A Review: Parametric Study on Concrete by Partial Replacement of Aggregates with Sea Shells and Coconut Shells

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Abstract— Use of sea shells and coconut shells in concrete has attracted widespread attention from construction industry due to the multiple sustainability benefits they offer. This paper critically reviews the current state of knowledge and technology of using sea shells and coconut shells to concrete. Detailed review on the various preparation techniques and the resulting properties of sea shells and coconut shells are presented and the effects of sea shells and coconut shells on the fresh and hardened concrete properties are discussed in this paper. The effect of sea shells and coconut shells on workability, plastic shrinkage, and compressive strength, splitting tensile strength, flexural strength, crack behavior and dry shrinkage is discussed in this paper. Pull-out behavior of the coconut shell in the concrete are also reviewed. Finally, some applications of the sea shells and coconut shells concrete are discussed.

Key words: Sea shells concrete, Coconut shells concrete, fresh properties of sea shells and coconut shell concrete, compressive strength

I. Introduction

The concept of environmentally friendly technology has inspired the researchers to do more in protecting the environment. Utilization of waste materials as alternative building materials has become the popular way to overcome the environmental problem in most developing countries. Waste materials such as Coconut Shells and Sea Shells have great potential to be used as building materials.

The basic constituents of concrete are cement, water and aggregate. In which aggregate tends to represent a relatively high volume percentage of concrete. Recent investigation of sea shells and coconut shells has indicated greater scope for their utilization as construction material (1-4). Greater utilization of sea shells and coconut shells will lead to not only saving such construction material but also assists in solving the problem of disposal of these waste products.

Sea shell is also known as shell which possess hard, protective outer layer created by an animal that lives in the sea. The sea shell is a part of the body of the animal. Empty seashells are often found washed up on beaches. The shells are found empty because of the animals are died in the shells and the soft part of the shell is eaten by another animal or have rotted out.

Seashells are found large quantities in the Asian ocean and Pacific Ocean. There is large quantities of calcium carbonate is present in shells such as oyster shells are sometimes used as soil conditioners in horticulture in some areas(2). The shells are broken or ground into small pieces in order to have the desired effect of raising the pH and increasing the calcium content in the soil.

Due to the shore ostreaculture, approximately 3.0 x 105tons per year of oyster shell (OS) which is one type of sea shells occurs in the southern and western sea of South Korea (especially, in Koje and Tongyong cities of South Korea)(2). Currently, although a limited amount of this type of sea shells are used in as in fertilizer. The extent of reuse is restricted due to problems of limits on reuse volumes, security of the container freight station at the time of handling, soil solidification from spreading of sea shells specially OS on farmland, and economic problems. Accordingly, most sea shells are not reused but are illegally discarded in the surrounding area (2).

Coconut shell waste is an agricultural biodegradable waste found in most of tropical countries especially in Asia India manufactures 15,730 million nuts annually, which is next to Indonesia with 16,498 million coconut shells dumped improperly to the environment provide breeding places for disease vectors such as rats and mosquitoes(3). It is a light-weight material which is becoming much popular nowadays because of its easy handling and low dead loads. It is a good alternative to wood and helps to prevent deforestation and also inexpensive.

As the status of living is increasing with their needs the amount of different types of wastes are increasing. So the need for the replacement of the present material that is the concrete manufacturing has to be changed to meet the needs of the structure. So the most economical, ecological, light-weight and ease of work construction of the structure is important in the present economy. Many attempts has been made for this such that in case of light weight concrete in addition to the weight and material benefits, studies have shown that it also has better thermal insulation and noise absorbing properties than normal weight concrete(3).Initially, the lightweight aggregate used typically fell into the 'naturally occurring' category and included volcanic materials like pumice and scoria, but as the availability of these materials became more limited, 'naturally occurring and processed' aggregate such as shale, slate, and clay began to be used as aggregate As demand continued to increase, new technologies were developed to discover and apply manufactured materials as lightweight aggregate. This has included materials such as fly ash, colliery waste, and blast furnace slag (4). There are several readily available materials that potentially could be used as lightweight aggregates. The coconut shells and Polyethylene terephthalate (PET) water bottle also used as construction materials (5). The coconut shells used daily by most inhabitants in their cooking but there is currently little use for the shells. In many tropical countries, coconut shells are common agricultural solid wastes. In different shapes with divergent properties concerning their affinity to paste or water. They are known to affect the workability and the flow characteristics of concrete. The degree to which workability decreases does depend on the type and content of fibers used, on the matrix in which they are embedded and the properties of the constituents of the matrix (6).

Apart from its use in production of fiber-roofing material, the other possibility of using CS as an aggregate in concrete production has not been given any serious attention.

II. Preparation and Properties of Coconut Shells and Sea Shells

Sea shells have higher amount of CaCO3 (91.18%) slightly greater than lime stone. The physical properties of sea shells were Specific gravity (2810 kg/m3) and Water absorption (0.80%) (1). Disadvantageous reactions at the interface between cement and OS or formation of new materials were not found, and cement hydrates and OS are independently detected (2).

The freshly discarded shells were collected from the local oil mills are used and they were well seasoned. The seasoned CS is crushed by a mini crusher. CS aggregates were used in saturated surface dry (SSD) condition (3). Durability of an aggregate is a measure of its resistance to wear, moisture penetration, decay and disintegration. The hardness of the CSs was measured by the durability test using the Los Angeles abrasion method. The test results indicated high values of 98.6% (3). This implies that concrete made from these two types of aggregate will possess a high degree of resistance to wear and can be used in the production of concrete intended for floors and pavements expected to be subject to heavy human traffic(3). In all cases the density of the concrete produced decreased with increase in the percentage replacement of conventional coarse aggregate (gravel) with CSs (3).

The moisture contents of the coconut and palm kernel shells (PKSs) used were found to be 5.13% and 4.35% (8). The water absorption capacity of CS was found to be 6.17% (8). Absorption capacity is a measure of the porosity of an aggregate. Since the values obtained are low, it is reasonable to conclude that the shells absorb very little amount of mixing water during concrete production (8). These values are also within the range of absorption capacity of lightweight aggregates which have been put at 5–20% (Portland Cement Association). The unit weight (density) and the specific gravity of the shells are 1738 kg/m3for CSs. These figures fall below the 2.5–3.0 range of specific gravity for normal weight aggregates. The CSs can therefore be classified as lightweight aggregates, the CSs having higher density and specific gravity (9). The clear differences in specific gravities of the shells (1.74), stone dust (2.35) and cement (3.15) explained why it was necessary, as done in this investigation, for the material quantities to be computed by the method of absolute volume.

III. Sea Shells and Coconut Shells Concrete

A. Fresh Concrete Properties

1) Slump

Workability of fresh concrete can be determined through a slump test. Eun-IK Yang et al. reported that substitution of fine aggregate with OS decreases slump, thus decreasing workability of fresh concrete (2). Coconut shell concrete probably has better workability due to the smooth surface on one side of the shells and also due to smaller size of CS used in the study (3, 10) reported by K. Gunasekaran et al.

2) Plastic Shrinkage

Plastic shrinkage test results of coconut shell concrete slab shows that if the percentage of coconut shells increases the plastic shrinkage crack area decreases that was reported by K. Gunasekaran et al. (11).

B. Hardened Concrete Properties

1) Compressive Strength

As shown in fig.1 the compressive strength of the coconut shell concrete decreased as the percentage of the coconut shells increased what was reported by E.A Olanipekun et al.(8). Test results for compressive strength of concrete with partial replacement of sand with dry oyster shell was shown in fig.2 what was reported by Eun-Ik-Yang et al. (12).

2) Splitting Tensile Strength

For the selected mixes, cement: Fine: aggregate: CS: w/c ratio (1:1.47:0.65:0.42) and (1:1.47:0.65:0.44), the splitting tensile strength of coconut shell concrete at 28-days is 2.70 N/mm2 (10.11% of compressive strength) and 2.38 N/mm2 (9.17% of compressive strength), respectively, for water–cement ratios of 0.42 and 0.44. Hence, it is evident that the behavior of Coconut shell concrete is similar to conventional concrete. A similar result is also reported for oil palm shell concrete (3) that was reported by K. Gunasekaran et al.

Generally speaking, the tensile strength development of high-strength concrete at an early age is high and the development after age 7 days is insignificant (7). In this test, the change in strength after age 7 days is not distinct, but, the deviation with mixture was apparent (7).When comparing the splitting tensile strengths. However, the tensile strength at an early age increased with SR of OS increase. The tensile strength with SR of OS at age 28 days decreased a little compared with the tensile strength of the standard mixture. This is because the influence of w/c ratio variance at early ages and the stress concentration occurring in the OS portion at old ages (7) that was reported by Eun-Ik Yang et al.

3) Flexural Strength

Brahim Safi et al. tested the flexural strength of self compacting mortar (SCM). Fig. 3 show changes in the flexural strength as a function of age for mixtures based mortars shells. From the results obtained, it is evident that the flexural strength increases with age for all mortars prepared. However, compared to the reference mortar SCMs (0%), there was a slight decrease (negligible) of strength in bending of mortars with the substitution of sand by crushed oyster shells (1).

Flexural test is another indirect tensile test for the measurement of the ability of concrete beam to resist failure in bending. Three-point loading and four-point loading are normally used in the flexural tests. For the three-point loading flexural test, results are more sensitive to specimens, because the loading stress is concentrated under the centre loading point (13).

K. Gunasekaran et al. (14) tested the flexure strength of reinforced lightweight coconut shell concrete beam. Flexural behavior of all the beams was typically structural in nature. At the level of reinforcement no horizontal cracks were observed (14), which indicates that there are no occurrences of bond breaking between the CSC and the reinforcement. In the constant-moment region vertical flexural cracks were observed and final failure occurred due to crushing of the compression concrete with considerable amount of ultimate deflection. Since singly reinforced beams were designed as under-reinforced beams, yielding of the tensile reinforcement occurred before crushing of the concrete cover in the pure bending zone. In case of doubly reinforced beams, since beams were designed as over-reinforced section, crushing of the compression concrete was observed before reinforcement yielded. These two cases clearly show that coconut shell concrete behaves similar to conventional concrete. At ultimate stage failure, the crushing depth of the concrete varied from 45 mm to 110 mm (14).

4) Cracking Behavior

K. Gunasekaran et al. (14) performed the measure of crack width of reinforced light weight coconut shell concrete beam at every load increment at the tension reinforcement level and the crack formations were marked on the beam. For the doubly reinforced beams, initial cracking occurred at about 6–10% and 8–13% of the ultimate load of CSC and CC beams, respectively, whereas for the singly reinforced sections, the cracks formed at about 12–17% and 15–21% of the ultimate load of CSC and CC beams, respectively. This indicates that for higher reinforcement ratios, the first crack occurs at lesser percentage of the ultimate load. It was noticed that the first crack always appeared close to the mid span of the beam. Vertical cracks were formed on the surface of the beams, indicating that failures of beams are in flexure. The first crack moment is taken as the point where a sudden deviation from the initial slope of the moment–deflection curve occurs .For structural members to perform satisfactorily there should not be excessive cracking. Wide cracks greatly reduce the stiffness of a member, promote ingress of harmful substances into the concrete, are unsightly, and may cause concern to occupants. The maximum allowable crack widths provided by various codes of practice usually lie in the range of 0.1–0.4 mm depending on the exposure condition. IS 456:2000 (16) stipulated that the surface crack widths should not be greater than 0.3 mm. It was observed that for CSC, the crack widths at service load were well below the maximum allowable value as stipulated by IS 456:2000 (16) for durability requirements. It was found that both codes gave reasonably close predictions of the crack width with better accuracy. Typical crack path of CSC specimens at earlier and at later age is shown in fig.4.

5) Drying Shrinkage

Drying shrinkage occurs due to the loss of water from the hard-ended concrete. The drying shrinkage can be quite significant in large flat areas like footpaths and slabs in hot, windy and dry environment. Steel reinforcing mesh is typically being large flat areas like footpaths and slabs in hot, windy and dry environment. Steel reinforcing mesh is typically being used to prevent the drying shrinkage cracks. Eun-Ik Yang et al. carried out experimental study to investigate the effect of oyster shell substitute for fine aggregate on concrete characteristics (12).

Fig. 5 shows the variation of drying shrinkage with increasing SR of OS. The absolute value of drying shrinkage and the shrinkage rate increased with increasing SR. According to suggested model equations, when the age was infinite the final shrinkage strain approached 456x10-6, 487x 10-6, and 581x 10-6, correspondingly, at each SR. The increase in drying shrinkage based on regression analyses was 7% and 28% at SR of 10% and 20%, respectively, compared with SR of 0%. These changes result from the lower rigidity of OS and the effect of size of fine powder.

6) Pull-Out Behavior Of Coconut Shell Concrete

The bond strength was determined using the pull-out test and the specimens were prepared as per IS 2770 (part-I 1967) (16). K. Gunasekaran et.al carried out experimental study for coconut shell concrete (3). The results showed that the bond strength of specimens with plain bars ranged from 3.56 to 7.49 N/mm2 (15–32% of compressive strength). For deformed bars, the bond strength ranged from 4.22 to 9.84 N/mm2 (18–42% of compressive strength). The theoretical bond strengths for plain bars in conventional concrete are 1.4 and 1.36 N/mm2 as per IS 456-2000 and BS 8110, respectively. The corresponding values for deformed bars are 2.24 and 2.42 N/mm2 In general; the bond strength of CSC is comparable to the bond strength of normal and other LWC.

In all the tests, plain bars failed by pulling out of the concrete whereas, deformed bars failed by concrete cover cracking and the failure was sudden with the formation of longitudinal cracks. The deformed bars had a good grip on the concrete through well-distributed mechanical anchorages along their length. This showed that the projections on the surface of the deformed bars played an important role in improving the bond strength. In case of plain bars, the absence of anchorages and smooth surface on one side of the CS aggregates coupled with the continuous presence of water might have prevented good bond between the smooth bars, which contributed to the lower bond strength as compared with deformed bars. However, even this lower bond strength value for plain bars is greater than the theoretical prediction as per standards. It was also observed that for both plain and deformed bars, as the bar size increases, the bond strength decreases. This may be because the surrounding volume of concrete and hence the confining pressure reduces on the reinforcing bar as the sizes increase (3). Similar trends were reported by Teo et al. (17).

IV. APPLICATIONS OF SEA SHELLS AND COCONUT SHELL CONCRETE

Sea shells and Coconut shells found large in quantities at coastal areas. Coconut shell waste is an agricultural biodegradable waste found in most of tropical countries especially in Asia. India manufactures 15,730 million nuts annually, which is next to Indonesia with 16,498 million. It is a light weight material which is becoming much popular now a day because of its easy handling and low dead loads.

Sea shells are found large quantities in Asian and Pacific Ocean. There is large quantities of calcium carbonate is present in shells such as oyster shells are sometimes used as soil conditioners in horticulture in some areas.

Sea shells and Coconut shell can be used as Coarse aggregate in place of conventional aggregate in concrete. The sea shell and coconut shell concrete can be used as non structural works such as road pavement design, minor bridges, slab, foundations where heavy loading is not expected.

V. Conclusion

Use of sea shells and coconut shells as aggregate in concrete instead of conventional aggregate becomes appealing to scientists and concrete industries. This paper has presented the current state of knowledge of using sea shells and coconut shells in concrete. It also reviews the reinforcing effects of coconut shells in concrete, environmental benefits and applications of sea shells and coconut shells concrete. The major conclusions drawn from the study are:

1) The sand substitution by crushed seashells has slightly decreased the fluidity of mortars and increases the bulk density.
2) The Drying shrinkage increased, Elastic modulus decreased with SR of OS increase.
3) Use of sea shells did not show negative influence on freezing and thawing; improve the chemical attack resistance and permeability resistance.
4) OS did not cause reduction in the compressive strength of concrete at age 28 days and development of compressive strength was faster as SR of OS increased.
5) If the percentage of coconut shell decreases, density and compressive strength of concrete is increases and vice-versa.
6) Coconut shells were more suitable than palm kernel shells when used as substitute for conventional aggregates in concrete production.
7) Bond strength of coconut shell concrete is higher than that of the conventional concrete.
8) Coconut shell concrete led to reduce plastic shrinkage cracking and more deflection compared to conventional concrete.
9) Also coconut shell concrete gives warning before its failure compared to conventional concrete.
10) The flowability of mortars based 100% of seashells, was better and is suitable for a fluid concrete (as a self-compacting concrete).
11) Coconut shell concrete is able to achieve its full strain capacity under flexural loadings.

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VI. LIST OF FIGURES

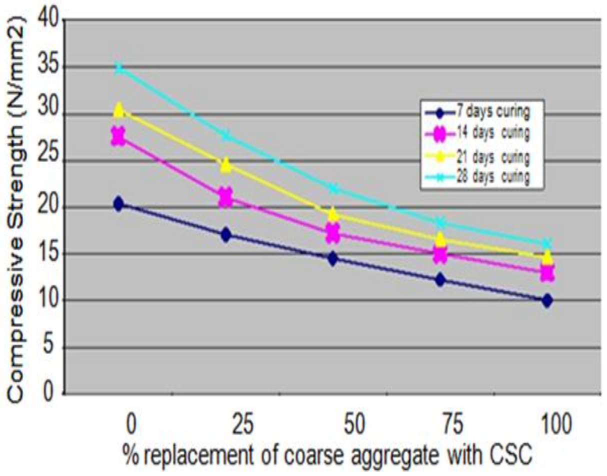

Fig. 1: Compressive strength of CSC of mix proportion 1:1:2

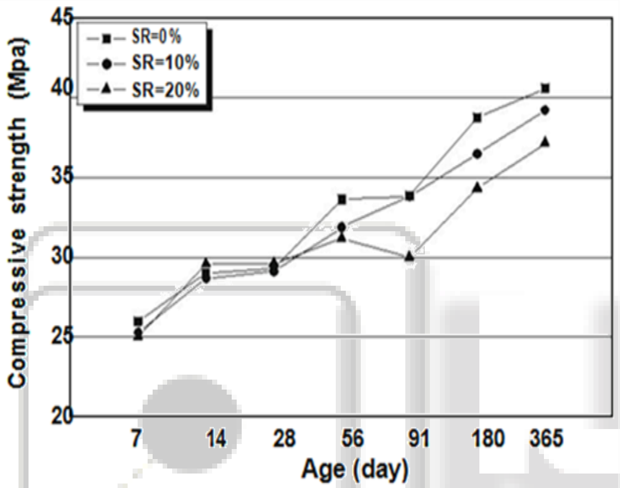

Fig. 2: Relationship between compressive strength and age with SR.

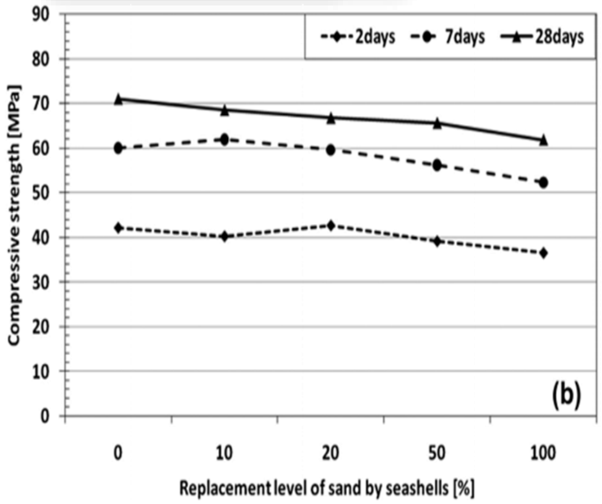

Fig. 3: The flexural strength of mortars as function the replacement level the sand by crushed seashells

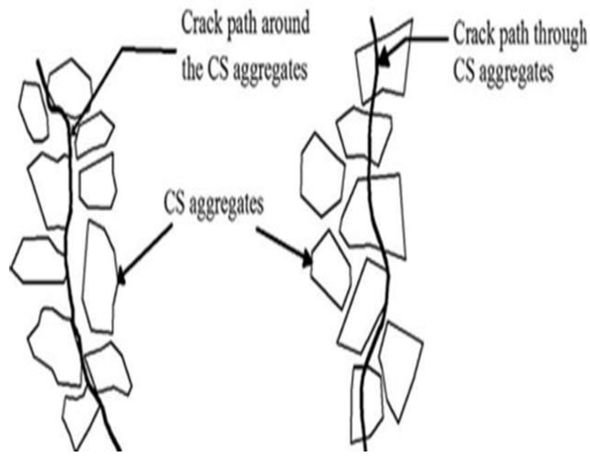

Fig. 4: Typical crack path of CSC specimens at earlier and at later age

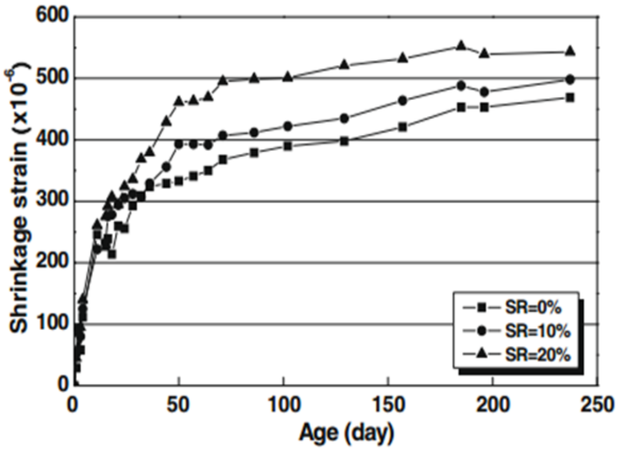

Fig. 5: Influence of SR on shrinkage strain