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Sustainable Natural Lightweight Concrete by Blending Locally Available Waste Materials

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Abstract: Lightweight concrete provides numerous benefits compared to conventional concrete, like reduction in dead load and operating costs. One of the prime methods of producing structural lightweight concrete is the utilization of lightweight aggregates. The relevance of waste substances as cement alternate or aggregates in concrete can help a solution in order to reduce negative influences of the concrete industry. One of the agricultural solid wastes derived from the industry of coconut is coconut shell (CS) which processes about 40% lower weight compared to normal weight aggregates. The paper reveals an investigation on the coconut shell as coarse aggregate as well as class F fly ash and sugarcane bagasse ash as complementary cementitious material to produce more environmentally adorable lightweight concrete. Based on the research outcome, the eco friendly structural lightweight aggregate concrete has the ability to be prepared by combining three kinds of waste substances: coconut shell as coarse aggregate and blended Class –F flyash and sugarcane bagasse ash (SCBA) as a substitution for cement (by mass) up to 60%. The process of replacing the cement by blended Class –F flyash and sugarcane bagasse ash leads to density reduction.

Keywords: Light Weight Concrete, Coconut Shell, Solid Waste, Sugarcane Bagasse Ash, Class – F Fly Ash.

INTRODUCTION

Concrete is a construction material which has been used significantly used all over the world [1]. Concerning the quantity of concrete that has been produced, used and their impact are considered as a mandatory part of the whole global environmental issues [2]. The influence of concrete is taking place in different stages starting from drawing out of the raw material until the end of structure existence [3]. Global warming due to release of CO_2, rising landfill sizes, and pollutions are the result of these impacts [4]. Mounting population density and increasing necessities for concrete have worsened the situation. Hence, it is necessary to go for sustainable concrete construction practices.

Based on a report, coconut is grown in more than 85 countries around the globe, with a total production of 55 billion nuts per year. India occupies the important position in the globe with a yearly production of 14 billion nuts, succeeded by Indonesia and the Philippines.

Class F fly ash emanates from anthracite and bituminous coals. It comprises chiefly of alumina and silica and has a higher Loss on Ignition than Class C fly ash. Class F fly ash moreover has a lower calcium content than Class C fly ash [5].

While utilizing Class F fly ash as a portland cement replacement, it is vital to understand several safety aspects [6]. The setting time may be slightly hampered, and the premature compressive strengths (before 28 days) may be delayed to some extent. If any organic admixtures such as air entrainment are used, the amount added must be customized since the carbon (LOI) in the fly ash adsorbs organic compounds. Finally, if the fly ash has high calcium content, it should not be employed in hydraulic applications. Hence while using Class F fly ash or other cementing material with

Portland cement, it is mandatory to form trial mixes to confirm proper proportioning for the intended properties [7].

The sugarcane bagasse comprises of approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin [8]. Each ton of sugarcane generates approximately 25% of bagasse (at a moisture content of 50%) and 0.61% of residual ash. The residue after incineration provides a chemical composition headed by silicon dioxide (SiO_2). Regardless of being a material of hard mortification and that provides few nutrients; the ash is being utilized in the farms as a fertilizer in the sugarcane harvests.

EXPERIMENTAL DETAILS

Materials Utilized

Ordinary Portland cement (OPC) with specific surface area of 3.48 m^2/g and specific gravity of 3.15 was used [9]. The sugarcane bagasse ash was procured from a local sugarcane plant. Fly Ash (FA) which was received from a local power station and was categorized as class F based on ASTM: C618. Table 1 shows the chemical composition of FA, OPC and SCBA.

Coarse aggregates were replaced by CS. CS has been cleaned and immersed in the water for 24 hours before casting and then dried at room temperature till total drying of the surface took place. Table 2 depicts the physical characteristics of CS. It can be noted that the local mining sand with fineness modulus of 2.90, the highest particle size of 4.70 mm, and water absorption of (0.80%) along with specific gravity of 2.60 was utilised as the fine aggregate in this research. Fine aggregate confirming to Zone II was used based on experimental study. In addition, Chemipol was used as superplasticizer. Its chemical name is polycarboxylate ether superplasticizer.

Table-1: Chemical Composition of OPC, SCBA and FA

Oxides	SiO_2	Fe_2O_3	CaO	MgO	K_2O	SO_3	Al_2O_3	P_2O_5	LOI
OPC	16.48	3.84	68.16	1.45	0.30	4.86	4.38	-	0.53
SCBA	68.30	0.210	2.60	0.56	1.02	4.40	5.72	1.34	15.85
FA	52.35	10.27	6.50	1.70	1.46	0.97	22.68	-	4.07

Table-2: Physical Properties of CS

Specific gravity (saturated surface dry)	1.34
Bulk density (kg/m^3)	784
Fineness modulus	6.78
24 hours water absorption (%)	23
Shell Thickness (mm)	3-8

Mix Proportions and Procedure

In order to carry out the investigations on the effect of replacing waste materials as a supplementary cementitious material (SCBA and FA) and CS as coarse aggregate to examine compressive strength and density of concrete [10].

Two concrete mixtures were generated in order to investigate the effects of high volume waste material as supplementary cementitious material (RHA and FA) and coarse aggregate (OPS) on the compressive strength and density of concrete [11]. The binder agent (cement, SCBA and FA) was set as 550 kg/m^3. Table 3 displays the information of the mixtures.

In mix CS60, OPC was partly replaced with 30% of SCBA and 30% of FA (by mass). All the substances were amalgamated for a period of 60 seconds exempting water and superplasticizer (SP). Next, the SP was added for a period of 180 seconds with 75% of water, and further the left over water was added to the mix for 3 minutes before transferring into cast iron moulds. Then, with the help of a vibrating table, the fresh concrete was kept in two layers in cast iron mould in the laboratory, which has relative humidity of around 68% and temperature of 28 ± 2ºC.

Table-3: Mix Proportions

Mix No.	Content (kg/m^3)					w / b	SP (% binder)
	OPC	SCBA	FA	Sand	CS		
CSC0	550	0	0	954	317	0.38	1.0
CSC60	220	165	165	954	317	0.54	1.6

Curing System

The importance of curing concrete plays a vital role in improving the microstructure and pore structure of concrete [12]. Concrete curing implies maintaining moisture content in the body of concrete during the premature ages and after, in order to develop the required properties in terms of longevity and strength. In this research, the specimens were removed 24 h after casting. After removal, the specimens were soaked in water at temperature of 22 ± 2ºC up to 90 days.

RESULTS AND DISCUSSION

Outcome of Blended SCBA-FA on Workability

Enhancing the percentage of OPC replacement with blended SGBA-FA from 0 to 60% (30% SCBA + 30%FA) decreased the concrete's slump. Test results of workability showed that 60% OPC replacement by SCBA, decreases the slump from 100 mm to 67 mm, which is in the suitable range of slump value (> 65 mm). To achieve preferred slump, extra water and SP was added. This is done due to the requirement of SCBA which needs higher water content comparing with normal OPC concrete. Earlier studies revealed that greater demand for water in SCBA concrete is because of the high carbon content of SCBA and high specific surface area.

Effect of Blended RHA-FA on Density

1950 kg/m^3 and 1794 kg/m^3 were found to be the demoulded density of CSC and CSC60 samples respectively. As per the experimental results, it was found that concrete density gets reduced by 8% when SCBA-FA is blended with CSC mixture up to 60%.

Oven dry density (ODD) of CSC and CSC60 samples was measured at 28 days and the values are found to be 1792 and 1543 respectively. By using CSC and CSC60 the density of the concrete mix has reduced by 25% and 36% respectively in comparison with normal concrete of density 2400 (kg/m^3).

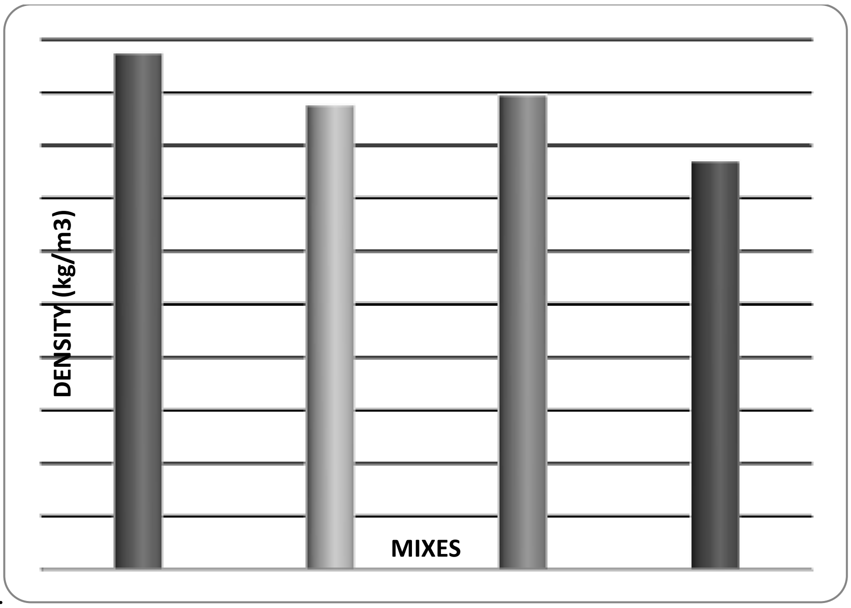

Fig-1: DD and ODD of Concrete

Compressive Strength

Coconut Shell concrete without cement substitution material (CSM) at 28 days was about 41.3 MPa, while the Coconut Shell concrete with cement substitution material (60 percent replacement of cement with 30 percent Class F Fly ash and 30 percent SCBA) at 28 days was observed to be 18.7 MPa. Compressive strength of the two mixes at various ages 1,3,7,28,90 days is shown in the Figure-2. CS concrete with CSM has lower compressive strength than the CS concrete without CSM since the cement content is low and the w/b ratio is high in the former mix.

Coconut Shell Concrete (CSC) when compared to (CSC60) has lower compressive strength of about 79%, 77%, 73%, 55% and 50% at 1,3,7,28 and 90 days respectively. The reduction of compressive strength in CSC60 is relatively small when compared to CSC when the curing time is 28 days and 90 days and hence CSC60 can be used for M15 and M20. And also the density of this concrete is substantially lower than CSC concrete. Moreover, only 165 kg/m^3 of cement was used in this concrete mix which can also be considered as a green concrete [13].

Table-4: Compressive Strength of Concrete without CSM and with CSM

Age of Concrete (Days)	Without CSM (MPa)	With CSM (MPa)
1	23.4	4.9
3	32.5	7.4
7	37.1	10.2
28	41.3	18.7
90	50.2	25.3

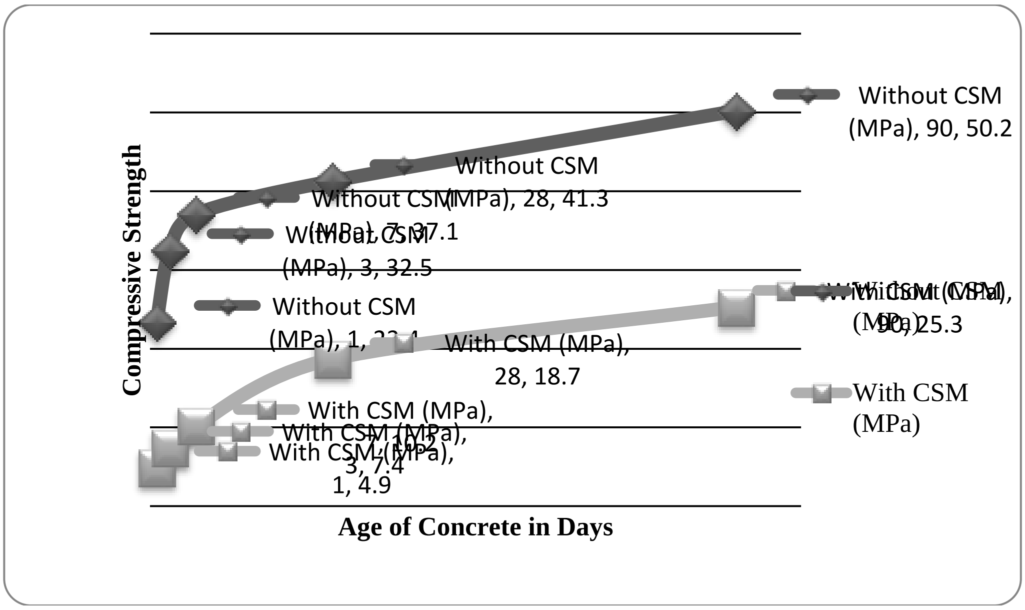

Fig-2: Compressive Strength of CSC and CSC60 at different Curing Periods

CONCLUSION

Coconut shell found in abundance as coconut cauldron which is obtained from the coconut oil industry has a tremendous potential to be used as light weight aggregate in the production of light weight concrete [14]. Based on the research outcome, environmentally adorable green concrete can be prepared by combing three kinds of waste materials [15]. Coconut shell as coarse aggregate and blended Class F Fly Ash and Sugarcane Bagasse Ash as a replacement for cement upto 60% [16]. The process of replacing cement by blending Class F Fly Ash and Sugarcane Bagasse Ash and also with the usage of Coconut Shell results in a reduction of density and compressive strength of concrete. Even though blended concrete has lower compressive strength M20 concrete can be satisfactorily produced with low cement content.

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