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Exploratory study on the use of crushed cockle shell as partial sand replacement in concrete

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ABSTRACT: The increasing demand for natural river sand supply for the use in construction industry along with the issue of environmental problem posed by the dumping of cockle shell, a by-product from cockle business have initiated research towards producing a more environmental friendly concrete. This research explores the potential use of cockle shell as partial sand replacement in concrete production. Cockle shell used in this experimental work were crushed to smaller size almost similar to sand before mixed in concrete. A total of six concrete mixtures were prepared with varying the percentages of cockle shell viz. 0%, 5%, 10%, 15%, 20% and 25%. All the specimens were subjected to continuous water curing. The compressive strength test was conducted at 28 days in accordance to BS EN 12390. Finding shows that integration of suitable content of crushed cockle shell of 10% as partial sand replacement able to enhance the compressive strength of concrete. Adopting crushed cockle shell as partial sand replacement in concrete would reduce natural river sand consumption as well as reducing the amount of cockle shell disposed as waste.

Keywords –Cockle shell, Concrete, Compressive strength, Environmental problem, Partial cement replacement

I. INTRODUCTION

The growing need of construction trade along with the issue of environmental problem created from the disposal of by-product generated from cockle shell business have initiated research towards producing a new green cement brick. The consumption of natural fine aggregate specifically river sand for concrete production to meet the escalating demand construction industry has caused environmental pollution. Continuous and increasing quantity of sand mined would pollute the river water and create ecological imbalance at river bed environment that would finally affect the quality life of future generation. The sand mining imposes negative impact to the environment in terms of reduced water quality, destabilization of stream bed and bank which in turn cause the destruction of riverine vegetation [1] leading to ecological imbalance. Unless action taken to reduce the high dependency of the industry on natural sand supply, more fauna and flora would face extinction in future. One of the solutions to this problem is to find locally available waste material and integrate it as partial sand replacement in concrete production. This idea has motivated some researchers [2, 3, 4, 5, 6] to investigate the possibility of introducing waste material to function as partial sand substitute in concrete production.

In the meantime, the continuously growing Malaysian cockle trade has opened the door for the increase in cockle shell disposed as waste.The availability of cockles a marine bivalve molluscs which is an important protein source in the South East Asian region is one of the factor that boost the cockle trade in Malaysia [7]. In Malaysia, cockle aquaculture areas extend about 10,383.09 hectares contributing a production of 78,024.7 tonnes in year 2010 [8]. This fact has been highlighted by [9] that the active cockle trade haslead towards the generation of abundant waste shell. The shells that been dumped and leftuntreated may cause unpleasant smell and disturbing view to the surrounding [10].Looking at the increasing cockles' production which the retail value of cockles aloneincreased by 33.53% by RM91.60 million in 2010 from 68.60 million the previous year[8], it is expected the availability of cockle shell as waste would be in larger amount aswell which in turn will pose negative impact to the nearby area. Realizing this problem, efforts has been taken to convert this waste material into profit contributing element which would also save the environment.

So far, there are few researchers [10, 11, 12, 13] who have attempted to use cockle shell in producing materials which is more environmental friendly. More discoveries on the potential use of cockle shell in any material production would ensure lesser amount of this waste ending at landfill. Therefore, placing the issue of environment preservation for the future generation being the utmost importance has led towards the effort of innovating a new product through integration of this freely available wastage of fisheries industries in concrete production. This preliminary research investigates the effect of using crushed cockle shell as partial sand replacement towards compressive strength of concrete. Success in integrating cockle shell as one of the mixing

ingredient in concrete production would expand the functionality of this waste thus reducing the amount of waste ending up as profitless and environmentally troubling waste as well reducing the natural sand consumption.

II. EXPERIMENTAL PROGRAMME

2.1Materials

During the preparation of the concrete specimen for the experimental work, among the mixing ingredients used are ordinary Portland cement, river sand, granite aggregate cockle shell, and tap water. Ordinary Portland cement (OPC) that conforms with [14] for Portland cement specification was used as the sole binder. Supplied tap water at the laboratory was used for concrete mixing work and curing purpose. Both aggregate river sand and granite aggregate was obtained from the local supplier. Cockle shells used in the research were obtained from a dumping site located in a district of Perak, West Malaysia. Fig. 1 and 2 illustrates the cockle before processed by cockle trade and cockle shell which disposed as waste. The cockle shell at dumping site were packed in the gunny sack and brought to the laboratory for further processing. Then, the shells were washed thoroughly until the dirt on its surface was removed. Then, it is air dried and crushed to be fine using jaw crusher before ready to be used for concrete preparation work. Crushed cockle shells appear more whitish as compared to river sand shown in Fig. 3 and 4 respectively. The XRF test result on crushed cockle shell presented in Table 1 indicated the high content of Calcium Oxide in this material.

Fig.1 : Cocklebefore processed by cockle trade

Fig. 2 : Cockle shell which dumped as waste

Fig.3 : Crushed cockle shell to be used in concrete

Fig.4 : River sand which normally used in concrete

Table 1 : Chemical ingredient results of crushed cockle shell

Chemical ingredient	**Percentage (%)**
Calcium Oxide (CaO)	67.28
Silicon Dioxide (SiO_2)	0.50
Sodium Oxide (Na_2O)	0.42
Iron Oxide (Fe_2O_3)	0.27
Aluminium Oxide (Al_2O_3)	0.19
Strontium Oxide (SrO)	0.19
Sulphur Trioxide (SO_3)	0.14
Magnesium Oxide (MgO)	0.07
Phosphorus Pentoxide (P_2O_5)	0.04
Potassium Oxide (K_2O)	0.03
Chlorine (Cl)	0.03
Manganese Oxide (MnO)	0.02
Titanium Oxide (TiO_2)	0.02

2.2Mix Proportioning

Six types of mixes namely plain concrete and crushed cockle shell concrete (KC) containing different content of crushed cockle shell as partial sand replacements were prepared. The concretes were prepared in the form of cubes (100x100x100mm). The control specimen, a plain concrete with 100% OPC of Grade 30 was designed using trial mix method. Next, the crushed cockle shell concrete was prepared by integrating a range of crushed cockle shell content as partial sand replacement. The use of crushed cockle shell as partial sand replacement in plain concrete was based on a simple approach viz. by direct replacement by weight of total fine aggregate content. The sand replacement is varied from 5% to 25% with 5% interval leading to the formulation of mix identified as K-0, K-5, K-10, K-15, K-20 and K-25 as tabulated in Table 2. Specimens were cast and then covered with wet gunny sack for 24 hours.After 24 hours, all specimens were removed from the mold and immersed in water tank for curing purpose. The compressive strength test was conducted at 7 and 28 days of curing adhering to the procedure in [15]. The compressive strength result for each mix was obtained by taking the average of three data.

Table 2. Mix proportion of concrete mixes

	Mix Proportion (kg/m^3)				
Mixes	Cement	Sand	Granite Aggregate	Crushed Cockle Shell	Water
K-0	432	694	1041	-	233
K-5	432	659	1041	35	233
K-10	432	624	1041	69	233
K-15	432	590	1041	104	233
K-20	432	555	1041	139	233
K-25	432	520	1041	174	233

III. RESULTS AND DISCUSSION

Based on the result presented in Fig. 5, all specimens exhibit strength increment as curing period become longer. The continuous water curing ensures occurrence of undisturbed hydration process that is vital for formation of calcium silicate hydrate gel. The C-S-H gels produced fills in the existing pores contributing to pore refinement leading to denser and stronger concrete. The effectiveness of this curing method in enhancing concrete strength has been pointed out by [16]. Another researcher [17] also added thatcontinuously supplying water to the concrete would positively help the C-S-H gel production. Looking at the effect crushed cockle shell as partial sand replacement; evidentlythere are variations in thecompressive strength valueexhibited by the concrete depending on the amount of cockle shell added.It also can be deduced that the achievement of highest strength gain for concrete integrating crushed cockle shell as partial sand substitute is possible only when right amount of this waste material is added.

As can be observed, the inclusion of crushed cockle shell up to 10% to replacement the river sand contribute towards enhancement of concrete strength. Replacement from 5% and 10% manage to aid towards achievement of higher concrete strength that is 117% and 118% respectively of the plain concrete (K-0). Probably, the strength increment is due to the effective function of crushed cockle shell as filler. Beyond 10% replacement, the compressive strength continues to drop as content of crushed cockle shell added increases. This initial stage of study has indicated that, integration of suitable crushed cockle shell content could be used to replace natural river sand for concrete production having enhanced compressive strength. This new findings has

opened a new door for research on the long term performance of concrete containing crushed cockle shell as partial sand replacement both in terms of mechanical properties as well as durability aspect.

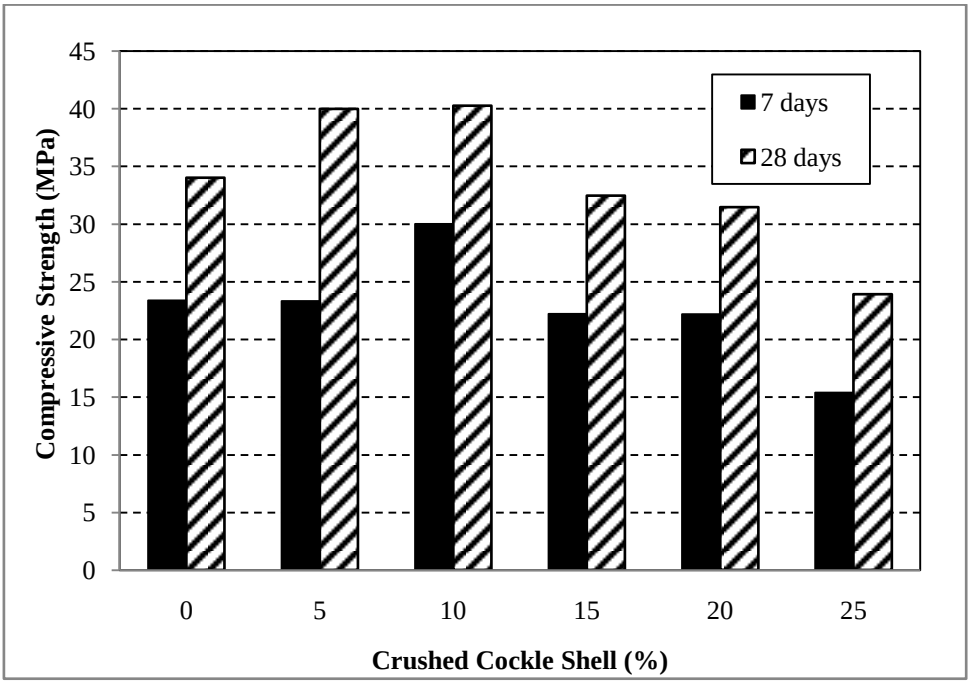

Fig.5 : Effect of crushed cockle shell content on compressive strength of concrete at 28 days

IV. CONCLUSION

This preliminary study discovers that integration of suitable percentage of crushed cockle shell as partial sand replacement would contribute towards enhancement of concrete strength. This early study has opened door for more investigation to be conducted on the performance of concrete containing crushed cockle shell in terms of durability in aggressive environment and also fire resistance. Generally, this discovery able to propose a more environmental friendly concrete with lower content of natural resources and most importantly, better strength performance compared to plain concrete.

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