WORKABILITY AND COMPRESSIVE STRENGTH OF CONCRETE CONTAINING CRUSHED COCKLE SHELL AS PARTIAL FINE AGGREGATE REPLACEMENT MATERIAL

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ABSTRACT

Various studies have been conducted on different waste products to determine the effectiveness of their use as a partial fine aggregate replacement in concrete. One such fisheries waste product is cockle shell. Cockle shell is a waste material usually dumped at landfill without treated that leads to pollution. In this research, the effect of crushed cockle shell as partial fine aggregate replacement material towards workability and compressive strength of concrete is tested. The cockle shell is crushed to obtain crushed cockle shell that suitable to be used as partial fine aggregate replacement materials. For this research, four different percentage which are 5%, 10%, 15% and 20% of cockle shell was used as partial fine aggregate replacement to produces several types of mixes. Then, specimen is prepared in form of cubes were water cured for 7, 14 and 28 days before subjected to compressive strength test. Finding shows that utilization of crushed cockle shell as partial fine aggregate replacement in concrete lower the mix workability and increase the compressive strength of concrete. At the same time, uses of cockle shell as partial fine aggregate replacement in concrete would reduce the high dependency on natural fine aggregate and offering alternatives to preserve natural sand for the use of future generation.

ABSTRAK

Pelbagai kajian telah dijalankan terhadap produk sisa yang berbeza untuk menentukan keberkesanan penggunaannya sebagai penggantian agregat separa halus dalam konkrit. Satu produk sisa daripada perikanan adalah kulit kerang. Kulit kerang adalah bahan buangan yang biasanya ditemui dibuang di tapak pelupusan sampah tanpa dirawat yang membawa kepada pencemaran. Dalam kajian ini, kesan terhadap kebolehkerjaan dan kekuatan mampatan konkrit yang mengandungi kulit kerang yang dihancurkan sebagai gantian agregat separa halus akan diuji. Kulit kerang akan dihancurkan untuk mendapatkan kulit kerang yang separa halus yang sesuai untuk digunakan sebagai bahan penggantian agregat separa halus. Bagi kajian ini, empat peratusan yang berbeza iaitu 5%, 10%, 15% dan 20% daripada kulit kerang digunakan seperti penggantian agregat separa halus untuk menghasilkan pelbagai jenis campuran. Kemudian, spesimen direndam dalam air selama 7, 14 dan 28 hari sebelum dikenakan ujian mampatan. Kajian menunjukkan penggunaan kulit kerang menurunkan kebolehkerjaan dan meningkatkan kekuatan mampatan konkrit Dalam masa yang sama, penggunaannya akan mengurangkan kebergantungan kepada agregat separa halus yang semulajadi dan membuka alternatif kepada pemeliharaan pasir untuk kegunaan generasi akan datang.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
°C	Celcius
kg	Kilograms
m	Meters
mm	Milimeters
m^3	Meter Cubes
MPa	Mega Pascal

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
BS	British Standards
BS EN	British Standards European Norm
OPC	Ordinary Portland Cement
CCS	Crushed Cockle Shell
OD	Oven Dry
AD	Air Dry
SSD	Saturated Surface Dry

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In this era of globalization, the construction industry is considered to be a major productive sector in Malaysia which continuously growing demand increased, at the same time the need for concrete material production, such as fine aggregate and coarse aggregate increased. Time will come where the sources of natural aggregate will soon decrease (Alshahwany, 2011) and Malaysia will encounter a reduction in its supply.

Aggregates produced in Malaysia are obtained from two primary sources, namely quarries and river beds. They consist mainly of granite and limestone rock types, and are abundant throughout the states of Perak, Selangor, Johor, Sabah and Sarawak. Production of aggregates in 2012 is estimated to have increased to 122,000,000 tonnes from 118,509,699 tonnes produced in 2011. Environmental problems occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials. The morphologies of the mining areas have demonstrated the impact on mining with the prowess to destroy the cycle of ecosystems (Ashraf *et. al.*, 2010).

According to fisheries research institute in Malaysia, cockle shells which are one of the main species in the aquaculture industry in Malaysia yield of shellfish in 2010 was 78,024.7 tonnes, in which the amount is clearly estimate the clamshell or cockleshell waste produced. Based on the monitoring of shellfish landing sites and places processing of shellfish, cockle shells founds to be dumped and left untreated that may cause unpleasant smell and disturbing view to the surrounding (Mohamed *et. al.*, 2012) and it also takes time to decompose. Due to the limited utilization of waste materials, the rate on which they disposed as landfill materials is expected to increase consequently leading to potential future environmental problem.

In order to overcome this issue, various types of waste materials has been analysed and investigated their capability and potential to be used as partial fine aggregate replacement material in concrete production. So far, waste materials that has been used as fine aggregate replacement are recycled rubber tires (Seyfu, 2010), quarry dust (Lohani *et. al.*, 2012), dry oyster shell (Yang *et. al.*, 2009) and Class F fly ash (Siddique, 2002). However, to the best of author's knowledge no work has been reported on the mechanical properties of concrete containing cockle shells as partial fine aggregate replacement material. Integration of cockle shell as partial fine aggregate replacement could reduce consumption of natural fine aggregate use and also contribute towards cleaner environment.

1.2 PROBLEM STATEMENT

Concern towards preserving fine aggregate for future generation has lead towards approaches of integrating cockle shell as partial fine aggregate replacement in concrete material. The availability of cockles a marine bivalve mollusks which is an important protein source in the South East Asian region is one of the factor that boost the cockle trade in Malaysia. It has been highlighted by Boey *et. al.* (2011) that the active cockle trade has leads toward the generation of abundant waste of shell. This waste is not yet exploited in other applications except that it has been used in small-scaled craft production.

The high dependence and demand for concrete has significantly depleted natural aggregate in Malaysia although supply is still regarded to be sufficient (Wong, 2012). The continuously growing construction industry has posed the possibility on depletion of natural aggregates in the future that would increase the cost of concrete material. Therefore, additional of cockle shell as partial fine aggregate replacement would reduce the high dependency on natural aggregate supply and it also assist towards preservation of this material for future generation.

1.3 OBJECTIVES OF THE STUDY

The objectives of the study are:

i. To investigate the effect of concrete containing various content of crushed cockle shell as partial fine aggregate replacement towards workability of concrete.

ii. To investigate the effect of concrete containing various content of crushed cockle shell as partial fine aggregate replacement towards compressive strength of concrete.

1.4 SCOPE OF STUDY

This research focused on investigating the effect of cockle shell content when used as partial fine aggregate replacement towards workability, compressive strength and flexural strength of concrete. There are two types of mix use in this study that is plain concrete with 100% of natural sand and another mix containing crushed cockle shell as partial fine aggregate replacement. For this research, five different percentages that is 0%, 5%, 10%, 15% and 20% of cockle shell has been used as partial fine aggregate replacement to produces several type of concrete mixes. The mixes will be used to produce cubes and beams which then subjected to water curing either for 7, 14 and 28 days.

1.5 SIGNIFICANCE OF STUDY

Cockle shell is one of the waste products usually found dumped at landfill without treated that leads to pollution. Use of cockle shell as partial fine aggregate replacement in concrete production would reduce amount of cockle shell at landfill. Thus, creating cleaner environment the excessive use of river sand can be reduce and avoid the depletion of natural fine aggregate in future.

1.6 LAYOUT OF THESIS

Chapter one explains the definition of the topic, the purposes, the problems and the benefits of the topic which is the use of cockle shell as fine aggregate replacement towards workability of concrete, compressive strength and flexural strength of concrete. The reasons for this research to be conducted are explained in this chapter while the problem statement highlight about the waste that been produce from cockle shell trade and natural fine aggregate depletion. Benefit obtained from this research is highlighted in significance of study.

Chapter two explains about the definition, properties, uses, production of fine aggregate in Malaysia and also the alternative material that being use as fine aggregate in concrete. Furthermore, it also explains about the definition, properties, availability of cockle shell in Malaysia and also environmental issues related to cockle shell. Towards the end of this chapter, durability of concrete are also briefly explained.

Chapter three discusses in detail the material, equipment and procedures needed in carrying out the experimental work to achieve the objectives of this research. First, how to prepare cockle shell and follow by making of concrete specimens which is cube and beam. Then, the procedures of all tests on concrete specimens which are workability test, compressive and flexural strength test are clearly explained in this chapter.

After all the tests being conducted, results are shown in chapter four. The results obtained are being discussed, analyzed and compared based on standard results. The data are present in form of tables and graphs. In the discussion part also, the possible logical reasons are discussed pertaining to how the durability of concrete can be affected under different reasons. Chapter five concluded all the findings obtained based on the test conducted on the samples in this project. Recommendations for future study are also included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

It is a natural fact that every action starts with a purpose. There are several subtopics will be discussed on the idea that drives toward the further studies about workability and compressive strength of concrete containing crushed cockle shell as partial fine aggregate replacement material throughout in this section. The sub-topics will begin with the explanation about fine aggregate in concrete. Due to the increasing concern in order to get the best fine aggregate to be used in concrete mixture, there are also the studies on the availability of cockle shell in concrete mixture that will be explored wider in this section. Same goes to the soccer ball impact that becomes one of the causes of the injuries to the players. Thus, the studies on workability and compressive strength of concrete containing crushed cockle shell were act as partial fine aggregate replacement material.

2.2 FINE AGGREGATE IN CONCRETE

2.2.1 Definition

Cementitious material, aggregate, and water are the mixture that will produce concrete. Among the three substances, aggregate is commonly considered inert filler, which accounts for 70 to 85 percent of the weight of concrete and 60 to 80 percent of the volume. It is a necessary component that defines the elastic properties, dimensional stability and concrete's thermal even though aggregate is considered as inert filler.

Aggregate is classified as two different types which are fine and coarse. Fine aggregate is usually less than 5 mm while coarse aggregate is usually gr eater than 5 mm as stated by Meddah (2010), Dumitru (1998), R.C (1954) , Abdullahi (2012) and Wai (2012). It is also stated by Falade (2010), Awang-Hazmi (2007) and Manguriu *et. al.*, (2013). The quality of aggregate is very important factor involves in the selection of aggregate for example the compressive aggregate should be emphasized. Most concrete aggregate are several times stronger compare to the other components in concrete when determining the strength of normal concrete. Compressive strength of the aggregates is also one of the factors that influence the lightweight aggregate concrete. Figure 2.1 shows the fine aggregate used in concrete production.

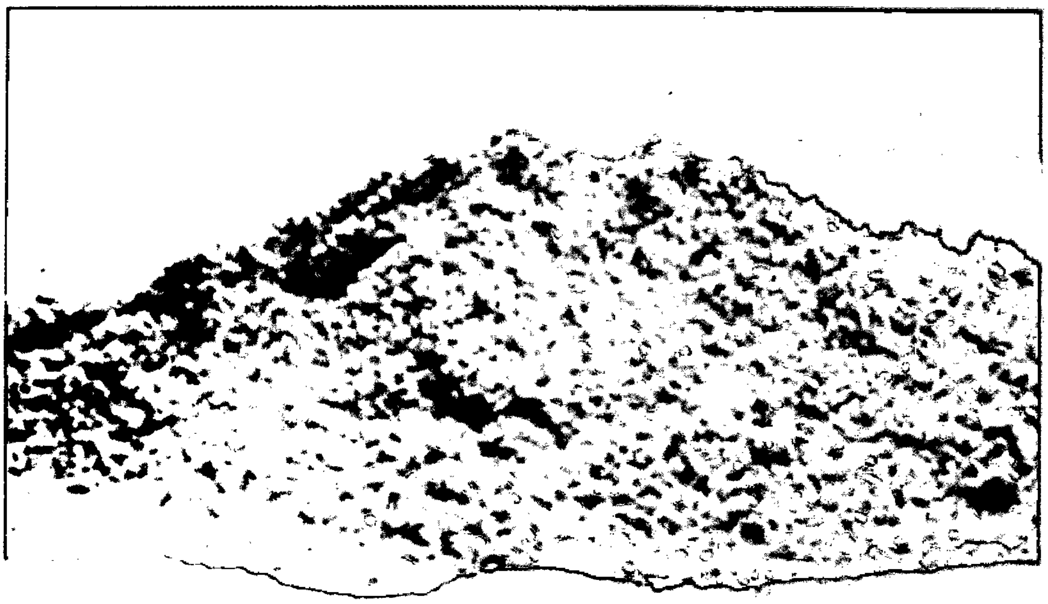

Figure 2.1: Fine aggregate

Source: Kimberly, 2004

2.2.2 Physical Properties of Fine Aggregate

In order to get a desirable mixture, physical properties of aggregate is very important to be known before mixing concrete. Shape and texture, size gradation, moisture content, specific gravity, reactivity, soundness and bulk unit weight are the example of the properties. The strength, workability, and durability of concrete can be determined by the properties along with water or cementitious material ratio. The properties of fresh concrete easily affected by the shape and texture of aggregate compare to hardened concrete. Instead of rough angular or elongated aggregate, concrete is more workable when smooth and rounded aggregate is used. Therefore, riverbeds or seashores are the suitable places to get most natural sands and gravel which are smooth and rounded as there are the excellent aggregates can be found. A workable mixture can be produced by using crushed stone where it produces much more angular and elongated aggregates. The aggregates have a higher surface-to-volume ratio and it requires more cement paste to get a better bond characteristics as well as to produce a workable mixture.

Besides that, both fresh and hardened concrete's properties strongly influence by coarse aggregate fraction. Hence, regarding the predicted performance of concrete it is important issue on the selection of both content and particle size distribution (PSD) for concrete mixture. From the reading stated, in order to investigate the effect of the PSD of aggregate on the properties of concrete, there are four granular fractions were combined in different proportions. Water reducer agent (WRA), two types of chemical admixtures, and superplasticizer were used to reduce the water-cement ratio which ranges from 0.58 to 0.40 (Meddah *et. al.*, 2010). Compressive strength function the PSD of coarse aggregate was determined at 7, 14 and 28 days. Thus, it is shows that assures a continuous granular size distribution, have shown the highest compressive strength of the mixtures without chemical admixture made with a ternary combination of granular fraction and having a highest size of 25 mm. Nevertheless, reducing the water-cement ratio by the inclusion of WRA or HRWRA requires a reduction of the maximum size of coarse aggregate and some adjustment in the granular size distribution system. The binary granular system has led to the highest compressive strength when dealing with low water-cement ratio.

The moisture content of an aggregate is very necessary factor when developing the proper water or cementitious material ratio. Based on the porosity of the particles and the moisture condition of the storage area, it shows that all aggregates contain some moisture. The moisture content can range from less than one percent in gravel to up to 40 percent in very porous sandstone and expanded shale. There are four different moisture states that include oven-dry (OD), air-dry (AD), saturated-surface dry (SSD) and wet where aggregate can be found. Among these four states, only OD and SSD correspond to a specific moisture state and can be used as reference states for calculating moisture content (Siddique R., et al 2002). Absorption capacity, effective absorption, and surface moisture are the three quantities that must be calculated in order to calculate the quantity of water that aggregate will either add or subtract to the paste.

In order to establish weight-volume relationships, the density of the aggregates is needed in mixture proportioning. By determining the densities using the displacement of water, specific gravity is easily calculated. The specific gravity value depends on whether these pores are included in the measurement as all aggregates contain some porosity. Absolute specific gravity and bulk specific gravity are the two terms that are used to differentiate this measurement. The solid material excluding the pore known as absolute specific gravity (ASG) and sometimes apparent specific gravity refers to bulk specific gravity (BSG) includes the volume of the pores. It is significant to know the space occupied by the aggregate particles, including the pores within the particles for the purpose of mixture proportioning. Although the specification of BSG is usually done to meet minimum density requirement, the BSG of an aggregate is not directly related to its performance in concrete.

Table 2.1: Physical properties of aggregates

Property	Fine Aggregate	Coarse Aggregate
Specific gravity	2.63	2.61
Fineness modulus	2.25	6.61
SSD absorption (%)	0.86	1.12
Void (%)	36.2	39.6
Unit weight (kg/m^3)	1690	1615

Source: Mohd, 2010

The different properties of aggregate have a huge impact on the strength, durability, workability, and economy of concrete even though aggregates are most commonly known to be inert filler in concrete. Designers and contractors have more flexibility in designing and construction requirement as there are various properties of aggregate.

2.2.3 Use of Fine Aggregate in Concrete

There are various types of aggregates and the potential use in concrete and road construction materials. The benefits and limitations of the use in concrete and road construction and their availability were described in terms of sources and production process, physical and mechanical characteristics. Only the suitable strength, durability and shape characteristics are considered in the source materials. Crushing, screening and possibly washing are generally involves in production process. Workability, bleeding rate, finishability and susceptibility to plastic cracking of concrete may affected by the shape, grading and excessive amount of fines. When unprocessed dust is put through an autogenous crushing action of specific crusher, an improvement in grain shape of manufactured sand can be achieved. More workable and generally superior concretes to those with fine and coarse natural sands can be produced by blending of 50% fine sand with manufactured sand (Dumitru, 1997).

The amount of –75 μm of up to 15% can be accounted realistic and not harmful to most plastic hardened properties of concrete pavement mix for both basaltic and crushed river gravel manufactured sands. In coarse aggregate to sand ratio or admixture dosages are essential to achieve the full benefits of the use of manufactured sand in concrete as the adjustments of concrete mix proportions (Dumitru *et. al.*, 1998). Removal of clay and silt from basalt crusher dust has been tried using numerous methods (Sullivan *et. al.*, 1997).

A main proportion of natural sand with no essential loss of performance in cement-based products can be replaced by manufactured.From the reading stated that most manufactured sands in Australia are not used as the only source of fine aggregate in most concrete mix designs. Manufactured sand may be customized for use in concrete, tile, asphalt, or masonry production. Table 2.2 shows the aggregate used in construction.

Table 2.2: Aggregate in construction

TYPE OF AGGREGATE	DESCRIPTION	APPLICATIONS	AVAILABILITY IN AUSTRALIA
Manufactured Aggregates			
Foamed Blast Furnace Slag	Water cooled blast furnace iron slag with stream trapped porous mass.	Lightweight concrete.	Not available.
Fly Ash	Sintered fly ash lightweight aggregate. Chemically bound fly ash aggregate.	Medium strength concrete. No data available.	Not available.
Manufactured Sand	Purposed-made crushed fine aggregate.	Partial sand substitute in concrete and asphaltic concrete.	Available commercially.
Polystyrene	Crushed waste expanded polystyrene or coated small polystyrene beads.	Lightweight concrete.	Proprietary products available.
Expanded Clays, Shales and Slates	Expanded clay lightweight aggregate.	Structural grades concrete.	Not available.

Source: Cement Concrete & Aggregate Australia, 2008

2.2.4 Production of Fine Aggregate in Malaysia

From the reading of the strength of concrete with ceramic waste as coarse aggregate and quarry dust as fine aggregate. There is industrial in Malaysia being one of the sources of ceramic waste and quarry dust (Abdullah *et. al.*, 2002). Currently, the production in ceramics industries goes as waste, which is not experience the recycle process yet.

Besides that, in Malaysia there are other previous research have been conducted using waste material such as agricultural by-product will be reviewed in the coconut shell plantation. Oil palm shell, wood, coconut shell in producing panel board and material used for construction which are the example of agricultural by-product have received rising attention in current years as one of the best solution to the escalating agricultural waste problem. Materials which can be used as replacement for normal materials which possess such properties as would enable their use for new designs and innovations have been continuously looking by scientists, engineers and technologies.

On the other hand, aggregates produced in Malaysia are obtained from two primary sources, namely quarries and river beds. They consist mainly of granite and limestone rock types, and are abundant throughout the states of Perak, Selangor, Johor, Sabah and Sarawak. Production of aggregates in 2012 is estimated to have increased to 122,000,000 tonnes from 118,509,699 tonnes produced in 2011 (Department of Mineral and Geoscience, Malaysia.).

2.3 COCKLE SHELL

2.3.1 Definition

A group of mostly small, edible, saltwater clams, marine bivalve molluscs in the family Cardiidae is known as cockle (Lamarck *et. al.*, 1809). Abundant species of cockles live in sandy, sheltered beaches throughout the world. The distinctive rounded shells of cockles are bilaterally symmetrical, and are heart-shaped when viewed from the end. Cockles *Katelysia scalarina* and *K. Rhytiphora*, and the Sydney cockle or mud ark, *Anadara Trapezia* are commercially harvested from NSW estuaries. The main targeted species in the commercial fishery is *K.Sclarina* which generally marketed as *Vongoli*. Sydney cockle can achieve a maximum size of about 7 cm whereas sand cockles can reach sizes of 4 cm for *K. Scalarina* and 6 cm for *K. Rhytiphora*. Different shell sculpture and colouration can help to distinguish these two types of cockle. On the other hand, one of the factors that boost the cockle trade in Malaysia is the availability of cockle's marine bivalve mollusks which is an important protein source in the South East Asian region (Awang-Hazmi *et. al.*, 2007). The active cockle trade has towards the generation of plentiful waste shell (Boey *et. al.*, 2011). There will be unpleasant smell and disturbing view to the surrounding when there are shells that been dumped and left untreated (Mohamed *et. al.*, 2012). It is expected the availability of cockle shell as waste would be in bigger amount as well which will lead to negative impact to the nearby area by referring the growing cockle production which retail the value of cockles alone increased by 33.53% by RM 91.60 million in 2010from 68.60 million the previous year (Department of Fisheries Malaysia (2010) Annual Fisheries Statistic 2010 Jabatan Perikanan Malaysia).

2.3.2 Physical Properties of Cockle Shell

Cockle shells is the name of a group of family double shell cardiidae that is one commodity that has long fishing cultivated as a side venture coastal communities. Technique facile sense of force, does not require large capital and can harvested after the age of 6-7 months. Shellfish harvest per hectare per year can reach 200-300 tons of shells intact or about 60-100 tons of shellfish meat (Porsepwandi, 1998).

Cockle shell shape like heart, symmetrical and have reinforcement on the outside as shown in Figure 2.2. Shell has three openings inhalen, ekshalen and pedal to drain the water and to remove the leg. Shells usually dig a hole with his feet and eat plankton obtained from water flow in and out. Cockle shells are also able to jump past the bend straighten his legs. In contrast to most double shell, clams are hermaphrodites. Composition of cockle shells of West Coast of Peninsular Malaysia (Zuki, 2007), is tabulated in Table 2.3.

Figure 2.2: Cockle shell

Table 2.3: Minerals composition of cockle shell

Component	**Percentage (%)**
Cac	98.7
Mg	0.05
Na	0.9
P	0.02
Others	0.2

Source: Zuki, 2007

2.3.3 Availability of Cockle Shell in Malaysia

From the reading, there is the study towards producing a new concrete material such as the growing needs of construction trade and by-product of cockle shell trade presented by two different industries in Malaysia. There is the possibility on depletion of natural aggregates in the future that would rises up the cost of the concrete material due to the continuously growing construction industry. Regarding on this issues, the demand for aggregate to be used in concrete production is still high as well as the natural resource is reducing (Alshahwany *et. al.*, 2011). In order to be used as partial coarse aggregate replacement material in concrete production for example oil palm shell (Mannan *et. al.*, 2004), periwinkle shell (Falade *et. al.*, 2010), recycled coarse aggregate

(Wai *et. al.*, 2012) and others, the potential of various types of waste materials have been investigated.

Besides that, cockles which known as *anadara granosa* is a type of bivalve shellfish that grows well in muddy coastal area. It is quite common to be prepared as local dishes as it is a cheap protein source. During Ninth Malaysia Plan, Malaysia is expected to produce 13000 metric ton of cockles 2007. *Utusan Malaysia*, 15 December. During 2010, Selangor aims to produce 10 mt/ha/yr of cockle.as stated in 2009 *Bernama*. 14 February. Involving 6000 hectare of cultivation area, Malaysia is having 1055 number of farmers working on cockle cultivation agriculture till 2007 (Izura *et.al.*, 2008).

2.3.4 Environmental Issues Related to Cockle Shell

From the reading, it indicated that in order to have an exclusive environmental friendly composite material as only a certain percentage of cockle shell could be integrated as partial coarse aggregate replacement material so that it could be produced creating a win-win situation between the two industries, fisheries and construction, finally producing an end product having better properties than the existing one and possess the potential to be used as building material. Concrete with upgrade strength could be achieved by the formulation of a right mix proportion consisting cockle shell as partial coarse aggregate replacement. In both long term engineering properties studies and durability aspect, this fact-finding study attempting to discover the potential of this free locally available waste in concrete production intended for building work requires further in depth research. Nevertheless, the amount of waste shells generated also indicates the vast availability of cockles. The shells that been dumped and left untreated may cause unpleasant smell and disturbing view to the surrounding.