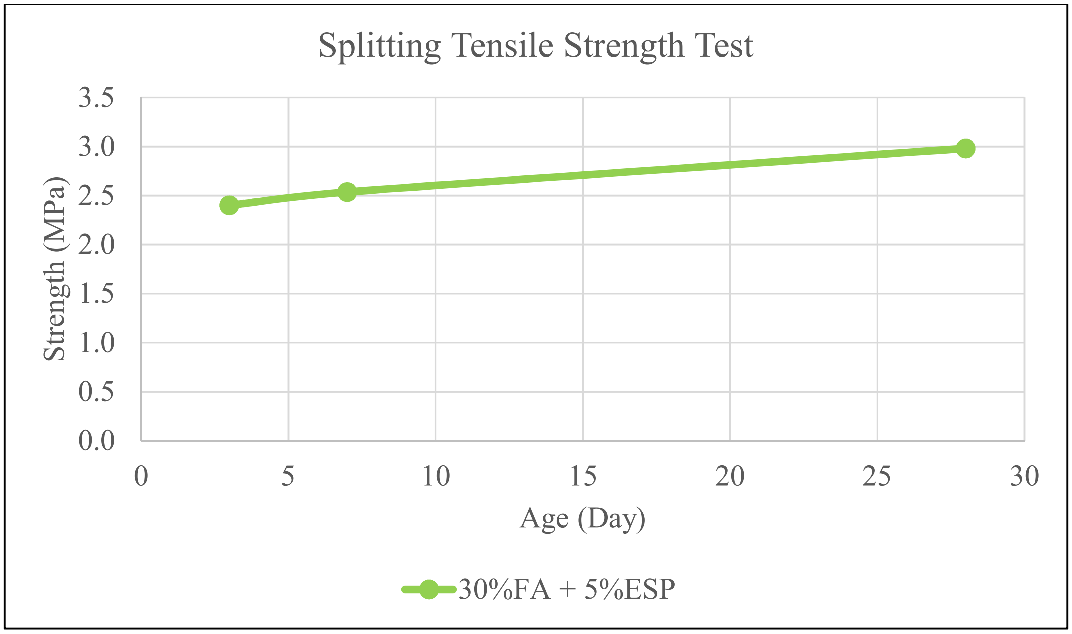

Figure 4.12: Splitting-tensile strength development of concrete of blended cement with 5% ESP and 30% FA

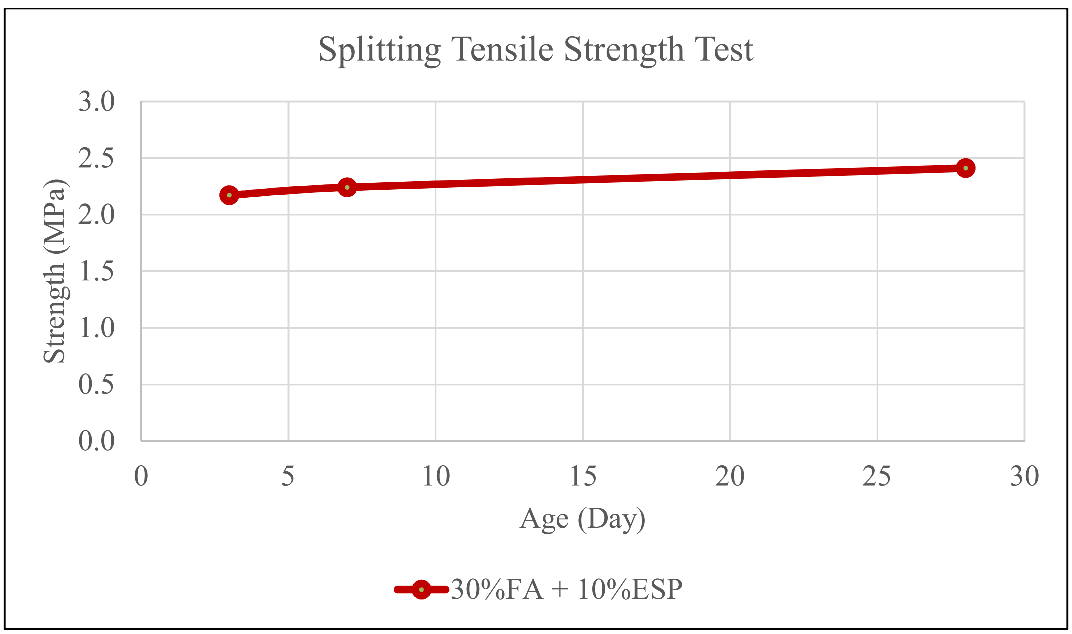

Figure 4.13: Splitting-tensile strength development of concrete of blended cement with 10% ESP and 30% FA

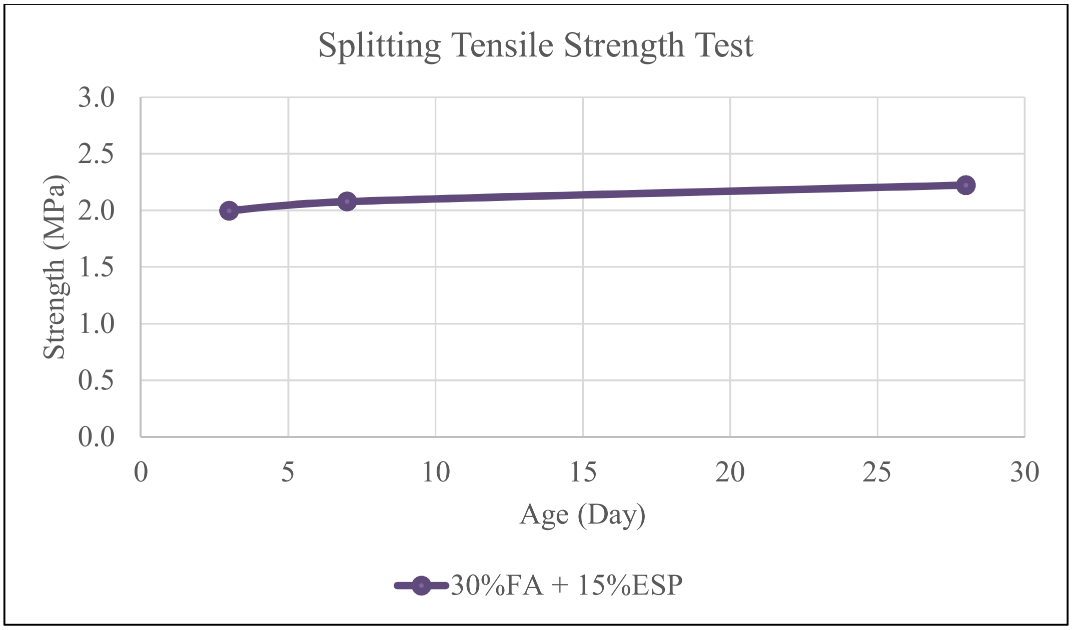

Figure 4.14: Splitting-tensile strength development of concrete of blended cement with 15% ESP and 30% FA

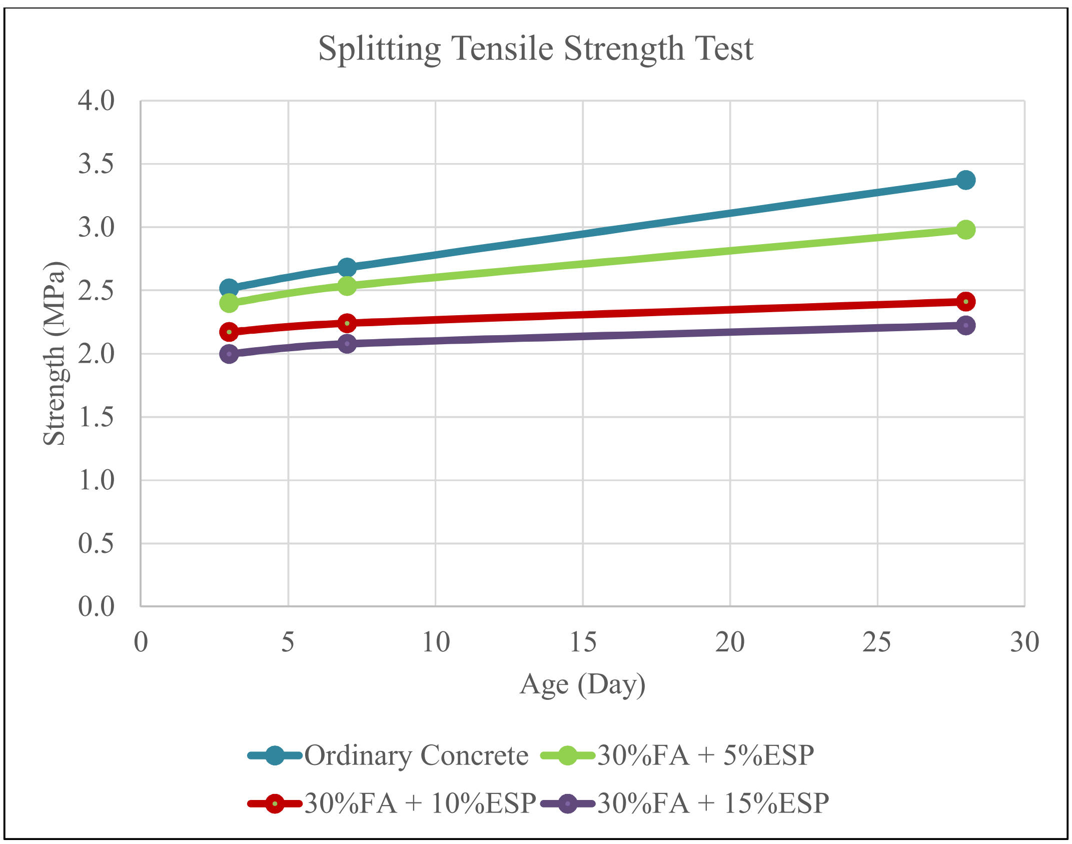

Figure 4.15: The effect of fly ash & eggshell powder on splitting-tensile strength development of concrete

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

For the last chapter, a number of conclusion regarding to this research study will be drawn based on the results and discussions made from previous chapter. The conclusion will also be linked with the outcome of research according to the objectives in Chapter 1. The objective of this research is to determine the mechanical properties of concrete of blended cement with eggshell powder and fly ash including compressive strength, flexural strength and splitting-tensile strength. Based on the result of mechanical properties, the optimum mix design for concrete of blended cement with eggshell powder and fly ash will be determined. Last but not least, several recommendations will be proposed for further investigation in future study related to this research.

5.2 CONCLUSION

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

i. It can be observed that all the casted concrete has achieved more than the designated compressive strength of 30MPa. Control concrete with 0% of eggshell powder and fly ash shows the highest compressive strength at 3^{rd}, 7^{th} and 28^{th} day of curing age. At the same time, it can be observed that the compressive strength of concrete decrease with the further increase in proportion of fly ash and eggshell powder. Concrete with 35% (5% ESP, 30% FA) of cement replacement is the optimum mix design of concrete of blended cement with eggshell powder and fly ash.

ii. All the concrete samples show increase trend in flexural strength development from 3rd to 28th day. Concrete with 30% of fly ash and 5% of eggshell powder shows a highest result in flexural strength at the age of 7th day and 28th day of curing age. However, there is a decline trend in flexural strength with further increase in fly ash and eggshell powder percentage. It can be concluded that 30% of fly ash and 5% of eggshell powder is the optimum dosage for concrete to achieve higher flexural strength.

iii. All the concrete samples show increase trend in splitting-tensile strength development at the age of 3, 7 and 28 days of ambient curing. However, it is discovered that further inclusion of eggshell powder and fly ash in concrete has reduce the compressive strength of concrete. Control concrete with 0% of eggshell powder and fly ash shows the highest compressive strength at 3rd, 7th and 28th day of curing age. Concrete with 35% (5% ESP, 30% FA) of cement replacement is the optimum mix design of concrete of blended cement with eggshell powder and fly ash. The results also demonstrated that irrespective of fly ash and eggshell powder percentage replacement, there is a good relationship between compressive strength and split tensile strength as both show similar trend in strength development.

5.3 RECOMMENDATIONS FOR FUTURE RESEARCH

The main objective of this research is to determine the mechanical properties of concrete of blended cement with eggshell powder and fly ash including compressive strength, flexural strength and splitting-tensile strength. Other than that, there are several recommendations could be conducted to improve the research for future study:

i. Determination of workability of fresh concrete of blended cement with eggshell powder and fly ash through slump test and ultrasonic pulse velocity test.

ii. Investigation of the thermal conductivity and fire resistance of concrete with blended cement and eggshell powder and fly ash.

iii. Determination of the impact of pozzolanic reaction of fly ash towards the long term compressive strength of concrete with blended cement and eggshell powder and fly ash.

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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

([illegible] University [illegible])

SAMPLE

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