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Utilization Potential of Waste from Sugarcane Factory of Bangladesh as Partial Replacement of Cement in Concrete

Shaikh Mohammad Shamim Reza [1]*, Sherajul islam [2]

1- University of Asia Pacific, Dhaka Bangladesh
2- Stamford University Bangladesh, Dhaka Bangladesh

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Abstract

Sugarcane bagasse easily found in sugar factories of Bangladesh. Some of them are used as fuel in sugar mills and rest of them are dumped into environment without any commercial return. The disposal of this material is causing environmental problems around the sugar factories. On the other hand, urbanization and industrialization is rapidly increasing in Bangladesh. So, the construction industry is rapidly expanding. Currently large amount of cement is needed for this construction industry. It will be increasing day by day. The study examined the potentiality of using classified Sugarcane bagasse ash (SCBA) to replace some part of OPC cement in concrete. In this study, bagasse sample was collected from Natore sugar mill. After collecting the sugarcane bagasse, it was dried in sun for a week and then it burned in aggregate burning oven at 800°C to 1000°C temperature for 20 minutes. Ordinary Portland cement (OPC) was replaced by SCBA at different percentage ratios at 0%, 5%, 7.5%, 10 and 12.5%. Normal consistency and setting time were investigated for these ratios. The compressive strengths of different concrete with SCBA addition were also investigated. Strength was tested for 7, 28 and 56 days. The test results indicated that up to 5% replacement of cement by bagasse ash results in better or similar concrete properties. It also showed the economic advantages by using SCBA as a partial cement replacement material.

Keywords: Industrial Waste, Sugarcane Bagasse, Ash, Pozzolanic material, Cement replacement, Sustainable Concrete, Setting time, Compressive strength

1 Introduction

Nowadays sustainable development and Environmental pollution are the major issues in the whole world. Over 5% of global CO_2 emissions can be attributed to Portland cement production (Worrell et. al, 2001). Production of 1 ton of cement contributes to about 1.25 ton of CO_2 into atmosphere (Griffin, 1987). Demand for cement is increasing day by day in Bangladesh. Being a developing country urbanization and industrialization is rapidly increasing. The construction industry is rapidly expanding because of infrastructure development of the country. A lot of mega-structures such as tall buildings, bridges, offshore structures, dams, monuments, fly way over, metro rail, elevated express way etc. As most of structures are made by concrete so, it needs a large amount of cement production.

In Bangladesh, sugarcane bagasse ash (SCBA) can be use in concrete as supplementary cementing materials due to its pozzolanic reactivity (Cordeiro et al., 2004). In this country sugarcane bagasse as natural agro-waste materials and it also obtained with requiring low cost, energy and time. As per study by Mahamud et.al, 2012, in Bangladesh around 425,000 acres of land are under sugarcane and the annual production is about 7.5 million tons, of which only 2.28 million tons are used in sugar mills and the rest goes to molasses making. Bangladesh now produces about 150,000 tons of sugar, 100,000 tons of molasses and 800,000 tons of bagasse per year. Bagasses are use as fuel in sugar mills (Habibullah et.al, 2014). According to Cordeiro et al., 2004, the resulting bagasse ash represents approximately 0.62% of the sugarcane weight. Unfortunately, having technical benefits, most of sugarcane bagasse are dumped into environment without any commercial return. In consequence, environmental pollutions are increased day by day.

Proper consumption of these sugarcane bagasse contributes in solving environmental pollution and production of cost-effective concrete; it can also play a vital role for the production of sustainable concrete.

Corresponding author: Shaikh Mohammad Shamim Reza, University of Asia Pacific, Dhaka Bangladesh. E-mail: engr.shamim.ce@gmail.com.

2 Materials and Method

2.1 Background information

The study was conducted to investigate the feasibility of using classified Bagasse Ash to replace some part of OPC cement in concrete. The effect of SCBA on concrete properties were analysed by means of the fresh properties of concrete and the mechanical properties i.e. Compressive strength, normal consistency and time of setting will study as the time dependent property.

2.2 Sugarcane Bagasse Ash (SCBA)

Bagasse is a fibrous residue obtained from sugar cane during extraction of sugar juice at sugarcane mills. Due to the pozzolanic reactivity, Sugar Cane Bagasse Ash (SCBA) is used as supplementary cementing material in concrete. Based on the available documented literature, it was found that SCBA could be used as supplementary cementing material up to a certain level of replacement without sacrificing strength of concrete. Bagasse ash mainly contains aluminium ion and silica. As per study by Villar et.al (2008), SCBA produced by burning sugarcane bagasse at 800°C to 1000°C temperature for 20 minutes. SCBA contains 58.61% to 59.55% SiO_2, 7.32% to 7.55% Al_2O_3 and 9.45% to 9.83% Fe_2O_3. This gives the total amount of SiO_2+ Al_2O_3+Fe_2O_3 which is in line with ASTM C618-17a requirement of 70% minimum for pozzolanas. Thus, SCBA meets the requirement for a pozzolana.

2.3 Collection of Material

Sugarcane bagasse obtained from local sugar mills in Natore district. OPC cement will collect from local market. Standard quality river sand will use as fine aggregate and stone chips will use as coarse aggregate.

2.4 Preparing SCBA

After collecting the sugarcane bagasse, it was dried in sun for a week. Then it burned in aggregate burning oven in material lab. Sugarcane bagasse burned at 800°C to 1000°C temperature for 20 minutes.

Figure 1: Sugarcane Bagasse was drying under the sun after collecting from sugar mill

Figure 2: Sugarcane Bagasse burning in oven at Lab

2.4 Specimen preparation and testing

In concrete specimen, the SCBA was used as a replacement of OPC by 0%, 5%, 7.5%, 10 and 12.5%. Concrete was tested for compressive strength. For this test 6 in. x 12 in. concrete cylinder were casted. The mix design used for making concrete is given in Table 1. It is to be noted here that no admixture was used in this study. Compressive strength of the cylinder specimens were tested following the ASTM Standard C 39. For concrete 7, 28, and 56 days strength was tested. Normal Consistency and setting time of OPC and SCBA mixed cement obtained according to ASTM C 150. The standard consistency was used to find out the initial and final setting time of OPC and SCBA mixed cement.

Table 1: Concrete mix proportion

Binder	Fine aggregate	Coarse aggregate	w/b
1	1.44	2.93	0.42

Figure 3: Preparing concrete cylinder

Figure 4: Compressive strength testing of concrete cylinder with universal testing machine (UTM)

2.5 Data processing and analysis

After getting all the test results, they were shown in tables.

2.6 Cost analysis

A comparative cost analysis had shown to find the economic benefit by partially replacing of cement in concrete.

3 Results and Discussion

3.1 Consistency and setting time

The results of setting time tests shown in Table 2. Indicate that the addition of SCBA retarded the setting time of the paste. This retardation was within limits as specified by ASTM C150 standard which is not less than 45 minutes for initial setting time and not greater than 375 minutes for final setting time.

Table 2: Normal consistency and Setting time

Replacement OPC : SCBA	% Consistency	Setting Time (min)	
		Initial	Final
100 : 0 (SCBA 0)	32.3	161	285
95 : 5 (SCBA 5)	33.8	207	401
92.5 : 7.5 (SCBA 7.5)	35.9	209	418
90 : 10 (SCBA 10)	36.3	224	427
87.5 : 12.5 (SCBA 12.5)	37.1	234	431

3.2 Compressive Strength of the concrete

From Table 3 it is found that, the compressive strength decreased with 5%, 7.5%, 10% and 12.5% replacement of bagasse ash in OPC. The compressive strength gradually decreased with the increasing replacement percentages of SCBA.

Table 3: Average compressive strength of concrete

Replacement (%) OPC : SCBA	Average Compressive Strength (N/mm^2)		
	7 days	28 days	56 days
100 : 0 (SCBA 0)	23.07	40.13	43.24
95 : 5 (SCBA 5)	22.88	39.09	42.78
92.5 : 7.5 (SCBA 7.5)	21.25	40.72	41.20
90 : 10 (SCBA 10)	20.27	39.20	40.11
87.5 : 12.5 (BA 12.5)	19.41	37.55	39.30

3.3 Cost Analysis

From table 4 and 5 we found that replacing 5% of SCBA with OPC in 1 M^3 concrete, reduced the cement cost from BDT 3541 to BDT 3364 which was 5.3%. So, the total cost of concrete is also reduced from BDT 9908 to BDT 9763 which was 1.48%. Here, the production cost of SCBA was about 1.5 BDT per Kg. SCBA production cost can be reduced by producing SCBA in bulk quantity.

Table 4: Costing for 1 M^3 concrete with 0% replacement

Material	**Quantity**	**Rate (BDT)**
Cement	431.81 Kg	3541
Sand	0.41 cum	729
Coarse	0.84 cum	5638
	Total:	**9908**

Table 5: Costing for 1 M^3 concrete with 5% replacement

Material	**Quantity**	**Rate (BDT)**
Cement	410.22 Kg	3364
Sand	0.41 cum	729
Coarse	0.84 cum	5638
SCBA	21.59 kg	32
	Total:	**9763**

4 Conclusions and Recommendations

4.1 Conclusions

Based on the experimental results, following conclusion was drawn:

- Addition of SCBA retarded the setting time of the paste and this retardation was within limits.
- 5% replacement of cement by the SCBA results the strength was close to the nominal strength of the concrete.
- It was also cost effective too by replacing with 5% of SCBA for 1 m^3 of concrete.

4.2 Recommendations

SCBA can be used as a partial cement replacement material with cement. Concerned stakeholder like sugar industries, cement industries and relevant government institutions, should be made aware about this issue. If they work in collaboration with higher education institutions then it will be possible to use SCBA as a partial replacement of cement in concrete in Bangladesh.

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Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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Author Profile

Shaikh Mohammad Shamim Reza received his Master of Engineering in Civil Engineering at University of Asia Pacific, Dhaka; in 2018 Also received his Bachelor of Science in Civil Engineering from Stamford University Bangladesh , Dhaka; in 2012. Currently he is doing Master of Business Administration at Army Isntitute of Business Administration, Savar under Bangladesh University of Professionals, Dhaka. He has more then 6 years working experience on Water Supply, Sanitation and Waste Management sectors. His research interests are in hazardous/medical waste management, municipal waste management, recycling of waste for sustainable development etc.

Sherajul islam received his Master of Engineering in Civil Engineering at University of Asia Pacific, Dhaka; in 2015 Also received his Bachelor of Science in Civil Engineering from Stamford University Bangladesh; Dhaka; in 2012. He has more then 6 years working experience on Water Supply, Sanitation, environmental impact assessment and Waste Management sectors. His research interests are in geotecnical engineering, environmetal polution control (air and noise), solid waste management, recycling of waste for sustainable development etc.