

# Strength Characteristics of Organic Waste Concrete

**Nagesh Belapure**

*Department of Civil Engineering*

*Lords Institute of Engineering and Technology Himayatsagar,  
Hyderabad (TS)*

**Budumuru Adinarayana**

*Department of Civil Engineering*

*Lords Institute of Engineering and Technology Himayatsagar,  
Hyderabad (TS)*

## Abstract

Excess demand of natural resources on account of expeditious urbanization and the scrapping problem of agricultural waste have paved the way for research in usage of organic waste in the construction industry. Scores of organic waste materials have found their usage in concrete as substitute alternatives for cement, fine aggregate, coarse aggregate and reinforcing materials. This paper highlights and examines some of the organic waste material used as partial replacement of fine aggregate in concrete which is being defined and termed as organic waste concrete in present context. The paper aims at evaluating the strength characteristics of organic waste concrete by using different organic wastes and thus understanding the feasibility of using each organic waste. Distinct properties of fresh and hardened concrete, their reliability when admixed with organic wastes are examined. It has been observed that the organic waste concrete containing groundnut shell, rice husk ash, saw dust ash demonstrated more desirable workability than their other substitutes did. Organic waste concrete containing bagasse ash, sawdust ash attained their required strength by 20% of replacement as fine aggregate which were maximum among all organic waste type concrete. Accurate comparison was predicted among compressive strength, flexural strength and tensile strength of organic waste concrete. Introduction of bagasse ash as fine aggregate in concrete improved the resilience to chloride tapping. After the careful investigation, it is of substantial conclusion that additional exploration and testing is justified on all fine aggregates substituting organic waste, which would give further certainty on their exploitation in concrete.

**Keywords: Aggregate, Feasibility, Bagasse, Replacement, Exploitation**

## I. INTRODUCTION

Any construction undertaking necessitates several materials such as concrete, steel, brick, stone, glass, sand, timber, and so on. Nevertheless, the cement concrete remains the principal construction material exploited in construction industries. For its versatility and flexibility with respect to the transforming environment, the concrete should be capable to save resources, safeguard the environment, economize and lead to proper employability of energy. To accomplish this, major importance must be laid on the use of wastes and by products in cement and concrete used for new constructions[12]. Organic waste has been generally used for various objectives like flooring, cladding etc., as a building material since the ancient times.

Expanding population, swelling urbanization, swift way of life due to technological innovations has led to a need of a huge amount of natural resources in the construction industry, which has resulted in dearth of resources. This dearth encourages the researchers to use, solid wastes spawned by industrial, mining, domestic and agricultural works. The industry's disposal of organic waste today contributes to one of the major environmental troubles around the world. It is seen that in India more than 600 MT wastes have been obtained from agricultural waste, which is badly leading to a disposal problem. Recycling and reuse of such wastes as durable construction materials take care of the issue of pollution, as well as the complication of area filling and the expense of building materials.

## II. MATERIALS AND METHODS

The materials used in the study are:

### A. Coconut Shell

The coconut shell was dried in sun for 2 days i.e. forty eight hours to discard moisture from it. It was then subjected to unrestrained combustion using open air burning for three hours and left to cool for about 12hours. The burnt ash was gathered and sieved through a BS sieve (75 microns). The resulting ash, which has the required fineness, was accumulated for use. The oxide composition of the ash was calculated and the result is shown in table 1 below. Using a mix design ratio of 1:1:2 and water binder ratio of 0.5, a total of 15 Concrete cubes of size 150mm x150mm x 150mm were cast. The cubes were cured and crushed after 7, 14 and 28 days respectively to determine the compressive strength. The density and strength results are presented in table 4 below.

### **B. Sugarcane Bagasse Ash**

The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominated by silicon dioxide (SiO<sub>2</sub>). In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in the sugarcane harvests.

In this experimental work, a total of 20 numbers of concrete specimens were casted. The specimens considered in this study consisted of 36 numbers of 150mm side cubes, 108 numbers of 150mm diameter and 300mm long cylinders, and 36 numbers of 750mm x 150mm x 150mm size prisms. The mix design of concrete was done according to Indian Standard guidelines for M 20 grade for the granite stone aggregates and the water cement ratio are 0.48.

Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 5, 10, 15, 20 and 25% replacement by weight were estimated. The ingredients of concrete were thoroughly mixed in mixer machine till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using table vibrator. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24h and then cured under water for a period of 7 and 28 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength were conducted using a 2000kN compression testing machine, the modulus of elasticity the test conducted using a compression testing machine and compressometer (strain measurements). For modulus of rupture was conducted using 1000kN universal testing machine. These tests were conducted as per the relevant Indian Standard specifications.

### **C. Groundnut Shell Ash**

The groundnut shell ash was obtained by burning the groundnut shells on an iron sheet in the open air under normal temperature. The idea of burning them in a furnace was dropped because it will be time-consuming and uneconomical for most people especially those at the rural levels. The burnt ash was passed through a BS sieve (75 microns). The portion passing through the sieve would have the required degree of fineness of 0.063mm and below while the residue was thrown away.

In this experimental work, a total of 15 numbers of concrete specimens were casted. The specimens considered in this study consisted of 36 numbers of 150mm side cubes, 108 numbers of 150mm diameter and 300mm long cylinders, and 36 numbers of 750mm x 150mm x 150mm size prisms. The mix design of concrete was done according to Indian Standard guidelines<sup>6-9</sup> for M 25 grade for the granite stone aggregates and the water cement ratio are 0.48.

Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 5, 10, 15, 20 and 25% replacement by weight were estimated. The ingredients of concrete were thoroughly mixed in mixer machine till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using table vibrator. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24h and then cured under water for a period of 7 and 28 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength were conducted using a 2000kN compression testing machine, the modulus of elasticity the test conducted using a compression testing machine and compressometer (strain measurements). For modulus of rupture was conducted using 1000kN universal testing machine. These tests were conducted as per the relevant Indian Standard specifications.

### **D. Sawdust Ash**

The Saw Dust used was obtained from Iree, Nigeria. After collection, the sawdust was openly heated. The ash was ground to the required level of fineness and sieved through 600µm sieve in order to remove any impurity and larger size particles.

Sawdust is an organic waste resulting from the mechanical milling or processing of timber (wood) into various shapes and sizes. The dust is usually used as domestic fuel. The resulting ash known as saw-dust ash (SDA) is a form of pozzolana. Dry sawdust concrete weighs only 30% as much as normal weight concrete and its insulating properties approximate those of wood. With proper cement to sawdust ratios, it is not flammable.

Sawdust collected from local saw mill was used in this study. The sawdust was openly heated to about the temperature of 600 °C; the ash was then grounded after cooling and graded in accordance with BS-812 [1967]. Chemical properties of SDA and their comparison with OPC are presented in Table 1.

Coarse aggregate from crushed basalt rock was used. Flakiness and Elongation Index were maintained well below 15 %. River sand was used as fine aggregate. Material used have been tested as per relevant codal provision [IS 2386 (I, III), 1963]. The mix was designed for target cube strength of 30 MPa at 28 days with water-cement ratio of 0.38. A simple method of mix proportioning using SDA (i.e. SDA as part replacement of cement by weight) has been adopted. This was adopted due to remarkable difference in specific gravity of SDA and OPCs. (SDA= 2.15, 33 OPC=3.14, 43 OPC=3.15 and 53 OPC = 3.20)

Various grades of ordinary Portland cement (OPC) classified by BIS namely: 33, 43 and 53 conforming to standard codal provision [IS 269-1989, IS 8112-1989 and IS 12269-1987] were used. The cement by SDA are 0, 10, 20, 30 and 40% per each grades. Fly ash has been added as percentage by weight of total cementitious material replacing cement by various percentages. Table 2 illustrates the detail of various percentages chosen.

Eighteen cubes of sizes 150x150x150 mm were cast per variety of sample per each grades of cement for strength test and water absorption test. Cube strength was examined at different age's i.e. 7, 28, 56 and 90 days. However, water absorption test

were examined at 56 and 90 days. For water absorption, the cubes were kept moist for the above test age in tap water and then heated for 24 hours at 110 °C in an oven.

Two un-reinforced beams of sizes 150 x150x1000 mm per each grade of cement were cast to measure the shrinkage. Shrinkage test of beam after 28 days of curing were done by measuring the change in length of the specimen at 7 days interval.

Six mortar cubes of 50x50x50 mm were cast per variety of the sample and per each grades of cement for durability test (sulphate resistance). The resistance to sulphate attack were evaluated by immersion of well-cured specimens after 28 days of curing in a standard sodium sulphate solution (Na<sub>2</sub>SO<sub>4</sub>) having concentration of 16 gm/l [Buenfeld and Newman, 1984]. An enhanced sulphate salt concentration as high as eight times that of average salt concentration of sea water was considered. The specimens were alternately wetting and drying at 7 days intervals and then determining the strength loss as a result of sulphate exposure for 28 days.

### **E. Wood Ash**

Wood ash is generated as a by-product of combustion in wood fired power plants, paper mills, and wood burning factories. Since wood is a potential source of energy and environmentally benign friendly material, there will be increased usage of wood in energy production in the future. As a result the quantity of ash generated will also increased and concurrently raising the issues of disposal. Incorporation of wood ash as a partial replacement of cement material in blended cement and concrete will be beneficial from both the environmental and economic point of views. This will give a solution to the waste management problem while minimizing the consumption of energy intensive hydraulic cement. Currently, wood ashes are frequently used as a soil supplement to improve the alkalinity of soil for agriculture applications and also as a filler material in the construction of flexible pavements for roads and highways (7).

Several studies have analyzed the suitability of wood ash as a partial cement replacement material in the production of structural grade concrete and self compacting concrete for applications in building construction (8, 9, 10, 11). Wood fly ash consists of particles which are highly irregular in shape with a highly porous surface (12). Physical, chemical and micro-structural properties of wood ash could significantly affect the pozzolanic and hydraulic reactivity. Therefore the properties of wood ash obtained from different sources should be characterized before being incorporated as cement replacement material in production of concrete. A study was evaluated the physical properties of wood ashes from five different sources which concluded that wood ash samples have varying values of unit weight that range from 162 kg/m<sup>3</sup> to a maximum of 1376 kg/m<sup>3</sup> (13). The specific gravity of wood ash ranged between 2.26 and 2.60. Low unit weight and specific gravity of wood ashes indicate the possibility of the reduction in the unit weight of concrete material by the partial substitution of cement with wood ash. The amount of ash generated after combustion could vary with the type of biofuel (14). The chemical compounds present in the wood and woody biomass ashes have been studied (15) and greater percentages of CaO have reported in most types of wood including in Birch bark, Pine bark, Spruce bark.

In Sri Lanka, sand cement blocks are widely used in the construction industry, as they could cemented rapidly. These blocks are mainly constructed using cement and fine aggregates with a standard composition. This study analyzed the compressive strength, water absorption ratios and heat holding capacity of sand cement blocks manufactured with wood ash through laboratory experiments.

The compressive strength was investigated in the laboratory by using crushing machine. Three samples were tested for each set of blocks and were tested at the age of 7, 14 and 21 days. The average compressive strength was determined by averaging the corresponding compressive strength values. The strength characteristics of S2, S3, S4 and S5 blocks were compared with the S1 cement block.

Water absorption was carried out in all five sets of cement blocks. Sample blocks from each set including the control (S1) were tested for water absorption assuming that it is a representative of the unit population. The sample blocks were oven dried for 24 hours at a temperature of 100-105 °C until the mass became constant and measured the dry weights of the blocks (W1). Then the same blocks were immersed in water for 24 hours and measured the wet weight of each block (W2). Percentage of water absorption of individual sample blocks was determined using the following equation.

$$\text{Percentage of water Absorption} = [(W2 - W1) / W1] \times 100$$

Where, W1 = Oven dry weight of the specimen, W2 = wet weights of the specimen

Heat holding test was carried out by using Thermal Imaging Scanner. Sample block from each set were kept in an oven at 100-105°C, for the time period of 24 hours and measured the emissivity within 2 hours. Then the heat holding and emitting pattern of all sample blocks including test specimens and control specimen were computed.

## **III. RESULTS**

Table 1 shows the oxide composition of Coconut Shell Ash (CSA) and OPC(Ordinary Portland Cement) respectively, while table 2 is the result of the average setting times for various OPC-CSA mixes. Table 3 is the result of the density and compressive strength test at 7, 14 and 28 days respectively and table 4 give the pozzolanic activity index of various mixes at 7, 14 and 28 days respectively.

The strength results for sugar cane bagasse ash obtained from the experimental investigations are showed in tables. All the values are the average of the three trails in each case in the testing program of this study.

### A. Workability

A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability.

The results by usage of groundnut shell ash, saw dust ash and oyster shell ash are tabulated in the succeeding page.

Table – 1  
Results by usage of groundnut shell ash saw dust ash and oyster shell ash

% Replacement Coconut Shell Ash	Curing Age (Days)	Average Density (Kg/m <sup>3</sup> )	Average Strength (N/mm <sup>2</sup> )
0 Percent	7	2525.5	13.78
	14	2522	18.82
	28	2514.5	34.22
10 Percent	7	2504.5	12.89
	14	2517.5	17.56
	28	2514.5	31.78
15 Percent	7	2471.5	11.11
	14	2475	14.89
	28	2456	23.23
20 Percent	7	2450.5	8.66
	14	2427.5	12.44
	28	2388	19.78
25 Percent	7	2357	6.67
	14	2338.5	9.11
	28	2340.5	16.67

Table – 2  
Results

Sample Designation	% of SCBA	Slump (mm)	Workability Compaction Factor
C0	0	60	0.95
N1	5	187	0.96
N2	10	200	0.96
N3	15	220	0.97
N4	20	225	0.97
N5	25	230	0.97

Table – 3  
Oxide composition of Coconut Shell Ash (CSA) and Ordinary Portland Cement (OPC)

Oxide	Percentage composition (%)	
	CSA	OPC
SiO <sub>2</sub>	37.97	20.7
Al <sub>2</sub> O <sub>3</sub>	24.12	5.75
Fe <sub>2</sub> O <sub>3</sub>	15.48	2.5
CaO	4.98	64
MgO	1.89	1
MnO	0.81	0.2
Na <sub>2</sub> O	0.95	0.6
K <sub>2</sub> O	0.83	0.15
P <sub>2</sub> O <sub>5</sub>	0.32	0.05
SO <sub>3</sub>	0.71	2.75
LOI	11.94	2.3

Table – 4  
Sample Designation

Sample Designation	% of SCBA	Compressive Strength (MPa)	Split Tensile Strength (MPa)	Flexural Strength (MPa)	Modulus of Elasticity (MPa)	Bulk Density (kg/m <sup>3</sup> )
C0	0	13.80	0.693	3.63	22800	2535.30
N1	5	15.83	0.97	3.35	23100	2541.23
N2	10	12.33	0.90	3.19	23000	2517.52
N3	15	8.79	0.70	3.04	21900	2494.81
N4	20	8.30	0.65	2.75	20100	2400.01
N5	25	7.55	0.42	2.30	19800	2396.04

Table - 5  
The average compressive strength of blocks

Wood Ash Content (%)	Strength/(N/mm <sup>2</sup> )		
	7 Days	14 Days	21 Days

0	1.9592	2.4338	3.1033
10	2.2939	2.2477	2.6142
15	2.1917	2.5074	3.6631
20	1.9736	2.6200	2.8046
25	1.1974	1.1974	1.4052

#### IV. DISCUSSIONS

The compressive strength of the cement - ash concrete did not meet up the standard stipulation of 26N/mm<sup>2</sup> minimum compressive strength of concrete at 28 days for both water cement ratios used in this research. It could be concluded that cement ash concrete at 10% partial replacement level at 0.35% water cement ratio can be used for structures that are non load bearing. From the results, the ash cement concrete set quite faster than the code given setting times for both water cement ratios and as such the ground nut shell ash can be taken as a set accelerator.

Compressive strength of the cement blocks made with partial replacement of wood ash ( $\leq 20\%$ ) did not show a significant difference from the control block (Tukey HSD;  $p < 0.05$ ). Cement block with a 15% wood ash replacement (S3) showed the highest compressive strength which is a 9% increase compared to control block (S1). It complies with the minimum standard value of 2.8 N/mm<sup>2</sup> according to BS 6073: Part 2: 1981. This higher compressive strength may be due to the pozzolanic reaction of wood ash. The pH value increases with the hydration of cement. Presence of potassium, magnesium and calcium in the wood ash increases the pH value of hydrated cement mixture and enhance the pozzolanic activity. Increased pH levels encourage the formation of hydrous silica. This compound reacts with Ca<sup>2+</sup> ions and produce insoluble compounds which are secondary cementations products. Large surface area associated with the ash particles also could be a factor which enhances the comprehensive strength of the wood ash based sand cement blocks as explained in a study conducted to analyze the contribution of rice husk ash on concrete (16). Sharp decrease in the compressive strength at more than 20% of wood ash replacement levels was observed. The decline of strength with the increase of proportions of ash was reported in many reports (17, 18).

The durability of the concrete is largely affected by absorption of water (19). The concrete blocks with lower permeability show a high resistance to deterioration. Decreasing water permeability is due to an extensive pore refinement caused by the ash in the matrix and in the interface layer (20). The results show that the water absorption level is lower than the control block after 21 days of curing period and the lowest absorption was detected from the sample block with 15% of wood ash incorporation.

The results show that the SCBA(Sugarcane Bagasse Ash) concrete had significantly higher compressive strength compare to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 15%. Although, the optimal level of SCBA content was achieved with 15.0% replacement. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential.

#### V. CONCLUSIONS

From the experimental work carried out and the analysis of the results following conclusions seem to be valid for possible use of SDA as partial replacement of cement.

- 1) Important oxides content was 65.45% by weight of SDA and has a pH value of 11.12, which shows that it's alkaline in nature. This shows that SDA has a significant physical and chemical property that encourages its uses as a pozzolanas.
- 2) Setting times increased in all grades of OPC upon the addition of SDA but are in the range recommended for pure cement.
- 3) Workability decreased upon the inclusion of SDA. Thus, mixes containing SDA will required higher water content than the corresponding conventional mixes.
- 4) Compressive strength of concrete increases with grade of cement. Early strength development was observed to be about 50-60% of their 28 days strength. Test results indicate that SDA concrete can attain the same order of strength as conventional concrete at longer curing periods. The rate of strength gain by SDA-33 grades OPC is lower as compared to 43 and 53 grades. However, study suggested the use of SDA as partial replacement of cement up to a maximum of 10% by volume in all grades of cement.

The results show that the SCBA in blended concrete had significantly higher compressive strength, tensile strength, and flexural strength compare to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 10%. Although, the optimal level of SCBA content was achieved with 1.0% replacement. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not substantial. The density of concrete decreases with increase in SCBA content, low weight concrete produced in the society with waste materials.

#### REFERENCES

- [1] Aigbodion.V.S, Hassan.S.B, Olajide.S.O, Agunsoye.O.J, AbdulRahaman.A.S. Okafor.G.E, The use of rice husk ash as an aggregate for foundry sand production in Nigeria, Proceedings of The Nigerian Metallurgical Society (NMS), (2008) Annual Conference & Annual General Meeting, pp 16-22.
- [2] Ganesan, K., Rajagopal, K., & Thangavel, K. 2007. Evaluation of bagasse ash as supplementary cementitious material. Cement and Concrete Composites, 29, 515-524.

- [3] Committee Board of sugar cane and sugar (2004). Summary of sugar cane and sugar industry in Thailand in 2003/2004, Division of sugar cane and sugar industry Policy, Ministry of Industry, Vol.2 Bangkok Thailand (in Thai).
- [4] Gunasekaran K, Kumar PS, Lakshmiathy M. 2011. Mechanical and bond properties of coconut shell concrete. *Construction and building materials* 25(1):92- 98.
- [5] Aggarwal P, Aggarwal Y, Gupta SM. 2007. Effect of bottom ash as replacement of fine Aggregates in concrete. *Asian journal of civil engineering (building and housing)* 8(1):49-62