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Lightweight Concrete Using Coconut Shells as Aggregate

K.Gunasekaran

*PhD Research Scholar, gunarishi@ yahoo.com
School of Civil Engineering, SRM University, Kattankulathur-603 203,
Tamilnadu, India*

P.S.Kumar

*Senior Lecturer, erpsuresh@ rediffmail.com
School of Civil Engineering, SRM University, Kattankulathur-603 203,
Tamilnadu, India*

Abstract

Aggregates provide volume at low cost, comprising 66 percent to 78 percent of the concrete. With increasing concern over the excessive exploitation of natural and quality aggregates, the aggregate produced from industrial wastes and agriculture wastes being viable new source for building material. This study was carried out to determine the possibilities of using coconut shell as aggregate in concrete. Utilising coconut shell as aggregate in concrete production not only solves the problem of disposing this solid waste but also helps conserve natural resources. In this paper, the physical properties of crushed coconut shell aggregate were presented. The fresh concrete properties such as density and slump and 28-day compressive strength of a lightweight concrete made with coconut shell as coarse aggregate also presented. The findings indicated that water absorption of the coconut shell aggregate was high about 24 % but the crushing value and impact value was comparable to that of other lightweight aggregates. The average fresh concrete density and 28-day cube compressive strength of the concrete using coconut shell aggregate were 1975 kg/m^3 and 19.1 N/mm^2 respectively. It is concluded that crushed coconut shells are suitable when it is used as substitute for conventional aggregates in lightweight concrete production.

Key words: Lightweight aggregate, Agriculture waste, Coconut shell, Physical properties, Compressive strength

INTRODUCTION

Concrete is the widely used number one structural material in the world today. The demand to make this material lighter has been the subject of study that has challenged scientists and engineers alike. The challenge in making a lightweight concrete is decreasing the density while maintaining strength and without adversely affecting cost. Introducing new aggregates into the mix design is a common way to lower a concrete's density. Normal concrete contains four components, cement, crushed stone, river sand and water. The crushed stone and sand are the components that are usually replaced with lightweight aggregates. Lightweight concrete is typically made by incorporating natural or synthetic lightweight aggregates or by entraining air into a concrete mixture. Some of the lightweight aggregates used for lightweight concrete productions are pumice, perlite, expanded clay or vermiculite, coal slag, sintered fly ash, rice husk, straw, sawdust, cork granules, wheat husk, oil palm shell, and coconut shell. (Basri.H.B et al., 1999, Khedari et al., 2000, Mannan.M.A.. and Ganapathy.C 2002).

The exponential growth rate of population (Loehr RC .1984), development of industry and technology, and the growth of social civilisation would be considered as the underlying factors that have causes the increased waste production. Recently, the importance of countermeasures to deal with waste materials has been pointed out, because such materials continue to increases in each and every year. The use of alternative aggregate has become necessity for the construction industry because of the economic, environmental and technological benefits derived from their use.

The high cost of conventional building materials is a major factor affecting housing delivery in India. In developing countries where abundant agricultural and industrial wastes are discharged, these wastes can be used as potential material or replacement material in the construction industry. This will have the double advantage of reduction in the cost of construction material and also as a means of disposal of wastes. It is at this time the above approach is logical, worthy and attributable.

Presently in India, about 960 million tonnes of solid wastes are being generated annually as by-products during industrial, mining, municipal, agricultural and other processes. Of this 350 million tonnes are organic wastes from agricultural sources; 290 million tonnes are inorganic waste of industrial and mining sectors. However, it is reported that about 600 MT of wastes have been generated in India from agricultural sources alone (Asokan Pappu (2007). The major quantity of wastes generated from agricultural sources are sugarcane baggase, paddy and wheat straw and husk, vegetables wastes, food products, tea, oil production, jute fibre, groundnut shell, wooden mill waste, coconut husk, cotton stalk etc., (Martirena J.F. 1998, Medjo Eko, R. and G. Riskowski.,1999, Turgut Ozturk and Muzaffer bayrakl, 2005, Alabadan B.A.2006, Demirbas.A. and Aslan.A.1998). The new and alternative building construction materials developed using agro-industrial wastes have ample scope for introducing new building components that will reduce to an extent the costs of building materials.

One such alternative is coconut shell (**CS**), which is a form of agricultural solid waste. It is one of the most promising agro wastes with its possible uses as coarse aggregate in the production of concrete. This has good potential to use in areas where crushed stones are costly. Statistical data of coconut production shows that, India is producing nearly 27% of total world production and the annual production of coconut is reported to be more than 12 million tons. Presently the coconut shell waste being used for making mosquito coils, agarpathies, etc (www. Foodmarketexchange.com).Only few studies have been reported on use of coconut shells as aggregate in concrete (Olanipekun E.A.2006)). This paper discussed the physical properties of crushed coconut shell aggregate and the compressive strength of the concrete made with coconut shell coarse aggregate.

MATERIALS AND MIX PROPORTIONS

All raw materials used in this investigation were locally obtained. These includes ordinary Portland cement confirming to Indian standard code IS 8112-1995, palar river sand as fine aggregate and crushed CS as coarse aggregate. The potable water was used for mixing and curing. After crushed the coconut shells, they were sieved and the aggregates passing 12.5mm sieve size was used for this investigation (**Fig.1 and Fig.2**). The physical and mechanical properties of the river sand, CS aggregate and granite aggregates are shown in **Table 1**. The sieve analysis of the river sand, CS aggregate and granite aggregates are illustrated in **Fig. 3.**

The normal design procedures for ordinary conventional concretes are not applicable to the mix design of lightweight aggregate concrete for two reasons: (i) the water content of the cement paste in the fresh lightweight aggregate concrete mix is reduced progressively through absorption by the aggregate and therefore the water-cement ratio will also decrease, and (ii) the compressive strength of lightweight aggregate concrete is not only influenced by the strength of the mortar but also by the aggregate used. Hence, it is recommended to go for trial mixes for designing lightweight concrete mix. For lightweight concrete, the cement was recommended in the range of 285–510 kg/m^3 (Mindess.S. and Young.J.F. 1981). Trial concrete mixes were carried out based on the recommended procedure for lightweight concrete (Mannan M.A. and Ganapathy C. ,2001). The concrete mix proportion obtained from the trials was 1: 1.63: 0.81. The mix proportion consists of 480 kg/m^3 cement with the water / cement ratio of 0.42.

SPECIMEN PREPARATION AND TESTING

For each mix, the density and workability (in terms of slump) of the fresh concrete were measured. The fresh concrete density and slump test were carried out in accordance with BS 1881: Part 107: 1983 and BS 1881: Part 102: 1983 respectively. For each mix, nine 100-mm size cubes were cast to determine the compressive strength at the age of 3, 7, and 28 days. Mixing was performed in a drum type mixer (capacity 50 kg) in the laboratory with an ambient temperature of 28±5ºC and the mixing time was adjusted for each mix type to obtain a uniform and homogenous concrete. All specimens were cast in two layers and compacted on a vibrating table until air bubbles appearing on the surface stopped.

Immediately after casting, the specimens were covered with plastic sheet, left in the mould for one day and then removed from the moulds. After that, they were cured in water at 23 ± 2 ºC until they were tested. The compressive strength was determined by crushing three 100-mm cubes in accordance with BS 1881: Part 116: and averages of the three values were obtained. The cubes used for compressive strength were also used to test the density at saturated-surface dried (**SSD**) condition at the age of 28-day. Table 2 presents the results of compressive strength and 28-day saturated surface dry density of concrete made with coconut shell aggregate.

RESULTS AND DISCUSSION

The average moisture content and water absorption of the crushed coconut shell was found to be 4.20 % and 24.00 % respectively. Since the coconut shells are basically wood based and organic material and therefore moisture retaining capacity would be more compared with the crushed stone aggregates. Due to the high water absorption of CS, the aggregates were pre-soaked for 24 hours in potable water prior to mixing and were in saturated surface dry (**SSD**) condition during mixing to prevent absorption of mixing water. In case of agricultural and wood based materials used in cement concrete, the pre-treatment is necessary to ensure that extractable materials do not upset the hardening qualities of the cement. The experiments have shown that most kinds of wood based materials can be improved substantially by soaking and washing with water before mixing (Paramasivam. P. and Loke. Y. O., 1980). This procedure is found suitable and easier and is therefore adopted in this investigation.

The specific gravity under SSD condition of CS and crushed granite was found to be 1.05 and 2.82 respectively. The specific gravity of an aggregate is used in mixture proportioning calculation to find the absolute volume that a given mass of material will occupy in the mixture. Absolute volume of aggregate refers to the space occupied by the aggregate particles excluding the voids between the particles. The specific gravity for normal weight aggregate used in concrete ranges from 2.30 to 2.90. However, the specific gravity of coconut shell is very close to that of oil palm shell (**OPS**) aggregates (Basri H.B. et al 1999).

The aggregate impact value gives relative measure of the resistance of an aggregate to sudden impact or shock. The aggregate impact value should not be more than 45 % by weight for aggregate used in concrete (Neville A.M 2005). From **Table 1**, it can be observed that the aggregate impact value (**AIV**) and aggregate crushing value (**ACV**) of CS aggregates are much lower compared to the crushed stone aggregates, which indicates that these aggregates have good absorbance to shock.

The slump obtained for the trial mix was 55 mm, which has showed that CS concrete has a medium degree of workability. The fresh concrete density and 28-day hardened concrete density (under SSD condition) using coconut shell were found to be in the range between 1975 - 2110 kg/m^3 and 1880 - 1930 kg/m^3 respectively. The 28-day compressive strength of the concrete using coconut shell aggregate was found to be 19.1 N/mm^2 (**Table 2**) under full water curing. The compressive strength of concrete using coconut shell coarse aggregate was more than 17.2 N/mm^2, which is a requirement for structural lightweight concrete (Mannan and Ganapathy 2004).

CONCLUSIONS

This paper presents the effective way of utilising crushed coconut shell aggregate in concrete. Presently, coconut shell is available at a low price in most of the tropical countries. Also the concrete obtained using coconut shell aggregates satisfy the minimum requirements of lightweight concrete. Hence it is possible to made lightweight concrete making use of coconut shells as an aggregate in concrete. Based on the investigation, the following conclusions were made.

- The average moisture content and water absorption of the crushed coconut shell were found to be 4.20 % and 24.00 % respectively. The CS aggregates have higher water absorption because of higher porosity in its' shell structure.
- The aggregate impact value and aggregate crushing value of CS aggregates were much lower compared to the crushed stone aggregate, which indicates that these aggregates have good absorbance to shock.
- The specific gravity under SSD condition of CS and crushed granite was found to be 1.05 and 2.82 respectively.
- The fresh concrete density and 28-day hardened concrete density using coconut shell were found to be in the range between 1975 - 2110 kg/m^3 and 1880 - 1930 kg/m^3 respectively.
- The 28-day compressive strength of the concrete using coconut shell aggregate was found to be 19.1 N/mm^2 under full water curing and it satisfies the requirement for structural lightweight concrete. It should, however, further investigations are required before it can be used as a building material.

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Table 1 Physical And Mechanical Properties of Coconut Shells, Crushed Granite and River Sand

Sl. No	Physical and mechanical properties		Coconut shells	Crushed granite	River sand
1	Moisture content		4.20 %	-	-
2	Water absorption		24.00 %	0.50 %	-
3	Specific gravity	SSD	1.05	2.82	2.57
4		Apparent	1.40	2.86	-
5	Impact value		8.15 %	12.40%	-
6	Crushing value		2.58 %	6.30 %	-
7	Bulk Density	Tamped	650 kg / m^3	1650 kg / m^3	-
8		Loose	550 kg / m^3	1450 kg / m^3	-
9	Fineness modulus		6.26	6.94	2.50
10	Shell thickness		2mm - 7mm	-	-

Table 2 Compressive Strength and Density of Coconut Shell Concrete (CSC)

Mix type	Compressive strength, N/mm^2			Fresh concrete density, kg/m^3	Hardened concrete density at 28-day (SSD condition), kg/m^3
	3-day	7-day	28-day		
CS concrete	10.2	14.9	19.1	1975-2110	1880- 1930

Fig. 1 Crushed coconut shell aggregate

Fig. 2 Closure view of coconut shell aggregate

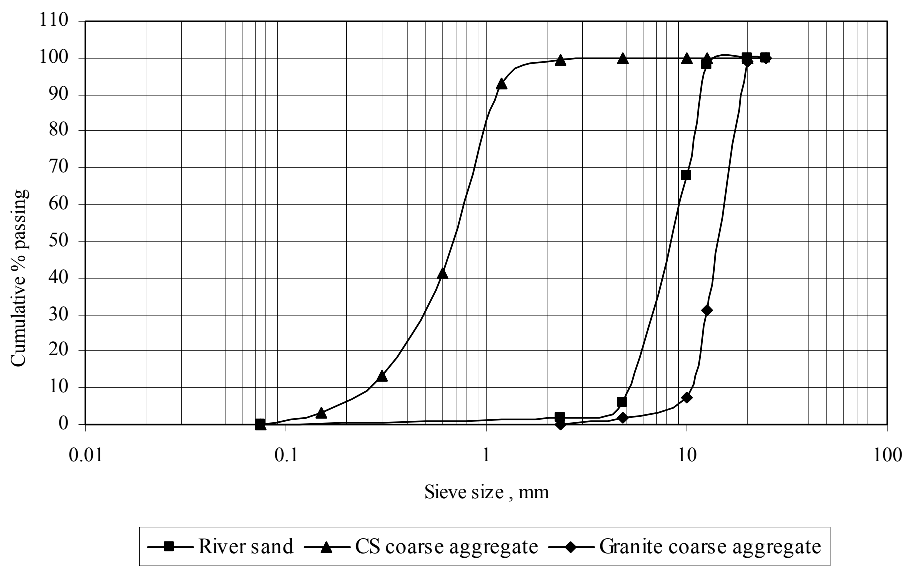

Fig. 3 Sieve analysis of coarse and fine aggregates