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Performance of Coconut Shell as Coarse Aggregate in Concrete: A Review

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Abstract
Different waste materials such as fly ash, silica flumes, copper slag, brick bat, demolished concrete has been successfully employed to produce various materials for building construction such as concrete, flush door, plywood, jute boards etc. Aggregate is a major ingredient for making concrete, occupy almost 70-80% part of concrete [1]. Conventionally crushed rocks are used as coarse aggregate and river sand as fine aggregate. Both are naturally available material. Due to rapid growth of construction activities, conventional aggregate sources are depleting very fast leading to significant increase in cost of construction. For sustainable development, these materials should be used wisely and alternative materials need to be searched to replace conventional aggregate. Large number of studies has been done to search alternative materials for production of concrete. At the same time due to rapid industrialization, production of waste material is increasing day by day. Its disposal has become real problem. Solution for this problem is to dispose waste on landfill site or use this waste for some positive activity. Space for landfill site is becoming costly affair. In view of this the option is either we should minimize the waste at production level, or utilize it.
India is the third largest coconut producing country in the world. Huge amount of waste is generated by coconut. The waste coconut shell may be used to replace conventional coarse aggregate. It may help to produce concrete economically and at the same time also will help to reduce its disposal problem. The aim of this paper is to address issue related to shortage of conventional material, problem of disposal of waste material and review the works done on use of waste coconut shell for concrete production.

Key words: coconut shell, concrete, coarse aggregate, compressive strength, waste disposal.

1. INTRODUCTION

Concrete is a composite material which composed of aggregates, cement and water. Concrete is used more than any other manmade material in the world. In addition, concrete is the 2nd most consumed substance in the world-behind water. About 7.23 billion tons of concrete is produced every year. Annual production represents one ton for every person on the planet. Production of concrete is increasing due to high growth of infrastructure development and construction activities in the world [3]. Production of concrete demand its constituents like aggregates, cement, water and admixtures. Sources of conventional aggregates occupy the major part of the concrete. The large scale production of concrete in construction activities using conventional coarse aggregate such as granite immoderately reduces the natural stone deposits and affecting the environment hence causing ecology imbalance. Increasing demand of natural aggregates show that crushed stone demand will be 2050 million metric tonnes in 2020 [3]. This huge demand of natural aggregate raises a serious question about preservation of natural aggregate sources for sustainable development. Extraction and processing of aggregates is also a major concern for environment. Therefore consumption of alternative waste material in place of natural aggregate in concrete production not only protects environment but also makes concrete a sustainable and environment friendly construction material. Different waste material like rubber, fly ash, glass, bottom ash, artificial sand etc has been used as alternative for replacing natural aggregates. Apart from the above mention waste material, a few studies shows that agriculture waste coconut shell can also be used as coarse aggregate for concrete.

2. COCONUT SHELL

Coconut is grown in more than 93 countries. India is the third largest, having cultivation on an area of about 1.78 million hectares for coconut production. Annual production is about 7562 million nuts with an average of 4248 nuts per hectare [4]. The coconut industry in India accounts for over a quarter of the world's total coconut oil output and is set to grow further with the global increase in demand. However, it is also the main contributor to the nation's pollution problem as a solid waste in the form of shells, which involves an annual production of approximately 3.18 million tonnes. It also presents serious disposal problems for local environment, is an abundantly available agricultural waste from local coconut industries. In developing countries, where abundant coconut shell waste is 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.

3. PROPERTIES OF COCONUT SHELL

1. Coconut shell has high strength and modulus properties.
2. It has added advantage of high lignin content. High lignin content makes the composites more weather resistant.
3. It has low cellulose content due to which it absorb less moisture as compare to other agriculture waste.
4. Coconuts being naturally available in nature and since its shells are non-biodegradable; they can be used readily in concrete which may fulfil almost all the qualities of the original form of concrete.

Table 1: Availability of coconut shell [5]

S.No.	Country	Coconut Production 2012 (metric tonnes)	% of World Total
1	Indonesia	18,000,000 t	30.0%
2	Philippines	15,862,386 t	26.4%
3	India	10,560,000 t	17.0%
4	Brazil	2,888,532 t	4.8%
5	Shrilanka	2,000,000 t	3.3%
Sources: FAOSTAT data, 2014 (last accessed by Top 5 of Anything: January 2014).			

4. COCONUT SHELL AS A ALTERNATIVE COARSE AGGREGATE

In view of thrust on energy saving and sustainable development, the use of alternative constituents of natural resources and the search of suitable alternative to conventional construction material is now a global concern. To make use of alternative aggregate in concrete which is coconut shell has never been a common practice among the people, particularly in areas where light weight concrete is required for non load bearing walls and non structural floors.

Concrete obtained using coconut shell as a coarse aggregate satisfies the minimum requirements of concrete. Coconut shell aggregate resulted acceptable strength which is required for structural concrete. Coconut shell may present itself as a potential material in the field of construction industries. The coconut shell is compatible with cement and no need to pre-treatment for using it as coarse aggregate. Because of the smooth surface on one side of the shells concrete made with coconut shell presents better workability. Coconut shell concrete shows good impact resistance. As compared to conventional aggregate water absorbing and moisture retaining capacity of coconut shell is more. The presence of sugar in the coconut shell, does not affect the setting and strength of concrete because it is not in a free sugar form. It is found that wood based materials being hard and of organic origin, will not contaminate or leach to produce toxic substances once they are bound in concrete matrix.

5. RESEARCH FINDINGS

Scarcity of conventional resources and coconut shell waste disposal problems made the researches to investigate and explore the possibility of utilize it for construction activities. A few studies are done on coconut shells and the outcomes of the researches are as following:-

Olanipekun (2006) carried out the comparative cost analysis and strength characteristics of concrete produced using crushed, granular coconut and palm kernel shell as substitutes for conventional coarse aggregate. The main objective is to encourage the use of waste products as construction materials in low-cost housing. Crushed granular coconut and palm kernel was used as substitute for conventional coarse aggregate in the following ratios: 0%, 25%, 50%, 75% and 100% for preparing of mix ratios 1:1:2 and 1:2:4. Total 320 cubes were casted, tested and their physical and mechanical properties were determined. The result showed that the compressive strength of the concrete decrease as the percentage of the coconut shell increases in the two mix ratios, Coconut shell exhibited a higher compressive strength than palm kernel shell in the test. Moreover, there is a cost reduction of 30% and 42% for concrete produced from coconut shell and palm kernel shell respectively [6,7].

Siti Aminah Bt Tukiman and Sabarudin Bin Mohd (2009) replaced the coarse aggregate by coconut shell and grained palm kernel in their study. Percentage of replacement by coconut shell were 0%, 25%, 50%, 75% and 100% respectively. Conclusion is that the combination of these materials has potential of being used as lightweight aggregate in concrete and also has reduce the material cost in construction [8].

Olutoge (2010) studied the saw dust and palm kernel shells (PKS). Fine aggregates are replaced by saw dust and coarse aggregates by palm kernel shells in reinforced concrete slabs casting. Conventional aggregates were replaced by saw dust and PKS in same ratios of 0%, 25%, 50%,75% and 100%. Compressive and flexural strengths were noted at different time intervals. It was seen that at 25% sawdust and PKS can produce lightweight reinforced concrete slabs that can be used where low stress is required at reduced cost. 7.43% reduction can be achieved

in terms of cost for every cubic meter of slab production with use of sawdust/PKS [9].

J. P. Ries (2011) observed that Lightweight aggregate plays important role in today's move towards sustainable concrete. Lightweight aggregates contributes to sustainable development by lowering transportation requirements, optimizing structural efficiency that results in a reduction in the amount of overall building material being used, conserving energy, reducing labour demand and increasing the life of structural concrete.

Abubakar and Muhammed Saleh Abubakar (2011) compared the physical and mechanical properties of coconut shell and crushed granite rock also a total of 72 concrete cubes of size 150x150x150mm with different mix ratios of 1:2:4, 1:1.5 :3 and 1:3:6 were casted and tested for evaluating different properties. Aggregate crushing value (ACV) for coarse aggregate was 21.84 and 4.71 for coconut shell. Elongation and flakiness index were 58.54 and 15.69 respectively for gravels, while for coconut shell, it was 50.56 and 99.19 respectively. Compressive strength of concrete cubes in N/mm2 of coconut shell at 7,14,21 and 28 days with mix ratios of 1:2:4, 1:1.5:3, and 1:3:6 are (8.6, 8.9 ,6.4,), (9.6, 11.2, 8.7), (13.6, 13.1, 10.7) and (15.1, 16.5, 11) respectively, likewise (19.1, 18.5, 9.6), (22.5, 23.0, 10.4), (26.7, 24.9, 12.9) and (28.1, 30.0, 15) respectively for gravel. Since the concrete strength of coconut shell with mix ratio 1:1.5:3, attained 16.5 N/mm^2 compressive strength at 28 days it can be used in plain concrete works, cost reduction of 48% will be achieved [10].

Amarnath Yerramala Ramachandrudu C (2012) in his experimental study, coarse aggregate was partially replaced by coconut shell and fly ash. Percentages of replacement by coconut shell were 10%, 15%, 20% and Percentages of coconut shell replacement by fly ash were 5%, 25%. He concluded in his study that workability decreased with increase in CS replacement. Compressive and split tensile strengths of CS concretes were lower than control concrete [11].

Maninder Kaur & Manpreet Kaur (2012) published a review paper in which it is concluded that use of coconut shells in cement concrete can help in waste reduction and pollution reduction. It is also expected to serve the purpose of encouraging housing developers in investing these materials in house construction. It is also concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production [12].

Vishwas p. Kulkarni et al (2013) studied that Aggregates provide volume at low cost, comprising 66 percent to 78 percent of the concrete. M20 Concrete is produced by 0%, 10%, 20%, 30% replacement of coarse aggregate by coconut shell. There is no need to treat the coconut shell before use as an aggregate except for water absorption. No bond failure was observed, confirming that there was adequate bonding between the coconut shell aggregate concrete and the steel bars [13].

Daniel Yaw Osei (2013) in this experimental study coarse aggregate is partially replaced by coconut shell. Percentages of replacement by coconut shell were – 0%, 20%, 30%, 40%, 50%, 100%. He concluded that CS can be used to produce lightweight concrete and 18.5% replacement of crushed granite with coconut shells can be used to produce structural concrete [14].

Tomas U. Ganiron Jr (2013) used coconut shells and fibre as substitute for aggregates in developing concrete hollow block. The study was carried out for various percentage of coconut shell content as partial replacement of conventional aggregate. Results showed that replacement of appropriate coconut shell content produces workable concrete with satisfactory strength. Integration of coconut shell enhanced the strength of concrete [15].

Parag S. Kambli & Sandhya R. Mathapati. (2014) prepared three different Mix Designs for M20, M35, M50 grades of concrete. Percentage replacement by coconut shell varied as 0%, 10%, 20%, 30%, 40% respectively. It is concluded in this study that for M20 grade concrete cubes with 30% replacement of CS aggregates had given strength of 23 MPa at 28 days. Concrete cubes with 30% replacement of CS aggregates had given strength of 42 MPa at 28 days for M35. For M50 grade concrete cubes with 30% replacement of CS aggregates had given strength of 51 MPa at 28 days [16].

Dewanshu Ahlawat & L.G.Kalurkar (2014) explored the possibility of producing M20 grade of concrete by replacing conventional aggregate of granite by coconut shell. Forty five cubes were casted. Percentage of replacement of conventional coarse aggregate by coconut shell were 2.5%, 5%, 7.5%, 10%. Compressive strength were 19.71, 19.53, 19.08, 18.91 N/mm2 respectively at 28 days. Workability and compressive strength had been evaluated at 7, 14 and 28 days. The compressive strength of concrete reduced as the percentage replacement increased. By these results it can be concluded that coconut shell concrete can be used in reinforced concrete construction. Author concluded that its utilization is cost effective and eco friendly.

Gopal Charan Behera, Ranjan Kumar Behera presented the comparative cost analysis and strength characteristics of concrete produced using crushed coconut shell as substitutes for conventional coarse aggregate. The main objective was to encourage the use of coconut shell waste as construction materials in low-cost housing.

Damre Shraddha and Shrikant Varpe (2014) replaced conventional coarse aggregate with coconut shell and concluded that- with 50% replacement of coarse aggregates by coconut shells, the strength attained reduces invariably from 10%-20% as compared to the conventional coarse aggregate concrete. With 50% replacement of coarse aggregates by coconut shells, the flexural strength attained reduces invariably from 10%-15% as compared to the coarse aggregate concrete [17].

P. Jayabalan and A. Rajaraman (2014)) carried out experimental investigation to know the effects on concrete by addition of natural coconut fibre and replacement of cement (by weight) with different percentages of fly ash on flexural strength, splitting tensile strength, compressive strength and modulus of elasticity. Test results demonstrate that the replacement of 43 Grade ordinary Portland cement with fly ash showed an increase in compressive strength, modulus of elasticity, flexural strength, and splitting tensile strength for the chosen mix proportion. Addition of coconut fibres resulting in fly ash mixed concrete composite (FMCC) did enhance the mechanical properties of fly ash mixed concrete composite and at the same time increased the energy levels reflected by increased failure strain, making the material suitable or seismic sustenance.

6. CONCLUSION

This review focuses on production of concrete using agricultural waste as point of this ingredients replacing fast depleting conventional aggregate sources construction material and there by finding the solution for social and environmental issues. At present, the rising cost of building construction materials is the factor of great concern. The challenge in making a lightweight concrete is decreasing the density while maintaining strength and without adversely affecting cost. Introducing new light weight aggregates into the mix design is a common way to lower a concrete's density.

- Coconut shell can be grouped under lightweight aggregate because 28-day air-dry densities of coconut shell aggregate concrete are less than 2000 kg/m3. Actual Density of coconut shell is in the range of 550 - 650kg/m3 [18].
- From the experimental results and discussions of above researches on coconut shell, the coconut shell has potential as lightweight aggregate in concrete. Also, using the coconut shell as aggregate in concrete can reduce the material cost in construction because of the low cost and its availability is abundance.
- Coconut Shell Concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional aggregates are costly.
- It is concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.
- Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption.
- These studies also paved the way to the recognition of using coconut shells and fibre as substitute for aggregates in developing concrete hollow blocks.
- From the above researches it also found that the addition of CS decreases workability and addition of fly ash either as cement replacement or aggregate replacement increases workability of CS concrete. We can also use fly ash to improve workability of CS concrete.
- The amount of cement content may be more when coconut shell are used as an aggregate in the production of concrete compared to conventional aggregate concrete.

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