USE OF WASTE COCONUT SHELLS AS SUBSTITUTE FOR COARSE AGGREGATE IN LIGHT-WEIGHT CONCRETE MIXES

M.B.M. De Costa[1], D.D.T. Dasanayaka[2], M.N. Tantirimudalige[3], K.M.L.A. Udamulla[4] and T.C. Ekneligoda[5]

[1,2,3,4,5]*Department of Civil Engineering, Open University of Sri Lanka*

INTRODUTION

Concrete is a premier construction material consisting of a natural aggregate, such as gravel/crushed rock as a coarse aggregate, sand as a fine aggregate, cement as a binding medium, water and admixtures. Usually, granite or granitic-gneiss rock is used as a coarse aggregate for concrete in Sri Lanka.

The coconut shell is a natural material that is available abundantly in Sri Lanka. Waste, generated by industrial and agricultural processes, has created disposal and management problems that pose serious issues of environmental pollution. In Sri Lanka, coconut shells are reused in many applications and some amounts of it are exported. However, the Coconut Development Authority statistics indicate that a considerable amount of coconut shells remain in the environment as waste (Coconut Development Authority, 2012). Therefore, the utilization of these materials in construction will be an important step to improve sustainability and eco-friendly construction. In addition to that, it will help to reduce the self-weight of concrete structures. This study will help to reduce other necessary ingredients in the production of concrete. The current study examines the suitability of the partial replacement of a coarse aggregate with coconut shells in the production of concrete.

METHODOLOGY

Coconut shell samples were collected, cleaned and prepared for testing. Particle size distribution tests (BS 812-103.1: 1985) were conducted for manually crushed coconut shell samples to calculate the amount of each size that should be mixed to obtain a well-graded aggregate sample. The physical properties of a coconut shell, its moisture content, water absorption, specific density, impact value, flakiness index and elongation index, were determined.

A concrete mix was prepared by using the British weigh batch method. The proportions used in the control sample of 1 m^3 are shown in the table below.

Table 1: Quantities of the Materials

Constituent	Water	Cement	Fine Aggregates	Coarse Aggregates
Quantity (kg)	225	450	836	1064

Concrete specimens for different trial mixes, with different combinations of crushed coconut shells namely 0%, 4%, 8%, 12%, 16% and 20%, were cast. For each trial mix proportion, 6 cubes of 150x150x150mm for testing Compressive strength as per BS 5328-1997 and 4 cylinders of 100x200mm for testing splitting tensile strength as per ASTM C496-90 guidelines were cast. Workability was measured using the Slump test for a target slump of 60-180mm. A water absorption test was carried out according to ASTM C642-82.

[3] Correspondences should be addressed to Eng. (Mrs.) M.N. Tantirimudalige, Department of Civil Engineering, The Open University of Sri Lanka (email: mntan@ou.ac.lk)

RESULTS AND DISCUSSION

Sieve Analysis

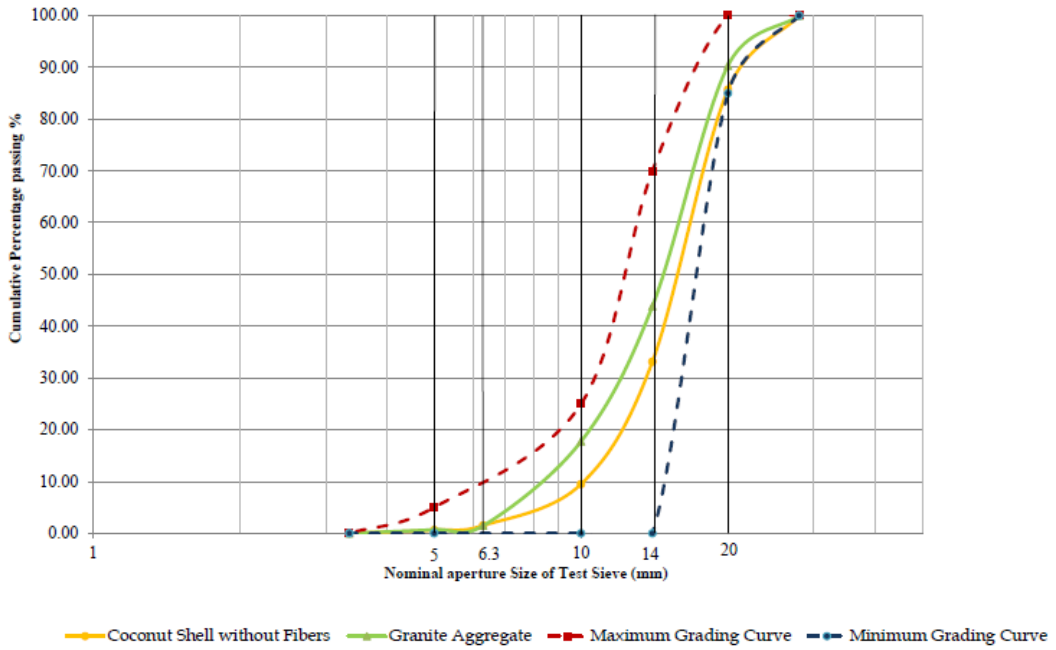

Figure 1: Grading curves of Coconut Shells & Conventional Coarse Aggregates Comparison with British Standard

The Gradation curve of a coconut shell falls within the recommended range for a coarse aggregate (BS 882). All tests were performed using aggregates from these well-graded coconut shell samples.

Physical properties of the Coconut Shells

Table 2: Physical properties of Conventional Coarse aggregate (granite) and coconut shell

Physical Properties	Testing Specification	Coarse aggregate	Coconut shell	Recommended value
Moisture Content dry (%)	BS812-109:1990	0.14	12.93	Depend on the Drying period of the aggregate
Moisture Content wet (%)	BS812-109:1990	0.14	11.45	
Specific Gravity	BS812:Part2:1995	2.73	1.31*	Normal weight aggregate 2.5-2.8
Water Absorption (%)	BS812:Part2:1995	0.49	26.05	Less than 3 BS 5337:1976
Aggregate Impact Value (%)	BS812:Part112	15	2.7	Maximum30 %BS882:1983
Flakiness Index (%)	BS812:105.1:1995	15.69	99.19	Maximum25 %
Elongation Index (%)	BS812:105.2:1990	58.54	50.56	Maximum25 %

* The specific gravity of the coconut shell satisfies the value for a lightweight aggregate, which is less than 2 (BS 812-2)

Properties of other ingredients

- Water: Portable water was used for the production of concrete mixes
- Cement: Ordinary Portland cement was used and the cement strength class was 42.5
- Fine aggregates: River sand was used and the particle size was sieved through a 5mm sieve. The specific gravity of fine aggregate is 2.63.

Workability of Concrete

Considering normal concrete applications and the grade of concrete, a target slump is taken as 60-180mm for a concrete mix design (Neville, 1990). The variation of the slump with the replacement of a coconut shell aggregate is shown in Table 03. The results indicate that the slump tends to increase with the increment of coconut shell percentages, resulting in higher workability.

Table 3: Workability of Concrete (slump mm)

Coconut shell replacement (%)	0	4	8	12	16	20
Slump (mm)	90	120	160	160	165	170

Compressive Strength

The compressive strength variations, according to the replacement of coconut shells, are given in Figure 2.

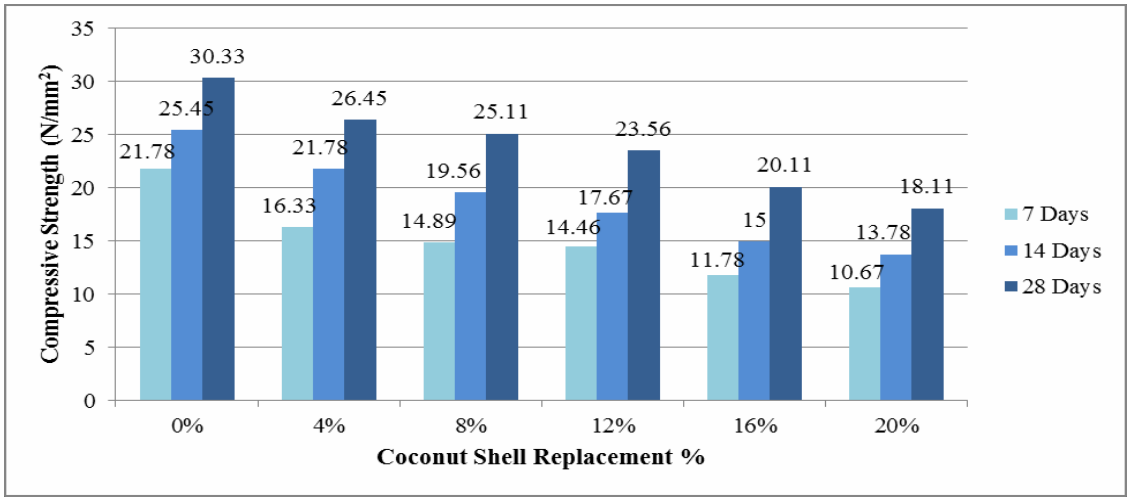

Figure 2: The relationship between Concrete Compressive Strength and Curing Days.

It can be seen from Figure 02 that compressive strengths decrease with the increase of the replacement of coconut shells. The compressive strengths achieved for 4% and 8% of coconut shell replacement satisfy the target strength of 25 N/mm^2 of the concrete mix design.

Splitting Tensile Strength

Figure 3 shows the variation of splitting tensile strength with the replacement of coconut shells.

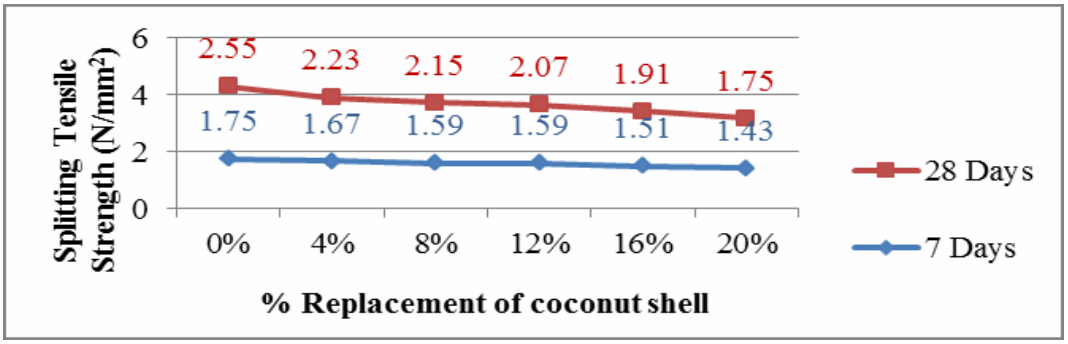

Figure 3: The relationship between Spitting Tensile Strength and a % Replacement of Coconut Shells

Water Absorption

Figure 04 shows the variation of water absorption of the concrete with the replacement of coconut shells

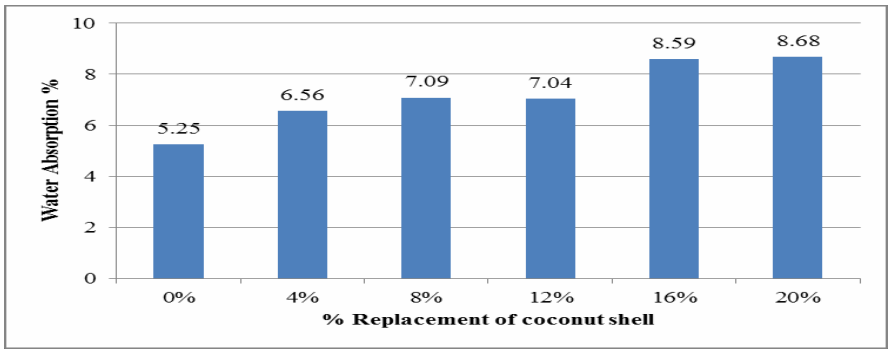

Figure 4: The variation of water absorption of concrete with a % replacement of coconut shells

It is observable that the water absorption of the concrete increases with coconut shell replacement.

CONCLUSIONS/ RECOMMENDATIONS

The properties of coconut shells are compared with those of conventional coarse aggregates to find the suitability of coconut shells as a replacement of coarse aggregates of concrete. Several conclusions can be drawn from the present work. Coconut shells have high toughness and abrasion resistant properties. The compressive strength decreases with increases of coconut shell content in the concrete, but gave satisfactory strength values after 28 days. It is observed that a proportion in the range of 4% - 8% satisfied the target strength 25 N/mm^2 (grade 25). However, grade 20 (20 N/mm^2) concrete is attainable by using replacement proportions of above 12%, but less than 20%. The water absorption of the concrete gradually increases with an increasing percentage replacement of coconut shell. Marginal tensile strength improvements were noticed when the coconut shell percentage was 4 % to 8 %.

It is worth comparing the value of 1 ton of waste coconut shells, which are available for Rs. 3000, with the same mass of a crushed rock aggregate (20 mm) at Rs. 5000.

The results from this research suggest that coconut shells can be applied as a partial substitute for a coarse aggregate in concrete in percentages subject to the characteristic qualities required in the structural member of normal concrete applications.

This study will help in reducing the usage of depleting resources by reducing the use of natural rock aggregate and in minimizing environmental hazards through waste disposal by making use of coconut shell as a construction material.

REFERENCES

Franklin, R. E., Teychenne, D. C., & Erntroy, H. C. (1988). *"Design of normal concrete mixes"* (2nd ed). England: Building Research Establishment.

Gunasekaran, K. (2011). "Utilization of coconut shell as Coarse Aggregate in the development of Light weight Concrete". Kattankulathur: SRM University.

Neville, A. M. & Brooks, J. J. (1990). *"Concrete Technology"* (1st ed),. England: Longman Group Limited,.

Coconut Development Authority. (2012). *Coconut Development Authority Statistics,*. Sri Lanka.

Vishwas, P, Kukarni, Kumar, Sanjay & Gaikwad B. (2013). *"*Comparative Study on Coconut shell Aggregate with Conventional Concrete*"*. *IJEIT*, Volume 2.