MECHANICAL PROPERTIES OF CONCRETE CONTAINING CRUSHED COCKLE SHELL AS COARSE AGGREGATE REPLACEMENT

SII HOU LEE

Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2013

ABSTRACT

Various studies have been conducted on different agriculture waste products to determine the effectiveness of their use as replacement material in concrete. Effort toward preserving natural source and reduce environmental problem has initiate the studies on integrating cockle shell as replacement material in concrete production. This thesis investigate the workability and compressive strength of cockle shell concrete containing different superplasticizer(sp), sand and aggregate content. Concrete mixes containing 0.6%, 0.8% and 1.0% of superplasticizer were cast and subjected to water curing for 7 and 28 days. In addition, cockle shell concrete with 700kg/m^3, 800 kg/m^3 and 900 kg/m^3 sand content were cast before subjected to water curing. Furthermore, cockle shell concrete with proportion 1:1.8:0.7, 1:1.4:1.1 and 1:1:1.5 were casted to investigate the effect of coarse and fine aggregate content on workability and compressive strength. Workability test and compressive strength test were carried in accordance to BS1881:Part102:1983 and BS1881:Part116:1983 respectively. Results show that appropriate amount of superplasticizer content able to increase the workability and compressive strength of concrete. 0.6% of sp produced 44.81MPa strength for cockle shell concrete. Increasing of sand content had reduced the workability of concrete but increase the compressive strength of concrete. 900 kg/m^3 sand content gave lowest workability but highest compressive strength which was 43.67MPa for cockle shell concrete. Meanwhile, 1:1.8:0.7 concrete proportion illustrated that lower volume of coarse aggregate and higher sand content produced higher compressive strength and workability. This ratio had produced cockle shell concrete with strength 45.9MPa. A suitable mix proportion of the ingredients would be able to produce concrete with the better strength.

ABSTRAK

Pelbagai kajian telah dijalankan ke atas bahan buangan pertanian yang berbeza untuk menentukan keberkesanan penggunaan sebagai bahan gantian dalam konkrit. Usaha ke arah memelihara sumber semula jadi dan mengurangkan masalah alam sekitar telah memulakan kajian mengenai integrasi kulit kerang sebagai bahan gantian dalam pengeluaran konkrit. Tesis ini mengkaji hasil pada kebolehan mengalir dan kekuatan mampatan konkrit kerang yang mengandungi kandungan superplasticizer, pasir, simen dan agregat yang berbeza. Campuran konkrit yang mengandungi 0.6%, 0.8% dan 1.0% superplasticizer telah dibancuh dan direndam dalam air selama 7 dan 28 hari untuk pengawetan. Di samping itu, konkrit kerang dengan kandungan pasir sebanyak 700kg/m^3, 800 kg/m^3 dan 900 kg/m^3 juga telah dibancuh sebelum menjalankan pengawetan air. Tambahan pula, konkrit kerang dengan nisbah 1:1.8:0.7, 1:1.4:1.1 dan 1:1:1.5 telah dibancuh untuk mengkaji kesan agregat kasar dan halus kepada kebolehan mengalir dan kekuatan mampatan konkrit. Ujian kebolehan mengalir dan ujian kekuatan mampatan telah dijalankan mengikut BS1881:Part102:1983 dan BS1881:Part116:1983 masing-masing. Keputusan menunjukkan kuantiti superplasticizer yang sesuai dapat meningkatkan kebolehan mengalir dan kekuatan mampatan konkrit. Kekuatan mampatan untuk konkrit kerang yang mengandungi 0.6% sp mencapai 44.81MPa. Kandungan pasir yang meningkat telah mengurangkan kebolehan mengalir konkrit tetapi meningkatkan kekuatan mampatan konkrit. 900kg/m^3 pasir memberikan kebolehan mengalir yang paling rendah tetapi kekuatan mampatan yang tertinggi iaitu 43.67MPa. Sementara itu, nisbah konkrit 1:1.8:0.7 nyatakan bahawa kuantiti agregat kasar yang rendah dan kandungan pasir yang tinggi menghasilkan kekuatan mampatan dan kebolehan mengalir yang tinggi. Nisbah ini telah menghasilkan kerang konkrit yang mempunyai kekuatan mampatan 45.9MPa. Kandungan bahan dengan nisbah yang sesuai akan menghasilkan konkrit dengan kekuatan yang lebih baik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

F	Maximum load recorded at failure
A	Cross-sectional area of the specimen

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
Al	Aluminium
Ca	Calcium
Ti	Titanium
V	Vanadium
Cr	Chromium
Mn	Manganese
Fe	Iron
Cu	Copper
Sr	Strontium
Ru	Ruthenium
O	Oxide

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Cockles is a type of bivalve shellfish that grows well in muddy coastal area. According to Utusan Malaysia (2007), cockle shells produced by Malaysia in Ninth Malaysia Plan were around 13000 metric ton. This is further supported by Department of Fisheries Malaysia (2009) which had reported that production of cockle increased by 6.22% in 2009 to 64,938.51 tons from 61,138.32 tons in 2008. Its value also increased by 4.53% to RM68.60 million in 2009 from RM65.63 million in the previous year. These figures do not only indicate the vast availability of cockle but also the amount of waste of cockle generated. Cockles which had retail values estimated to be over 32 million USD dollars and has been regarded as the waste (Boey, 2011). The wastes of cockles were left at dumpsite to naturally deteriorate which may cause environmental problems. Therefore, it will be very useful when cockle shells can be applied in construction material such as concrete block.

Cockle shells were found to be the alternative as the potential biomass source for calcium carbonate, $CaCO_3$ (Rashidi, 2011). According to Barros (2009),. cockle shells containing 95-99% by weight of $CaCO_3$ which enables cockle shells applied in construction material. Calcium carbonate from cockle shell can act as a calcium precursor and can be a new source for bone substitute materials (Mohammad, 2010). According to researcher Mannan (2007), natural resource was decreasing while the demand of aggregate used in concrete production still high. Replacement of natural aggregate by cockle shell in concrete production would definitely slower the depletion of natural aggregate in future. Meanwhile, utilize of waste material as ingredient in concrete production would reduce the cost of construction. Many researches such as Kucharczykova (2012), Chen (1999) and Awang (2007) try to utilize the waste materials in concrete production. Waste material such as palm oil clinker, cockle shell, and other industry by-product has been applied to produce low cost concrete. This will maximize the potential and usage of waste material.

1.2 PROBLEM STATEMENT

According to Department of Fisheries Malaysia, production of cockle at year 2007 around 49000 metric ton occupied 25% of total agriculture production. It was around 32 million US dollar of the retail value of cockles in year 2007 (Department of Fisheries, 2008). Increasing of cockle productions year by year is expected to escalate the amount of cockle shell dumped as waste in the same time and this will cause huge negative impact to environment. The cockle shells which are untreated and disposed in landfill release unpleasant smell which causes air pollution and unpleasing view. It means that the cockle shell is abundant in Malaysia and this waste is not yet exploited. Recycling of this disposed material in concrete making is seen as one of the approach to reduce cockle shell ending at dumping area thus creating environmental problem. Incorporating of cockle shell as coarse aggregate replacement in concrete will definitely reduce the waste and at the same time would result in environmental friendly construction material.

1.3 OBJECTIVES

The objectives of this study are as follows:

i. To investigate the effect of superplasticiser content on workability and compressive strength of cockle shell concrete
ii. To investigate the effect of sand content on workability and compressive strength of cockle shell concrete
iii. To investigate the effect of sand and coarse aggregate content on workability and compressive strength of cockle shell concrete

1.4 SIGNIFICANCE OF RESEARCH

This research is imperative to increase information on effect of mixing ingredient towards workability and compressive strength of concrete produced using cockle shell as aggregate replacement. Usage of cockle shell in concrete production would reduce the amount of cockle shell ending at landfill thus assisting towards cleaner environment. Furthermore, integration of the waste in concrete making would result in cheaper and more environmental friendly construction material.

1.5 SCOPE OF STUDY

This study investigates the effect of integrating various percentages of superplasticiser, sand content and coarse aggregate content towards the compressive strength of cockle shells (CS) concrete. Two sets of mixing ingredient were prepared which were normal concrete and cockle shell concrete. In normal concrete, coarse aggregate used was granite meanwhile in cockle shell concrete, coarse aggregate has been replaced by cockle shell. Granite and cockle shell size of 9.5mm as maximum size has been used in this study. Slump test has also been conducted to study the effect of various mixing ingredients toward the workability of concrete. Specimens of 100mm x 100mm x 100mm has been cast and cured in water until 28 days. The compressive strength of the specimens has been tested at 7 and 28 days. All the experiments conducted accordance to the existing standard.

1.6 LAYOUT OF THESIS

There are five chapters in this thesis. Chapter one contains the introduction to this thesis. The background of the present study has been given to identify the problem. The objectives of the study, significance and scope of the study have been described as well as in this part. Chapter two was research and finding information from the past experiment and testing related to cockle shell concrete and cockle shell. In the early part of this chapter, factors influencing the compressive strength of concrete have been discussed. Information related to cockle shell and its application has been included in this part as well.

Chapter three presents the experiment details of the cockle shell concrete. This chapter describes the material preparation process, mixing ingredients, process of casting, curing, and compressive strength tests of the cockle shell concrete. Equipment and machinery used for the casting and testing also has been illustrated in this section. Experimental procedure such as workability test and compressive strength test were described in detail in this part.

Chapter four presents and discusses the results of workability and compressive strength testing of concrete containing cockle shells. Result from the slump test and compressive strength test of different mixing ingredients have been recorded in this part. Analysis of the results has been conducted based on the results obtained. Discussions were done based on the result of testing and compared with control specimens. Finally, chapter five presents conclusion of this study including the recommendation for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Rapid development of the country brings to expansion of the industry field especially in construction field. The continuously growing of construction industry may result in depletion of natural aggregates. According to Mannan (2007), exhaustion of natural aggregate is still continuing due to demand in concrete production is increasing. Therefore, manufactured aggregate from waste materials are adopted to replace the usage of natural aggregate in concrete production to preserve the natural aggregate. Hence, many researches have been done on waste materials to investigate their potential as natural aggregate replacement in concrete production such as oil palm shell, cockle shells and others.

The utilization of waste materials in the construction industry is an effective way to sanitize the environment. Cockle is high protein seafood which is commercially important in Malaysia industry. According to Mohamed (2012), Malaysia is expected to produce 13000 metric ton of cockle shells in Ninth Malaysia Plan. The shells from cockle are treated as waste and left at dumpsite. The shells dumped at landfill may release unpleasant smell and become habitat of pests which brings diseases to nearby residents. Thus, recycling of such waste material as an alternative construction material (Faridah, 2011) would help to create more environmental friendly cockle industry. Success in incorporating cockle shells as fine and coarse aggregate replacement in concrete production would open up a new horizon in green concrete research and contribute towards healthier environment.

2.2 CONCRETE

According to Neville (2010), concrete defined as any products or mass produced by cementitious medium. This medium is the product in between hydraulic cement and water. Another researcher, Li (2011) said that concrete is a composite material composed of granular material such as aggregate or filler which embedded in a hard matrix of material (cement or binder) that fills the space among aggregate particles and bind them together. Depending on what kind of binder is used, concrete can be categorized into different groups. For example, concrete made of non-hydraulic cement is called non-hydraulic cement concrete while concrete made by hydraulic cement known as hydraulic concrete. Asphalt concrete, polymer concrete and fiber concrete are concrete which developed from different binder and production technique. Nowadays, concrete can be made with various types of cement and also containing pozzolan, fly ash, blast-furnace slag, microsilica, additives, recycled concrete aggregate, and these concretes can be heated, shock-vibrated, steam-cured, autoclaved, vacuum-treated, hydraulically pressured and sprayed. Fine and coarse aggregates occupied almost three-quarters of the volume of concrete (Li, 2011). This kind of aggregates such as sand and gravel are taken from natural deposits without changing the nature during production. Therefore, it can be concluded that concrete production considering mixture of cement, water, admixture, coarse and fine aggregates.

2.3 CHARACTERISTIC OF AGGREGATE USED IN CONCRETE

Neville (2010) had proved that three-quarters of concrete was made by aggregate, therefore it was not surprising that the quality of aggregate would limit the strength of concrete. Aggregate is usually viewed as an inert dispersion in the cement paste. However, the physical, thermal and chemical properties of aggregate will influence the performance of concrete, for example, the strength and durability of concrete. For economically concrete production, it is advantageous to use maximum aggregate content and as low as possible cement content. However, the desired concrete properties should be satisfied when applying high aggregate and low cement content due to cost benefit in concrete production.

Sand and gravel are common aggregate used in concrete production. These kind of natural aggregates are formed from weathering process, abrasion, or crushing a larger parent rock. Thus, the properties of aggregate depend on the properties of parent rock. For example, specific gravity, pore structure, shape and size, surface texture and absorption of aggregate may have influence on the quality of concrete.

2.3.1 Type of Aggregate

Chandra (1992) stated that aggregate can be divided into two main groups, which are natural aggregate and industrial by-product aggregate. Industrial by-product aggregate also know as manufactured aggregate. Manufactured aggregate is artificial aggregate that produced by wide variety of raw materials and industry procedure (Chi, 2003). Manufactured aggregate is produced by thermal treatment of industry activities such as pulverized fly ash and blast furnace slag (Chandra, 1992). Manufactured aggregate used in concrete application to reduce landfill disposal while conserving primary source.

Natural aggregate occurs naturally and ready to use only with mechanical treatment such as crushing and sieving. For example, volcanic pumice and perlite are types of natural material. Natural coarse aggregate also can obtained from different type of rock such as granite, calcareous, basalt and marble (Pereira, 2009). Figure 2.1 shows the type of manufactured aggregate (fly ash) and natural aggregate (volcanic pumice) respectively.

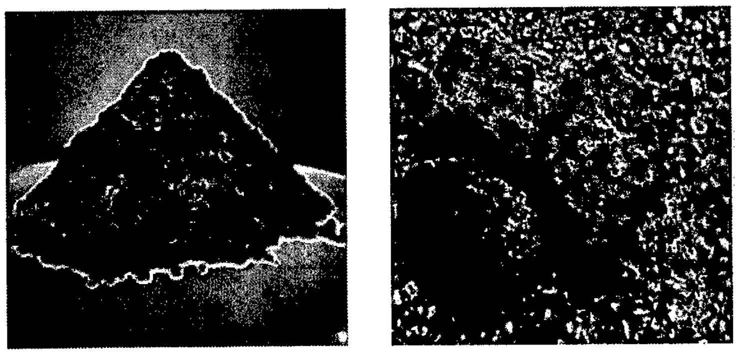

Figure 2.1: Fly ash (left) and volcanic pumice (right)

2.3.2 Shape and Texture

Workability of concrete affected by shape of the aggregate due to differences in surface area caused by different shapes. Sufficient paste is required to coat the aggregate to provide lubrication. Spherical, cubical and irregular shape can benefit the concrete strength meanwhile flat and needle-shaped of aggregates are weak and easily broken (Li, 2011). Table 2.1 shows the particle shape classification of aggregate with examples.

Table 2.1: Particle shape classification of aggregate with examples.

Classification	Description	Examples
Rounded	Fully water-worn or completely shape by attrition	River or seashore gravel; desert, seashore and wind-blown sand
Irregular	Naturally irregular, or partly shaped by attrition and having rounded edges	Other gravels; land or dug flint
Flaky	Material of which the thickness is small relative to the other two dimensions	Laminated rock
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rock of all types; talus; crushed slag

Source: Neville (2010)

The texture aggregate can be classified in 6 groups: glassy, smooth, granular, rough, crystalline and honeycomb. Fluidity of fresh concrete and the paste between aggregate and cement of hardened concrete are influenced by surface texture of aggregate. Table 2.2 describes the texture classification of aggregates with examples.

Table 2.2: Surface texture classification of aggregate with examples

Surface texture	Characteristic	Examples
Glassy	Conchoidal fracture	Black flint, vitreous slag
Smooth	Water-worn, or smooth due to fracture of laminated or fine-grained rock	Gravels, chert, slate, marble, some rhyloite
Granular	Fracture showing more or less uniform rounded grains	Sandstone, oolite
Rough	Rough fracture of fine or medium-grained rock containing no easily visible crystalline constituents	Basalt, felsites, porphyry, limestone
Crystalline	Containing easily visible crystalline constituents	Granite, gabbro, gneiss
Honeycomb	With visible pores and cavities	Brick, pumice, foamed slag, clinker, expanded clay

Source: Neville (2010)

2.3.3 Size Classification

The particle size distribution of aggregates is known as grading. Generally, coarse aggregate ranges from 5mm to 150 mm according to Li (2010). Structural member such as beam and columns basically use the maximum size 25mm. For mass concrete such as dams or deep foundation, maximum size of aggregate can reach 150mm.

Aggregate passing through 4.75mm sieve and predominated retained on 75µm sieve are classified as fine aggregate. In concrete production, river sand is the most common material used as fine aggregate. According to Neville (2010), sand have lower size limit of about 0.07mm. Aggregate size range between 0.02mm and 0.06mm is known as silt while the smaller particle called clay.

2.3.4 Porosity and Absorption

Porosity and absorption of aggregate will affect the bond between cement paste and aggregate, resistance to abrasion, resistance to freezing and thawing. The pores in aggregate result in penetration of water through the pores. Since three-quarters of the volume of concrete is made up by aggregate, it is clearly that the porosity of aggregate directly contributes to overall porosity of concrete and affect in strength of concrete.

The water absorption defined as the presence and amount of water in the pores and on the surface of aggregate. Neville, (2010) defined that water absorption is determined by measuring the decrease in mass of saturated and surface-dry concrete after undergo 24 hours drying process. Aggregate can be oven dried, air dried, saturated surface dried and wet. During concrete mixing, total water required has to deduct with actual water absorption of aggregate to achieve effective water/cement ratio.

2.4 ENGINEERING PROPERTIES OF CONCRETE

Generally, concrete is tested for compressive strength, flexural strength, tensile strength and Modulus of Elasticity (MOE). Strength is defined as ability of material to withstand stress which generated by external force without failure. Strength of concrete influenced by several factors such as water/cement ratio, curing method, mix design, properties of aggregate, cement content and specimen size.

2.4.1 Compressive Strength

Compressive strength test is carried out to determine the maximum load that can be withstand by concrete. It is depended on the mix design and curing conditions of the concrete (Alengaram, 2013). Compressive strength of concrete under moisture curing is greater than air curing at 90 days according to Smadi (1990). In the research of Niyazi (2010), concrete with high porosity of aggregate has lower compressive strength compared with normal concrete. The 28 days compressive strength of the concrete will decrease with the increase of percentage aggregate in the concrete specimen (Hossain, 2011). It shows that the total aggregate volume in concrete will influence the strength of concrete. Higher aggregate density and lower water-cement ratio will enhance the compressive strength of the concrete. In addition, Yang and Huang (2003) had also demonstrated that compressive strength of concrete affected by volume fraction and properties of the aggregate.

Volume content, particle density, crushing strength and shape index of aggregate show influence on the prediction model for compressive strength of concrete (Cui, 2012). The achievable strength of concrete is generally determined by the particle strengths of the aggregate which is further affected by the relative values of the modulus of elasticity for the aggregate (Chen, 1999). On the other hand, researchers Lo and Cui (2012) highlighted that compressive strength of concrete influenced by aggregate strength, water/cement ratio, effect of pores distribution number and bonding of aggregate with cement paste. Besides that, the compressive strength of concrete is also drastically affected by the size and aspect ratio of specimens due to non-scaled aggregates, different frictions between concrete surfaces and loading platen, and variations of crack propagation (Wang, 2006). Cement dosage will increase the compressive strength of the concrete. It is supported by Remzi (2003) which had reported that a 10% higher cement dosage will give approximate 5% increase in compressive strength. Since the strength of concrete is affected by bunch of factors, it is important to consider these feature when design for good quality of concrete.

2.4.2 Tensile Strength

Tensile strength can be obtained through splitting cylinder tensile strength test. According to Dhir (1984), tensile strength was proportional to the compressive strength of the concrete. Besides that, Smadi (1990) had also found out the similar results which show that tensile strength of the concrete is directly influence by compressive strength. Increasing of the percentage of coarse aggregate in concrete will decrease the tensile strength (Hossain, 2011). Another researcher, Mannan and Ganapathy (2007) reported that tensile strength also depends on the curing condition and physical strength of the aggregates.

Cui and Lo (2012) had carried out research on particle density of the aggregate which may affect the tensile strength of concrete. It is also influenced by the crushing strength of the lightweight aggregate. Aggregate quality, water absorption coefficient of aggregate, and macroporosity of aggregate would definitely affects the tensile strength of the concrete (Ke, 2009). Basically, it can be seen that tensile strength of the concrete is directly influenced by the compressive strength of the concrete which determined by the aggregate characteristic and also curing method.

2.4.3 Modulus of Elasticity (MOE)

The MOE depends on hydrated cement matrix, type of aggregates, the water/binder ratio, and the volume of cement (Topcu, 2010). Besides, Okafor (1988) had found out that mix proportion would change the MOE of the concrete. Modulus of elasticity (MOE) will decrease with the increase of the volume content of aggregate. From the research of Cui (2012), he shows that higher particle density of aggregate resulted in concrete with higher MOE. Another researcher, Hossain (2011) said that the 28-days MOE decreased with the increase of percentage coarse aggregate in concrete. Characteristic of the aggregate is one of the factors which might greatly influent the MOE of concrete. Porosity of the aggregate affects the MOE of the concrete (Kim, 2011). From the previous research and investigation, it can be observed that the factors affect the MOE of concrete are analogous with the factor affect the compressive and tensile strength.

2.5 OTHER PROPERTIES OF CONCRETE

Water absorption of the aggregate will influence the water/cement ratio of the concrete. When mixing, some adjustment is necessary due to water absorption properties of the aggregate. Water absorption of the aggregate is different based on the types of aggregate. Due to the water absorption of aggregate, the effective w/c ratio will decrease and the strength of the hardened concrete will be higher. According to Kucharczykova (2000), aggregate should be pre-soak for 60 minutes before mixing with other materials.