THE EFFECT OF EGGSHELL POWDER ON CONCRETE BRICK PERFORMANCE AS PARTIAL REPLACEMENT OF CEMENT

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ABSTRACT

Concrete is one of the materials that is widely used in construction all around the world. This material is widely used because it has several benefits such as, more durable, energy-efficient, low maintenance, affordability, fire-resistance, excellent thermal mass and also versatility. This study describes investigation into use of poultry waste in concrete development by incorporating with eggshell powder. Different eggshell powder concrete brick were developed by replacing 5-20% of eggshell powder for the cement in order to determine the optimum percentage and observe the strength of concrete brick to produce good cementations material for eggshell powder. The results indicated that eggshell powder can successfully be practice as partial replacement of cement in concrete brick production. The data collected show the cover strength development and durability properties. With respect to the results, at 5% replacement of eggshell the strength was higher than control concrete brick and indicates that 5% of eggshell replacement was an optimum content for maximum strength. Furthermore, the performance of eggshell powder concrete brick was comparable up to 10% eggshell powder replacement in terms of durability properties with control concrete brick.

ABSTRAK

Konkrit adalah salah satu bahan yang digunakan secara meluas dalam pembinaan di seluruh dunia. Bahan ini digunakan secara meluas kerana ia mempunyai beberapa faedah seperti, lebih tahan lama, tenaga yang cekap, penyelenggaraan rendah, kemampuan, api rintangan, jisim haba yang sangat baik dan juga serba boleh. Kajian ini menerangkan penyiasatan penggunaan sisa ternakan dalam pembangunan konkrit dengan menggabungkan dengan serbuk kulit telur. Berbeza kulit telur bata konkrit serbuk telah dibangunkan dengan menggantikan 5-20% serbuk kulit telur untuk simen untuk menentukan peratusan optimum dan memerhati kekuatan bata konkrit untuk menghasilkan bahan cementations baik untuk serbuk kulit telur. Hasil kajian menunjukkan bahawa serbuk kulit telur boleh berjaya akan mengamalkan gantian separa simen dalam pengeluaran bata konkrit. Data yang dikumpul menunjukkan pembangunan dan ketahanan sifat kekuatan perlindungan. Berkenaan dengan keputusan, di penggantian 5% daripada kulit telur kekuatan yang lebih tinggi daripada mengawal bata konkrit dan menunjukkan bahawa 5% daripada penggantian kulit telur itu merupakan suatu kandungan optimum untuk kekuatan maksimum. Tambahan pula, prestasi serbuk kulit telur bata konkrit adalah setanding sehingga 10% penggantian serbuk kulit telur dari segi ciri-ciri ketahanan dengan kawalan bata konkrit.

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LIST OF SYMBOLS

Symbol		Item
%	-	Percentage
g	-	Gram
°C	-	Degree celcius

LIST OF ABBREVATIONS

UPV	-	Ultrasonic Pulse Velocity
BS	-	British Standard
UMP	-	University Malaysia Pahang
ASTM	-	American Society for Testing and Materials
SIRIM	-	Standards and Industrial Research Institute of Malaysia
CO_2	-	Carbon dioxide
SiO_2	-	Silicon oxide
Al_2O_3	-	Aluminum oxide
Fe_2O_3	-	Iron oxide
CaO	-	Calcium hydroxide
MgO	-	Magnesium oxide
K_2O	-	Potassium oxide
Na_2O	-	Natrium oxide
SO_3	-	Sulfur trioxide
w/c	-	Water cement
NiO	-	Nickel (II) oxide
Cl	-	Chlorine
Sro	-	Strontium oxide
P_2O_5	-	Phosphorus pentoxide
LOI	-	Loss on Ignition
$CaCO_3$	-	Calcite

GHG	-	Greenhouse gas
MPa	-	Mega Pascal
μm	-	Micron
mm	-	Millimeter
kg	-	Kilogram
min	-	Minute
hr.	-	Hour
v	-	Velocity
km/s	-	Kilometer per second
s	-	Second

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Throughout the world, concrete is being widely used for the construction of most of the buildings, bridges and others. Hence, it has been properly labeled as the backbone to the infrastructure development of a nation. Nowadays, the construction industries are searching for alternative products that can reduce the construction cost. Various types of waste material with processing and treatment might be replaced as a potential building material and to be used in many types of construction project. However, not all the waste material can be reuse as building materials even to process it as well. Thus, researches and experiment to evaluate the effective and potential of waste reuse for construction industry is required. The usage of waste product such as eggshell powder as cement replacement to produce a new upgraded brick are seen to be the most effective way to maximize the profit while reducing the amount of waste.

Eggshells are known to have good strength characteristics when mixed with concrete. Calcium rich eggshell is a poultry waste with chemical composition nearly same with the limestone (Amu et al., 2005). Besides, its chemical composition almost similar to that of ordinary Portland cements (Uma Shankar & Balaji, 2014). However, as limestone is a natural mineral resource, quarrying and further uses of limestone may lead to problems related to environment. A part from that, lime production involves energy intensive process and consumes water. Therefore, identifying analogous material from waste and using the same in concrete production could be wise idea. Use of eggshell waste instead of

natural lime to replace cement in concrete brick can have benefits such as reducing the use of cement. The use of eggshell powder in concrete production reduced the cost of raw material and contributes to the construction industry. Thus, eggshells can be applicable to reduced cost of construction material and produced a new raw material for development in the construction industry.

Several researches and studies about the eggshell have been made to know it characteristic. Based on Okonkwo et al. (2012) eggshell established to be a good accelerator for cement-bound materials and considerable reduction in alkali-silica and sulfate expansions Dinesh et al. (2014). Research show that eggshell has a cellulosic structure and contain amino acids, thus is expected to be a good bio-sorbent or in other word bio sorption. It is a metabolically passive process which it does not require energy that bind contaminants onto its cellular structure and concentrate adsorbents from aqueous solutions resulting in a reduction of sorbet concentration in the solution. So it's have excellent durability as well as save money as less material required.

Recently, the brick is mainly from clay or concrete and the clay is the most common material used in the production of brick. Since the material is nonrenewable source and may deplete on the coming years and it's seen like non economical to produce due cost of brick which produced with the above material increased continuously. Furthermore, the clay brick has come under a different kind of fire due to its environmental impact. The firing process in the manufacture of clay bricks has raised some sustainability concerns because of the energy consumption and greenhouse gas (GHG) emission such carbon dioxide (CO2) and it is considers accelerating climate change. Thus, there have to consider incorporated recycle content into the conventional bricks (Chusid, et al., 2009). Therefore, identifying analogous material from waste and using the same in concrete production could be wise idea.

1.2 PROBLEM STATEMENT

Eggshell is classified as a waste material by the food industry but is in fact a highly sophisticated composite. However, majority of eggshell waste is deposited as landfills. It is observed that Malaysia consumed the highest chicken and egg consumption among the Asian countries. High consumption of eggs has generated large amount of eggshells to be disposed. The usage of food waste such as eggshells in Malaysia is very limited compared to the European countries (Maybank IB research, 2011). Its increasing with high demand due to food plants constantly accumulating substantial quantities of eggshell. As a consequence, huge problem of pollution is generated as well as it can attract rats and worms due the organic protein matrix, resulting in a problem of public health (Jayasankar et. al, 2010).

There are several types of waste disposal system. The common waste disposal systems used in Malaysia are open burning, ocean dumping, compositing, incineration and land filling. Almost all the waste in Malaysia are dispose using landfill method and majority of the sites are poorly managed. Due to the large amount of waste production, the number of landfilling sites has increased and the number of landfilling sites is expected to increase as result to growth in population, economy and agriculture (Zaini, 2011). A part from that based on his research, dumping site in Malaysia has increased in alarming rate. So identifying material from waste and using in concrete production could be some wise idea as Portland cement costly, energy intensive and produces large amounts of carbon emissions (P. Vipul Naidu & Pawan Kumar Pandey, 2014).

Therefore, research study about use of a waste material as a replacement to cement and aggregates is necessary to conduct as recycling eggshells into the useful product gives good potential benefit on many levels, both for food manufacturers and a much wider construction industry. This research will focus on the utilization of eggshell powder in the brick production due to the brick as a main building material.

1.3 OBJECTIVES

The aim of this study is to investigate the possibility of eggshell powder as a partial replacement of cement in brick production in order to produce good cementations material. There are few objectives will be done to achieve the target. The objectives of this study are

i. To determine the optimum percentage replacement of eggshell powder in concrete brick.
ii. To investigate the effect of eggshell powder use on concrete brick strength properties.
iii. To examine the water absorption of eggshell concrete brick.

1.4 SCOPE OF STUDY

The scope of this research will cover study about the performance of the chicken eggshell as a cement replacement in concrete mixed using ratio 1:3. The main material used for the experiments was eggshell and the composition of concrete brick including composite Portland cement and sand with w/c ratio 0.5. The eggshells used through in the research were obtained from Eggtech Manufacturing Sdn Bhd, Selangor. Different eggshell powder concrete brick were developed by replacing 5-20% of eggshell powder for the cement in order to determine the optimum percentage and observe the strength of concrete brick to produce good cementations material for eggshell powder. The experiments that will be carry out to investigate are compressive strength, water absorption test and ultrasonic pulse velocity test respectively. These eggshells must be grinded into fine powder. This test will be tested at 3 day, 7 day and 28 days to get the strength. Compressive strength test will determine the hardened concrete brick. On the other hand, the water absorption test is carried out to determine the durability of concrete. Durability is one of the important characteristic of concrete and is tested for the absorption rate of the concrete brick. Besides that, the ultrasonic pulse velocity test used to predict the concrete strength and also to detect the presence of internal flows in the concrete brick.

1.5 SIGNIFICANT OF STUDY

This study is very important because waste management is one major issue in Malaysia as this method will help to reduce the amount of eggshell waste and contribute in reducing the cost of construction. Therefore, it was decided that this is a method to solve the problem from the issues that arise from the problem of waste disposal, including support for environmental problems mainly caused pollution to public health. In addition with concrete test particular, it will increase the strength properties and durability of concrete as well as help our economy rising in the construction industry section.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Literature review is various studies that discussed the relevant materials which related to this project. Since the eggshell is related to the topic, the application and characteristic of eggshell waste will be discussed in this chapter based on previous research. Besides that, characteristic of concrete, cement, aggregate, water and industrial waste also discussed.

2.2 CONCRETE

Concrete is a composite material consisting of embedded filler in hard matrix materials occupy between aggregate particles and glue them together. We can also consider the concrete as composite materials consist essentially in the medium to bind in the embedded particles or fragments of the aggregates. Concrete productions are made up of several methods to produce high strength concrete such as batching, mixing, consolidation, finishing and curing. Every step of the process of making process will produce a unique contribution to the quality of the final products of concrete (Kejin & Jiong, 2005).

As for the rest of the green building issues and problems, concrete management has evolved in relation to the environment in a sustainable development perspective. Part of it, Portland cement production generates large amounts of carbon dioxide emissions and energy intensive (Naidu & Pandey, 2014) which hazardous that lead to environmental

problems. Thus, components such as oil palm waste and sludge is mixed into concrete to reduce waste and mitigate environmental pollution.

2.3 CONCRETE DURABILITY

Durability of concrete is the major issue in concrete. The durability of concrete is concrete's ability to remain fully functional in the long term under normal service conditions for the purpose for which it was designed. Besides causing by load on structure, cracking of concrete also contributed by durability and long-term life (Mihashi et al., 2004). The durability of concrete normally associated to permeability. Permeability means the rate at which aggressive agents can penetrate to attack the concrete and steel reinforcement. Corrosion damage related with concrete structures is a main problem relating with the cost of repairs and sometimes the replacement of structure that normally expensive (Reddy et al., 2012).

When concrete cracks, it result in the increasing of water permeability and aggressively water able to penetrate more easily into the interior, thus speeding up the process of deterioration which form a result of a progressive loss of strength and loss of mass due to loss of cohesiveness in the cement hydration products. Sometimes, concrete expansion caused serious structural problems (Monteiro, n d).

2.4 CEMENT

There are various different properties and uses of cements to be apply in concrete including Portland, blended, and hydraulic cements. Portland cements is a main element of the concrete. Cement is hardened because of the water and chemical reaction that acts as a bonding agent to concrete. The aggregates and sand together bond together by cement, along with water to produce high compressive strength after it hardened.

According to Portland Cement Association (2009), the concrete basic material is a closely controlled chemical combination of calcium, aluminum, silicon, iron and a little

amounts of other ingredients to which gypsum is added in the end of grinding process to control the setting time of the concrete lime and silica make up about 85% of the mass. Common among the materials used in the manufacture are limestone, shells and chalk or marl combined with shale, clay, slate or blast furnace slag, silica sand and iron ore. Thus, the properties of concrete are influenced by the properties of cement. Types and proportions of cement affect both the fresh and hardened properties of concrete. Understanding of the characteristics of the cement can be imparted to many of the issues arise in concrete construction. The chemical properties of cement are shown in Table 2.1 (Kurtis, n d).

Table 2.1: The Cement Properties (Kurtis, no date)

OXIDE ANALYSIS	PERCENTAGE (%)
SiO_2	20.6
Al_2O_3	5.07
Fe_2O_3	2.90
CaO	63.9
MgO	1.53
K_2O	0.73
Na_2O	0.15
SO_3	2.53
LOI	1.28

2.5 FINE AGGREGATE

Fine aggregate is one of important component of concrete. Fine aggregates consist of natural resources and manufactured from gravel. Aggregates impart higher volume stability and better durability than hydrated cement paste in concrete and provide around 75% of the body of concrete. The most common fine aggregate used is natural river sand. Finer aggregate have better positive effects on the properties of concrete and hardened high performance concrete. Fine aggregate will play a role in the concrete mixtures. In addition,

particle shape and texture of fine aggregate affect concrete mainly through their influence on the workability of fresh concrete (Steven et al., 2005).

If the quality of fine aggregate is not available for any reason, blending sand need to be done by adding more coarse sand to achieve the desired finest modulus which meet the requirements. Particle size is measured with samples through a series of screens with various sizes of opening (Nelson, 2006). The quality of fine aggregates or sand can be check by several techniques, one of them is put some quantity of sand in a glass of water. If the clay is present in sand, its distinct layer is formed at the top of sand. Some aggregates have higher permeability of the capillary pores of the cement paste because they are larger. (Monteiro, n d).

2.6 WATER

Water is chemical compounds in form of liquid which clear and transparent in characteristic. A water molecule contains oxygen and two hydrogen atoms bond together by covalent bonds. Water is a liquid at standard temperature and pressure, but it often co-exists on earth with a solid state, liquid state, and gaseous state. Water used in mixing concrete should be free from acid, alkali, oil and organic purities. Wash water is naturally used as mixing water in ready mixed concrete. Excessive impurities in the mixing water not only can affect setting time and strength of concrete, but also may cause staining, efflorescence, corrosion of reinforcement, reduce durability and volume instability.

The mix's water/cement ratio is important to concrete performance. In hydration process of the cement, water is essential for providing concrete mechanical strength, but it must be dosed properly. Excessive water may increases the porosity of the concrete, thereby reducing the durability and mechanical performance. However, lack of water in the mixture will lead to incomplete reaction of cement hydration and decrease the workability of fresh concrete (Fernando et al., 2013).

2.7 INDUSTRIAL WASTE

Industrial production increased the demand of the raw material for its purpose. As the material for production considered as non-renewable sources and will be reduce in the coming years. Therefore, disposal of industrial wastes were used to replace the raw material for various beneficial use. However, the disposal of different wastes that produced from different industries is a huge problem because lots of them are non-biodegradable (Tara & Mishra, 2010). A part from that, not only industrial wastes containing solid waste, it also includes with the hazardous waste. Fortunately, the types of industrial waste which produced in developing countries not usually in large quantities of hazardous waste for disposal.

With a rapidly number of industrial wastes generated, there are opportunities to improve recovery of waste as resource and also help to reduce the industrial dependency on the non-renewable resources such as raw material. Waste recovery practice was supported by Malaysian government through policies and laws (Fariz, 2008).

Part of the industrial waste will be disposed of as construction material, if this material can be used as in construction, pollution and disposal problems may be reduced in part. Therefore, the disposal of industrial waste must be handled properly to reduce environmental problems and also have a significant impact on economic growth.

2.8 EGGSHELL

Egg is a significant food for Asian country such as Malaysia, Singapore, Philippines and Thailand. Egg contains lots of nutritious, however, the main content is protein and protein's content in egg is higher compare with other foods. High consumption of egg also follows increasing the eggshell waste development rate.

Based (Okonkwo et al., 2012) eggshell established to be a good accelerator for cement-bound materials. There are a lot of experimental works carried out by introducing

recycled materials like egg shell powder as a substitute for cement with different percentages to enhance the properties of concrete. Eggshell also considerable reduction in alkali-silica and sulfate expansions (Santhanatham, 2014). Research show that eggshell has a cellulosic structure and contain amino acids, thus is expected to be a good bio-sorbent or in other word bio sorption. It is a metabolically passive process which it does not require energy that bind contaminants onto its cellular structure and concentrate adsorbents from aqueous solutions resulting in a reduction of sorbet concentration in the solution. So its have excellent durability as well as save money as less material required.

The eggshell is an important structure for two reasons which it forms an embryonic chamber for the developing chick and providing protection of the contents and a unique package for a valuable food. Most good quality eggshell from commercial layers contain approximately 2.2g of calcium in the form of calcium carbonate. Calcium rich eggshell is a poultry waste with chemical composition nearly same with the limestone (Amu et al., 2005). The chemical properties of cement are shown in Table 2.2 (Jayasankar et al., 2010).

Table 2.2: The Eggshell Properties (Jayasankar et al., 2010)

OXIDE ANALYSIS	PERCENTAGE (%)
SiO_2	0.09
Al_2O_3	0.03
Fe_2O_3	0.02
CaO	50.7
MgO	0.01
NiO	0.001
Na_2O	0.19
SO_3	0.57
Cl	0.219
Sro	0.13
P_2O_5	0.24

Based on chemical analysis on eggshells, the chemical composition of the avian eggshell waste sample shows that calcium oxide (CaO) was the most abundant component. The high amount of calcium oxide is associate the presence of calcium carbonate, which is the main component of avian eggshell. In addition, it was also observed that the loss ignition for waste sample was found to be 47.8%. This high value of Loss of ignition (Loi) is caused mainly by decomposition of the calcite with formation of CaO and carbon dioxide (CO2). The avian eggshell waste sample is basically consisted of calcium carbonate in the form of calcite (CaCO3). Then, the eggshell waste material can be of immense interest as a construction raw material.

2.9 EGGSHELL STUDY

Good qualities of eggshell contain approximately 2.2 g of calcium in the form of calcium carbonate from commercial layers. Dry Eggshell contain about 95% of calcium carbonate weighing 5.5 g and the other are contains about 0.3% phosphorous, 0.3% magnesium, and traces of sodium, potassium, zinc, manganese, iron and copper (Amu & Salami, 2010). The organic material has calcium binding properties, and its organization during shell formation influences the strength of the shell. The organic material must be deposited so that the size and organization of the crystalline components mostly calcium carbonate are ideal, thus leading to a strong shell.

Most parts of the world did not use the eggshell as stabilizing material but it can be the other type of stabilization if it is use as a replacement. The mixture consist of lateritic soil and eggshell can produce the low binding properties and significant to improve the strength of the soil which had been used as a sub grade where have good performance. The requirements of the capacities of the stabilization of the base or sub base for road construction have not met the minimum needed. The increase of the eggshell content can increased the optimum moisture content but it can reduced the maximum dry density of the soil-cement eggshell ash stabilized lateritic soil and the strength properties of the cement-stabilized matrix increase up to about 35% averagely (Okonkwo et al., 2012).

It proved that the eggshell is suitable to use as the stabilizing materials and it also can improve the strength of the soil. The result from the study shows that eggshell significantly increase the maximum dry density and optimum moisture content of the soil. As 8% eggshell stabilization lateritic soil processes close optimum moisture content and maximum dry density properties. Therefore, the eggshell is also suitable in road construction and also in the building construction field.

2.10 BRICK

Brick may be defined as a small, solid or cored building unit in the shape of a rectangular block. Bricks are of uniform size and hence they do not need any dressing. Bricks are one of the oldest building material and known to have been used in the Mesopotamia region since the third millennium BC (Cultrone & Eduardo, 2009). Bricks are present as a leading as a leading material of construction because of its durability, strength, light-weight, thermal insulation property and east a viability.

Based on ASTM standard, there are several specifications to covered different type of bricks and the have different requirement for different types of bricks. The table 2.4 shows the several types of designation for concrete bricks in ASTM standard.

Table 2.3: Designation for Concrete Brick (National Concrete Masonry Association, 2007)

Types of unit	ASTM Designation
Concrete Building Brick	C55
Calcium Silicate Brick	C73
Loadbearing Concrete Masonry Units	C90
Nonloadbearing Concrete Masonry Units	C129
Concrete Facing Brick	C1634

Besides, there are some general brick specifications to control the quality of the bricks. There have a few basic tests to evaluate the quality of brick which is compressive strength test and water absorption and saturation coefficient. The combination of the minimum compressive strength, maximum water absorption and maximum saturation coefficient are used to predict the durability of the bricks (Technical Notes on Brick Construction, 2007).

Bricks are made from many different types of materials in various ways of manufacture. Each type of brick has its own advantage and disadvantage. Generally, there are 3 types of brick, which is clay brick, sand lime brick and concrete brick. Concrete brick are made from sand, crushed rock, water and about 15% by weight of Ordinary Portland Cement, concrete brick can have strength and density similar to fired clay brick. Concrete brick can make in various colours, using either gray or white Portland cement and the colour can achieved with mineral oxides. However, production of the Portland cement used in this brick contributed large quantities of carbon dioxide (Chusid M. et. al, 2009).

The manufacturing process consists of machine-molding very dry and no slump concrete into the desired shape. When the bricks shape were formed, there are required subjected to the curing stage and either by burning the bricks in the steam kiln at the temperature ranging from 120 to 180 °C and up to 18 hours (Jaffe, 2004). ASTM provided minimum requirement for the three types of concrete bricks which is lightweight, medium weight and normal weight. Based on ASTM standards, the minimum requirement for the concrete brick will shows at the table 2.4.

Table 2.4: Specifications for Concrete Bricks (National Concrete Masonry Association, 2007)

ASTM standard	Minimum Compressive Strength (MPa)	Maximum Water Absorption (%)
C55-06	17.3	13
C1634	20.7	12