INVESTIGATION OF MECHANICAL BEHAVIOUR OF CONCRETE BY REPLACING CEMENT WITH COCONUT SHELL ASH & STONE DUST

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ABSTRACT

Escalating cost of construction material is a matter of concern. High demand of concrete and scarcity of raw material mainly causes for this rising cost. Hence most of the researchers have focus on use of the waste materials in concrete. This project investigates the possible use of coconut shell ash (CSA) and stone dust (SD) as partial replacement of ordinary Portland cement (OPC). Several cylinders were cast, cured and crushed at 3, 7, 28 and 90 days for uniaxial compression test (UCS) and 3, 7 & 28 days for static elastic modulus test (SEM). Concrete beams were crushed at 3, 7, 28 days for flexural strength test (FS). Drying shrinkage test (DS) also performed by using mortar beams. The coconut shell ash was replaced from 0 to 30 percent at 10% intervals. It was observed that the compressive strength increased by 7.50% when cement was replaced by 10% of CSA & SD. On the other hand, static elastic modulus and flexural strength were increased by 44% and 3.50% for the same mix proportions (10%). Also, drying shrinkage decreased by 53% when cement was replaced by 10% of CSA & SD.

Keywords: *Coconut shell ash, stone dust, concrete, compressive strength, flexural strength.*

1. INTRODUCTION

The high cost of construction materials like cement and reinforcement bars, has led to increased cost of construction. This, coupled with the pollution associated with cement production, has necessitated a search for an alternative binder which can be used sorely or in partial replacement of cement in concrete production (Habeeeb, G. A., 2010). More so, disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and coconut shell have constituted an environmental challenge, hence the need to convert them into useful materials to minimize their negative effect on the environment (Aho, M.I., 2012). Research indicates that most materials that are rich in amorphous silica can be used in partial replacement of cement (Tyagher, S. T., 2012). It has also been established that amorphous silica found in some pozzolanic materials reacts with lime more readily than those of crystalline form(Nehdy,M., 2003). Use of such pozzolanas can lead to increased compressive and flexural strengths (Oyetola, E. B., 2006). Many researches have made efforts for preparing carbon black from agricultural by-products such as coconut shell apricot stones, sugarcane bagasse, nutshells, forest residues and tobacco stems. Coconut shells have little or no economic value and their disposal is not only costly but may also cause environmental problems (Nagalakshmi, R., 2013). Coconut shell concrete has better workability because of the smooth surface on one side of the shell. The impact resistance of coconut shell concrete is high when compared with conventional concrete. Moisture retaining and water absorbing capacity of coconut shell are more compared to conventional aggregate. Using alternative material in place of natural aggregate in concrete production makes concrete as sustainable and environment friendly construction material. The composition of World Cement Consumption in the year 2010 is 3,313 Million Metric Tons. Among that 7.0% in India, 57.7% in China, 9.4% in developed Countries, 25.9% in other Emerging. (Ahlawat, D., 2012)

The aim of this study is to determine the suitability of coconut shell ash (CSA) for use in partial replacement of cement in concrete production. Also, this study include ascertaining the optimum replacement level of Portland cement with CSA that will still give required compressive strength as well as compare the setting times of OPC paste with OPC- CSA pastes at various replacement levels.

2. METHODOLOGY

The basic properties of coconut shell ash such as physical, chemical, mechanical properties, and the compatibility of coconut shell ash with cement were studied. Based on the standard procedures and methods followed for the production of conventional concrete, the coconut shell aggregate concrete were produced. The acceptable trial mixes were then identified and finally, the workability, strength, density and durability requirements for different applications of concrete were taken into consideration during the selection of the optimum coconut shell aggregate concrete mix. Several specimens such as concrete cylinders and mortar bars were prepared for laboratory test & relevant graphs also drawn. Comparison studies between cement concrete and coconut shell ash concrete were conducted only on the fresh concrete properties, compressive strength, basic and mechanical properties. Comparisons of some properties for coconut shell aggregate concrete were made using some codes of practice.

3. ILLUSTRATIONS

3.1 Materials

3.1.1 Fine Aggregate

For experimental work, Sylhet sand was used as fine aggregates. In gradation, fine aggregate was passing through #4, #8, #16, #30, #50 & #100 sieve and fineness modulus was found 2.94. Gradation curve was found to be uniform graded. Also, Specific gravity of Sylhet sand was found 2.50.

3.1.2 Coarse Aggregate

Coarse aggregate used in concrete making contain aggregates of various sizes. This particle size distribution of the coarse aggregates is termed as "gradation". Proper gradation of coarse aggregates is one of the most important factors in producing workable concrete. Any gradation curve represents size of aggregates in sample and classified based on graphical shape. Stone chips was used as coarse aggregate, having specific gravity 2.76 & FM value 3.29.

3.1.3 Cement

Various properties of cement given in table 1

Table 1: Physical properties of cement

Property	Test Result
Specific Gravity	3.17
Normal Consistency	27%
Initial Setting Time	107 min
Final Setting Time	225 min

3.1.4 Coconut Shell

3.1.4.1 General description

Coconuts are referred to as "man's most useful trees", "king of the tropical flora" and "tree of life". Coconuts or its scientific name Cocos Nucifera are the most important of cultivated palms and the most widely distributed of all palms. Coconut is a tall cylindrical-stalked palm tree, reaching 30 m in height and 60-70 cm in diameter. It is a tropical plant for low altitudes. It needs sunshine and a soil rich in calcium and phosphorus, and is thus generally suitable for cultivation in sandy seashore.

Although coconut cultivation is concentrated in tropical belts of Asia and East Africa, it is also found in Latin America on a smaller scale. The most important part of the tree is its fruit, which is egg-shaped, about 30 cm long, and 25 cm in diameter. The more external layer of the fruit is thin and smooth; its fibrous mesocarp is 3-5 cm thick, and the endocarp is very hard. The fruit has a large central cavity, which contains a sweet liquid (coconut water). (Gunasekaran, K., 2011)

3.1.4.2 Present status of coconut shell

The coconut palm is one of the most useful plants in the world. Coconut is grown in 92 countries in the world. Global production of coconut is 51 billion nuts from an area of 12 million hectares. South East Asia is regarded as the origin of coconut. The four major players India, Indonesia, Philippines and Sri Lanka contribute 78% of the world production.

Global production of coconuts was 61.5 MT with Indonesia, Philippines, India, Brazil and Sri Lanka as the major contributors to coconut production (FAO, 2007). The total world coconut area was estimated as approximately 12 million hectares and around 93 percent is found in the Asian and Pacific region. The average annual production of coconut was estimated to be 10 million metric tons of copra equivalents. Of the world production of coconut, more than 50 percent is processed into copra (Jalal, M., 2012). While a small portion is converted into desiccated coconut 5 and other edible kernel products, the rest is consumed as fresh nuts.

3.1.4.3 Characteristics & chemical composition

The weight of shells varies with nuts of tall palms over the normal range of size, but average about 255 of the husked nuts. Although the lignin content is higher and the cellulose content is lower, coconut shells are similar in chemical composition to hard woods. There has been a general impression that since the shells burn in such a characteristics way, there are likely to contain oily or resinous substances. Actually this is a not so they contain little or no oily and resinous matter. The ash from burned shells contains a fair amount of potash though less than in the ash of the husk.

Calculated on the dry basis, coconut shell contain approximately the following percentage: cellulose 33.61; lignin 36.51; pentosans 29.27 and ash 0.61. the percentage composition of coconut shell ash is approximately as follows: K_20, 45.01; Na_20, 15.42; CaO, 6.26; MgO, 1.32; Fe_20_3 + Al_20_3, 1.39; P_20_5, 4.64; $S0_3$, 5.75 and SiO, 4.64. (Maruthachalam, D., 2012)

The moisture content of coconut shells show considerable variation according condition and maturity. Air dried mature shells, under average conditions may be reckoned to contain 6-9% of moisture, and thus retain less moisture than most woods, which contain 10-25% on the dry basis.

3.1.4.4 Coconut Shell Ash (CSA)

Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, and Sri Lanka. Many works have been devoted to use of other natural fillers in composites in the recent past years and coconut shell filler is a potential candidate for the development of new composites because they have high strength and modulus properties along with the added advantage of high lignin content. The high lignin content makes the composites made with these filler more weather resistant and hence more suitable for application as construction materials. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells also absorb less moisture due to its low cellulose content the report focuses on studying the effectiveness of coconut shell particles as a source of natural material for reinforcing epoxy resins towards their flexural properties.

Coconut shells have little or no economic value and their disposal is not only costly but may also cause environmental problems. Coconut shell is suitable for preparing carbon black due to its excellent natural structure and low ash content. Conversion of coconut shells into activated carbons which can be used as adsorbents in water purification or the treatment of industrial and municipal effluents would add value to these agricultural commodities, help reduce the cost of waste disposal, and provide a potentially cheap alternative to existing commercial carbons.

3.1.5 Stone Dust (SD)

Stone waste is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Utilization of the stone dust in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. It is most essential to develop eco-friendly concrete from stone waste. In this research study the OPC has been replaced by stone dust.

3.2 Test Works

3.2.1 Uniaxial Compressive Strength

Three duplicate 4” diameter & 8” high cylinders were tested at 3, 7, 28, and 90 days after casting. The cylinders were demolded at 24 hr. and moist cured for the duration of their lifetime. Using a UTM machine, uniaxial compressive load was applied. The failure load was measured and used to calculate the compressive strength. As the test procedure, failure type of cylindrical specimens were mortar failure. Testing specimens & crushed cylinders also showed in figure 1.

Figure 1 : Crushed Concrete Specimen

3.2.2 Static Elastic Modulus

The elastic modulus was measured at 3, 7 and 28 days. The test was performed using three duplicate 4×8 inch cylinders. Similar to those used for the compressive strength test, the cylinders were demolded at 24 h and moist cured until moments before testing at 3, 7 and 28 days. This measurement takes into effect the elastic region from the 50 micro strain point to 40% of the ultimate (failure) load for the age tested, otherwise known as the chord modulus.

The readings were analyzed and converted to strains and compared against the applied stress to quantify the elastic modulus for the concrete.

3.2.3 Flexural Strength

Three duplicate 2”×2”×8” beams were tested at 3, 7, and 28 days after casting. Flexural tests of moist-cured specimens shall be made as soon as practical after removal from moist storage. Surface drying of the specimen results in a reduction in the measured flexural strength. When using moulded specimens, turn the test specimen its side with respect to its position as moulded and centre it on the support blocks .When using sawed specimens, position the specimen so that the tension face corresponds to the top or bottom of the specimen as cut from the parent material. Centre the loading system in relation to the applied force. Bring the load-applying blocks in contact with the surface of the specimen at the third points and apply a load of between 3 and 6 % of the estimated ultimate load. Using 0.004 in. (0.10 mm) and 0.015 in. (0.38 mm) leaf-type feeler gages, determine whether any gap between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 1 in. (25 mm) or more. Grind, cap, or use leather shims on the specimen contact surface to eliminate any gap in excess of 0.004 in. (0.10 mm) in width. Leather shims shall be of uniform1⁄4 in. (6.4 mm) thickness, 1 to 2 in. (25 to 50 mm) width, and shall extend across the full width of the specimen. Gaps in excess of 0.015 in. (0.38 mm) shall be eliminated only by capping or grinding. Grinding of lateral surfaces should be minimized inasmuch as grinding may change the physical characteristics of the specimens. Capping shall be in accordance with the applicable sections of Practice C 617. Load the specimen continuously and without shock. The load shall be applied at a constant rate to the breaking point.

3.2.4 Drying Shrinkage

Drying shrinkage was measured using 1”×1”×6” mortar prisms to lessen the effect of moisture gradients that develop in larger concrete prisms. Four duplicate mortar specimens were tested for each mixture. Mortar bars were cast, demolded at 24 h, and submerged in a lime-water bath for an additional 27 days. At age 28 days, the specimens were removed from lime-water bath and surface dried, and their length was measured to the nearest

0.0025 mm. Drying was then commenced inside an environmental chamber at 23±1°C and 50±5%RH. Comparator and weight measurements were recorded after 1, 4, 11, 18, 25, and 39 days of drying. The mechanisms affecting the drying shrinkage of concrete are capillary stresses, disjoining pressures, and changes in the surface-free energy (Mindess et al. 2003). These mechanisms dominate the bulk shrinkage within the typical field temperatures (−9.5–35°C) and relative humidity (40–100%).

3.3 Results & Discussion

3.3.1 Uniaxial Compressive Strength

Table 2 shows test results and figure 2 illustrates the strength of all the concretes increased with curing age. Cement concrete gained 68 %, 76% and 99% over its 90 days compressive strength at 3 days, 7 days and 28 days of curing respectively. Strength of the coconut shells concretes increased 66-68% at 3 days, 71-78% after 7 days and 92-94% after 28 days of curing than its corresponding 90 day strengths respectively. This observation suggests that as coconut shells percentage increased the 28 days strength gain also increased with corresponding 90 day curing strength. The coconut shells concretes, especially 20% replacement level the concretes failed to maintain same strength gain, which had first 7 days of curing. This may be due to lack of sufficient bond between the particles. As the first 7 days of curing, majority of the compressive strength of the concretes depends on paste strength. However, at later age, the strength of concrete depends on strength of the paste, strength of the aggregate and bond strength between the aggregate particles and cement paste. Evidently, in the present investigation, the visual observations on specimens failed in compressive strength test suggested that the coconut shells particles were separated from the paste phase. For 10% replacement, concrete strength increases for all duration. Furthermore, the strength decreased with coconut shells replacement.

Table 2: Compressive Strength for various percentages based on different curing days

Coconut Shell Ash +Stone Dust	Compressive Strength (MPa) Different Curing Days			
	3 Days	7 Days	28 Days	90 Days
0% + 0%	12.78	14.25	17.24	18.76
5% +5%	13.49	15.61	18.59	19.89
10% +10%	11.64	13.46	16.17	17.73
15% +15%	10.97	11.75	15.33	16.51

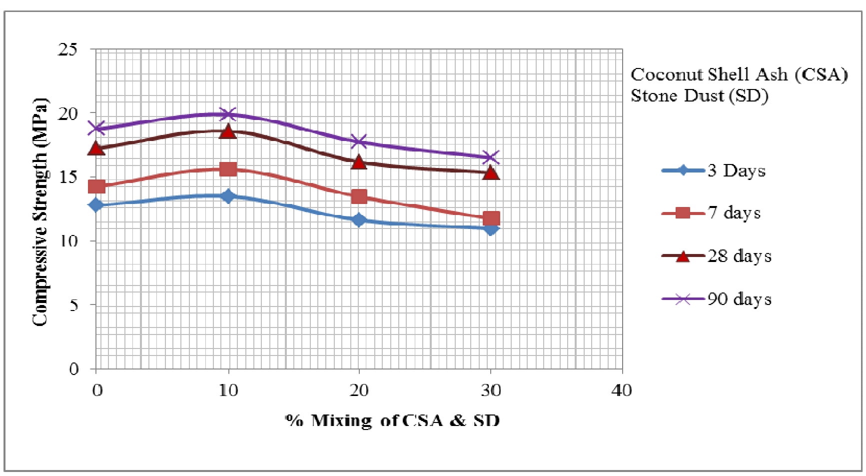

Figure 2: Compressive Strength (MPa) for different duration Vs % Mixing of CSA and SD

3.3.2 Static Elastic Modulus

Defining modulus of elasticity of concrete is difficult. Because concrete is not a linearly elastic material. Since the slope of σ-ε curve of concrete is not constant. We must first describe modulus of elasticity (Ec). This is not influenced by the time effect. Instantaneous E_c can be defined in 3 ways:
i) Initial Modulus of Elasticity, (E), ii) Secant modulus, iii) Tangent modulus

In this test work, 1st method was use to found slope of the curve i.e. modulus of elasticity of concrete.

Table 3 represents the results for the 28-day static elastic modulus. The results show that the 10% replacement of OPC by coconut shell ash and stone dust gives twice elastic modulus value corresponding to cement concrete. The graphical representation also shows in figure 3.

Table 3: Static elastic modulus of 28-days specimen

Static Elastic Modulus, E (GPa)	Coconut Shell Ash + Stone Dust			
	0% + 0%	5% + 5%	10% +10%	15% + 15%
	0.82	2.05	1.18	0.61

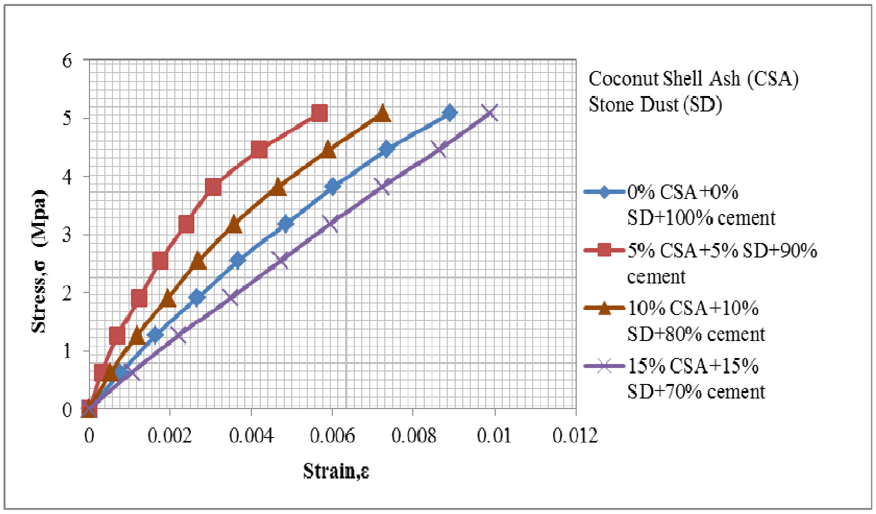

Figure 3: Stress-strain curve for 28-days specimen

3.3.3 Flexural Strength

Table 4 shows the flexural strength of OPC concrete and the concrete produced by replacing OPC by coconut shell ash and stone dust by 10%, 20% and 30%. It is observed that the flexural strength gives 20% more value than cement concrete for the 10% replacement of OPC, but further incremental percentages responsible for reducing flexural strength of concrete. This phenomenon induced because of pozzolanic property of coconut shell ash and stone dust. From correspondent test results, flexural strength Vs curing time graph shows in figure 4.

Table 4: Flexural Strength of various duration based on CSA & SD percentages

Curing Days	Flexural Strength (KN)			
	Coconut Shell Ash + Stone Dust			
	0% + 0%	5% + 5%	10% + 10%	15% + 15%
0	0	0	0	0
3	3.30	4.12	3.67	2.95
7	4.49	4.99	4.63	4.14
28	5.87	6.64	6.07	5.41

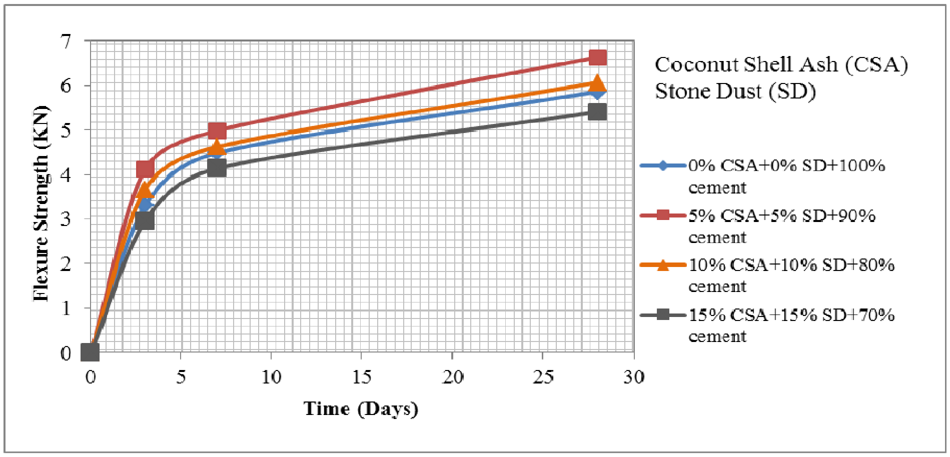

Figure 4: Flexural strength (KN) Vs curing time (Days)

3.3.4 Drying Shrinkage

From the figure 5, the value of drying shrinkage reduces for 10% replacement of cement by coconut shell ash & stone dust mixture and increases for 30% replacement. The higher amount of water in the fresh concrete, the greater the drying shrinkage affects. The amounts of water and admixtures used during mixing also have direct and indirect effects on drying shrinkage of cement mortar. The relationship between the amount of water content of fresh concrete and the drying shrinkage is linear. Increase of the water content by 1% will approximately increase the drying shrinkage by 3%. The drying shrinkage test results are given in table 5.

Table 5: Drying shrinkage of mortar beam for various percentages based on different duration

Time (days)	Drying Shrinkage (mm)			
	Coconut shell ash + Stone dust			
	0% + 0%	5% + 5%	10% + 10%	15% + 15%
0	0	0	0	0
5	1.49	0.96	1.19	1.66
10	1.99	1.27	1.49	2.09
15	2.13	1.36	1.58	2.25
20	2.18	1.41	1.63	2.32
25	2.21	1.44	1.69	2.37
30	2.24	1.46	1.74	2.26

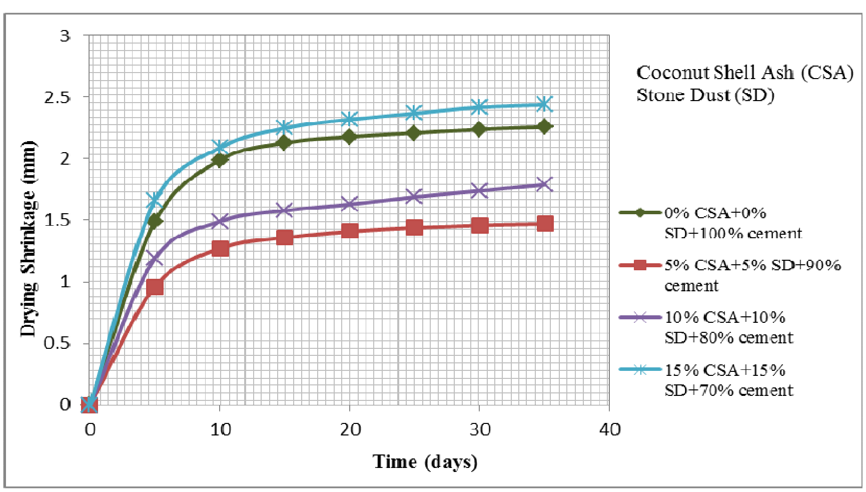

Figure 5: Drying shrinkage of mortar beam for various percentages of cement replacement Vs different duration

4. CONCLUSIONS

In this study, four types of percentages i.e. 0%,10%, 20%, 30% coconut shell ash (CSA) & stone dust (SD) additives were used as replacement of cement. Several concrete cylinders & mortar beams were prepared for uniaxial compressive strength (UCS), static elastic modulus (SEM), flexural strength (FS), drying Shrinkage (DS) test. The main conclusions based on test results are:

i) The uniaxial compressive strength shows an increase in strength by 7.50% for 10% replacement of OPC by coconut shell ash (CSA) and stone dust (SD).

ii) The static elastic modulus test shows an increase in modulus of elasticity by 44% for 10% replacement of Ordinary Portland cement (OPC) by CSA and SD.

iii) The flexural strength test shows an increase in strength by 3.50% for 10% replacement of OPC by CSA and SD.

iv) The drying shrinkage test shows a decrease in 53% for 10% replacement of OPC by CSA and SD.

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