Journal of ENVIRONMENTAL Treatment Techniques

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal web link: http://www.jett.dormaj.com

Experimental Studies of Strength and Cost Analysis of Mortar Using Bagasse Waste Obtained from Sugarcane Factory of Bangladesh

Shaikh Mohammad Shamim Reza*

University of Asia Pacific, Dhaka Bangladesh

Received: 09/02/2019 Accepted: 12/06/2019 Published: 30/09/2019

Abstract

Sugarcane bagasse is an available waste material in Bangladesh which is a by-product of sugar factories. Proper uses of bagasse ash in cement mortar may give the optimum solution for environmental issues. Whereas the construction industry is rapidly expanding in Bangladesh, so the country needs a large amount of cement. In this study Sugarcane bagasse ash (SCBA) was used to replace some part of Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC) in the mortar. Bagasse sample was collected from Natore sugar mill. After collection, bagasse was dried in sun for a week and then it burned in at 800°C to 1000°C temperature for 20 minutes. OPC and PCC was replaced by SCBA at different percentage ratios at 0%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25%, 27.5% and 30%. The compressive strengths of different mortar with SCBA addition were also investigated. Strength was tested for 3, 7 and 28 days. The test results indicated that up to 30% replacement of OPC by Sugarcane bagasse ash (SCBA) in mortar satisfied the BNBC (2006) code. On the other hand, up to 27.5% replacement of PCC by SCBA in the mortar was satisfied by code. Cost analysis showed the economic advantages of using SCBA. For OPC-SCBA mortar the cost was reduced over 20%. On the other hand, the cost was reduced by almost 20% for PCC-SCBA mortar. Use of SCBA can also reduce the waste disposal problems of the sugarcane industries.

Keywords: Industrial Waste, Sugarcane Bagasse, Ash, Cement Mortar, Pozzolanic material, Cement replacement, Sustainable, Compressive strength, Cost effective

1 Introduction

According to a study, over 5% of global CO_2 emissions occurs during Portland cement production (Worrell et. al, 2001). About 1.25 ton of CO_2 release into atmosphere during the production of 1 ton of cement (Griffin, 1987). Being a developing country demand for cement is increasing day by day in Bangladesh for its ongoing infrastructure developments such as tall buildings, bridges, offshore structures, dams, monuments, fly way over, metro rail, elevated express way etc. Whereas the most of structures are made by concrete, a large amount of cement is needed for the country which is very alarming for the environment.

On the other hand, sugarcane bagasse is treated as a waste in Bangladesh. A study says, in Bangladesh the annual production of sugarcane is about 7.5 million tons (Mahamud et.al, 2012). Bangladesh now produces 800,000 tons of bagasse per year. Some of them are used as fuel in sugar mills (Habibullah et.al, 2014). Most of them are dumped into environment. As a result, it pollutes the environment because of disposal problem.

But sugarcane bagasse ash (SCBA) can be used in mortar as supplementary cementing materials due to its pozzolanic reactivity (Cordeiro et al., 2004). Proper utilization of this sugarcane bagasse can solve environmental pollution and production of cost-effective concrete. It can also take part in 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 compressive strength using Bagasse Ash to replace some part of OPC and PCC cement in mortar. A cost analysis was also conducted to find the cost effectiveness.

2.2 Sugarcane Bagasse Ash (SCBA)

Sugar Cane Bagasse Ash (SCBA) has the pozzolanic reactivity. So, it can be used as supplementary cementing material in mortar. SCBA produced by burning sugarcane bagasse at 800°C to 1000°C temperature for 20 minutes

(Villar et.al, 2008). It 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 (Villar et.al, 2008). It meets the requirement of ASTM C618-17a which indicate to have 70% minimum for pozzolanas.

2.3 Ordinary Portland Cement (OPC)

The type of this cement is CEM-I. Which contains 95-100% Clinker and 0-5% Gypsum. Its standard meets BDS EN 197-1:2003 Comply to ASTM C 150.

2.4 Portland Composite Cement (PCC)

The type of this cement is CEM-II/B. Which contains 72-79% of Clinker, 21-28% of Blast Furnace Slag and Limestone and 0-5% of Gypsum. Its standard meets BDS 232:1993, BDS EN 197-1:2003; Comply to ASTM C 595.

2.5 Collection of Material

Sugarcane bagasse collected from local sugar mills in Natore district. OPC and PCC cement collected from local market. Standard quality river sand was used as fine aggregate.

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

2.6 Preparing SCBA

After collecting sugarcane bagasse, it kept under sun light for a week. It burned in an oven in material lab. The temperature was between 800°C to 1000°C temperature. It burned for 20 minutes.

Figure 2: Sugarcane Bagasse burning in the oven at Lab

2.7 Specimen preparation and testing

In mortar specimen, the SCBA was used as a replacement of OPC and PCC by 0%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25%, 27.5% and 30%. Mortar was tested for compressive strength. According to ASTM C109, compressive strength of the hydraulic cement mortars is determined by using 2 inch or 50 mm cube specimens. The mix design used for making concrete was according to BNBC (2006), which is given in Table 1. It is to be noted here that no admixture was used in this study. For mortar specimen 3, 7 and 28 days strengths were tested.

Table 1: Concrete mix proportion

Grade of Mortar	Binder	Fine aggregate	w/b
M_2	1	4	0.45

Figure 3: Preparing mortar cube

Figure 4: Mortar cubes before test

2.8 Data processing and analysis

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

2.9 Cost analysis

A comparative cost analysis had shown. It will help to

find the economic benefit by partially replacing of cement in mortar.

3. Result and Discussion

3.1 Compressive Strength of the concrete

From Table 2 and 3 it is found that, the compressive strength gradually decreased with the increasing replacement percentages of SCBA in both cases.

Table 2: Compressive strength of OPC-SCBA (OPBA) mortar

Replacement (%)	Mix Code	Average Compressive Strength (N/mm^2)		
OPC : SCBA		3 days	7 days	28 days
100:0	OPBA 0	11.01	18.06	27.13
100 : 5	OPBA 5	11.11	18.00	26.99
92.5 : 7.5	OPBA 7.5	10.94	17.73	26.84
100 : 10	OPBA 10	10.65	17.27	26.41
87.5 : 12.5	OPBA 12.5	9.85	16.52	25.98
85 : 15	OPBA 15	8.94	15.59	25.27
82.5 : 17.5	OPBA 17.5	8.70	15.08	24.55
80 : 20	OPBA 20	8.31	14.32	23.40
77.5 : 22.5	OPBA 22.5	8.18	13.74	22.26
75 : 25	OPBA 25	8.29	13.54	21.72
72.5 : 27.5	OPBA 27.5	8.18	13.28	21.19
70 : 30	OPBA 30	7.97	12.86	20.40

Table 3: Compressive strength of PCC-SCBA (PCBA) mortar

Replacement (%)	Mix Code	Average Compressive Strength (N/mm^2)		
PCC : SCBA		3 days	7 days	28 days
100:0	PCBA 0	8.40	15.60	23.34
100 : 5	PCBA 5	8.27	15.36	22.98
92.5 : 7.5	PCBA 7.5	7.63	14.17	21.20
100 : 10	PCBA 10	7.23	13.42	20.08
87.5 : 12.5	PCBA 12.5	6.30	11.70	17.50
85 : 15	PCBA 15	5.49	10.19	15.25
82.5 : 17.5	PCBA 17.5	4.78	8.88	13.29
80 : 20	PCBA 20	4.17	7.74	11.58
77.5 : 22.5	PCBA 22.5	3.63	6.75	10.10
75 : 25	PCBA 25	3.17	5.88	8.80
72.5 : 27.5	PCBA 27.5	2.76	5.13	7.67
70 : 30	PCBA 30	2.41	4.47	6.68

The compressive strength of OPBA 20 mortar was greater than the compressive strength of PCBA 0 mortar which satisfied the BNBC code of M2 grade mortar's required strength. It is also found that the compressive strength of OPBA 30 mortar was very close to PCBA 0 mortar. It also satisfied the BNBC code of M_2 grade mortar's required strength. In case of PCC-SCBA mortar, the entire replacement ratio from PCBA 5 to PCBA 27.5 mortar the BNBC code of M_2 grade mortar's required strength.

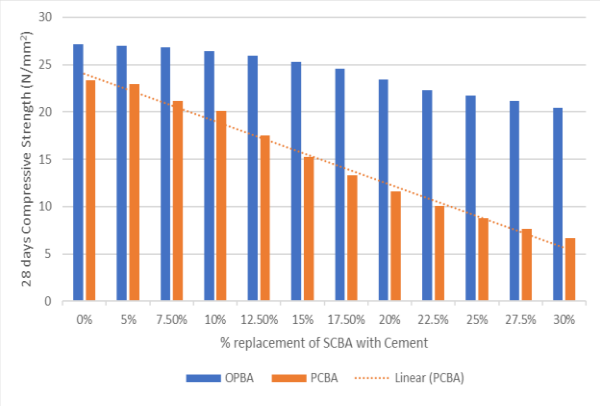

Figure 5: Comparison of 28 days compressive strength between OPC-SCBA and PCC-SCBA mortar

From figure 5, it was found that the strength decreasing pattern of OPC-SCBA mortar (OPBA) was differ from decreasing pattern of PCC-SCBA mortar (PCBA). The strength of OPBA was higher than 20 N/mm^2. On the other hand, the strength PCC-SCBA mortar showed a huge difference between PCBA 0 to PCBA 30. The lowest strength was 6.68 N/mm^2 at 30% replacement of SCBA in PCC-SCBA mortar.

3.2 Cost Analysis

For cost analysis the PWD (2018) was followed. Cost analysis was divided into two parts. One was for Mortar used in Brickwork with 1st class bricks in superstructure in 1:4 cement-sand ratio considering 100 sft of work. Another was 3/4" thick cement plaster in 1:4 cement-sand ratio on one side of the walls considering 100 sft of work.

The unit price of OPC considered BDT 8.80 per kilogram when the price of 1 bag OPC was BDT 440 which contains 50 kilogram of cement (The independent, 2018). Similarly the unit price of PCC considered BDT 8.30 per kilogram when the price of 1 bag PCC was BDT 415 which contains 50 kilogram of cement (The independent, 2018). The unit price of sand (F.M. 1.2) was BDT 14 per cft (PWD, 2018). Here, the production cost of SCBA was about 1.5 BDT per Kg.

According to the results obtained from compressive strength of OPC-SBCA and PCC-SCBA mortar the strength of the mixing ratios which were met the BNBC standard considered for cost analysis. In this scenario, only PCBA 30 failed to meet the standard.

From table 4 it was found that, replacing 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25%, 27.5% and 30% of SCBA with OPC in mortar for brickwork, reduced

the material cost then 'OPBA 0' accordingly 3.42%, 5.13%, 6.84%, 8.55%, 10.27%, 11.98%, 13.69%, 15.40%, 17.11%, 18.82% and 20.53%.

From table 5 it was found that, replacing 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25% and 27.5% of SCBA with PCC in mortar for brickwork, reduced the material cost then 'PCBA 0' accordingly 3.35%, 5.02%, 6.69%, 8.36%, 10.03%, 11.70%, 13.38%, 15.05%, 16.72% and 18.39%.

Analysing table 4 and 5 it was also found that, replacing 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25%, 27.5% and 30% of SCBA with OPC in mortar for brickwork, reduced the material cost then 'PCBA 0' accordingly 2.26%, 4.06%, 5.85%, 7.65%, 9.44%, 11.24%, 13.03%, 14.83% and 16.62%.

From table 6 it was found that, replacing 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25%, 27.5% and 30% of SCBA with OPC in mortar for 3/4" thick cement plaster work, reduced the material cost then 'OPBA 0' accordingly 3.58%, 5.37%, 7.16%, 8.95%, 10.74%, 12.52%, 14.31%, 16.10%, 17.89%, 19.68% and 21.47%.

Table 4: Costing for 100 sft mortar in brickwork (using different percent replacement of SCBA with OPC)

Mix Code	Material Quantity			Total Cost BDT
	Cement (kg)	Sand (cft)	SCBA (kg)	
OPBA 0	300	40	0	3200
OPBA 5	285	40	15	3091
OPBA 7.5	277.5	40	22.5	3036
OPBA 10	270	40	30	2981
OPBA 12.5	262.5	40	37.5	2926
OPBA 15	255	40	45	2872
OPBA 17.5	247.5	40	52.5	2817
OPBA 20	240	40	60	2762
OPBA 22.5	232.5	40	67.5	2707
OPBA 25	225	40	75	2653
OPBA 27.5	217.5	40	82.5	2598
OPBA 30	210	40	90	2543

Table 5: Costing for 100 sft mortar in brickwork (using different percent replacement of SCBA with PCC)

Mix Code	Material Quantity			Total Cost BDT
	Cement (kg)	Sand (cft)	SCBA (kg)	
PCBA 0	300	40	0	3050
PCBA 5	285	40	15	2948
PCBA 7.5	277.5	40	22.5	2897
PCBA 10	270	40	30	2846
PCBA 12.5	262.5	40	37.5	2795
PCBA 15	255	40	45	2744
PCBA 17.5	247.5	40	52.5	2693
PCBA 20	240	40	60	2642
PCBA 22.5	232.5	40	67.5	2591
PCBA 25	225	40	75	2540
PCBA 27.5	217.5	40	82.5	2489

From table 6 it was found that, replacing 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25% and 27.5% of SCBA with PCC in mortar for 3/4" thick cement plaster work, reduced the material cost then 'PCBA 0' accordingly 3.31%, 5.26%, 7.01%, 8.76%, 10.52%, 12.27%, 14.02%, 15.77%, 17.53% and 19.28%.

Table 6: Costing for 100 sft mortar in 3/4" thick cement plaster work (using different percent replacement of SCBA with OPC)

Mix Code	Material Quantity			Total Cost BDT
	Cement (kg)	Sand (cft)	SCBA (kg)	
OPBA 0	75.00	7.5	0.00	765
OPBA 5	71.25	7.5	3.75	738
OPBA 7.5	69.38	7.5	5.63	724
OPBA 10	67.50	7.5	7.50	710
OPBA 12.5	65.63	7.5	9.38	697
OPBA 15	63.75	7.5	11.25	683
OPBA 17.5	61.88	7.5	13.13	669
OPBA 20	60.00	7.5	15.00	656
OPBA 22.5	58.13	7.5	16.88	642
OPBA 25	56.25	7.5	18.75	628
OPBA 27.5	54.38	7.5	20.63	614
OPBA 30	52.50	7.5	22.50	601

Table 7: Costing for 100 sft mortar in 3/4" thick cement plaster work (using different percent replacement of SCBA with PCC)

Mix Code	Material Quantity			Total Cost BDT
	Cement (kg)	Sand (cft)	SCBA (kg)	
PCBA 0	75.00	7.5	0.00	728
PCBA 5	71.25	7.5	3.75	702
PCBA 7.5	69.38	7.5	5.63	689
PCBA 10	67.50	7.5	7.50	677
PCBA 12.5	65.63	7.5	9.38	664
PCBA 15	63.75	7.5	11.25	651
PCBA 17.5	61.88	7.5	13.13	638
PCBA 20	60.00	7.5	15.00	626
PCBA 22.5	58.13	7.5	16.88	613
PCBA 25	56.25	7.5	18.75	600
PCBA 27.5	54.38	7.5	20.63	587

From figure 6, it was found that the pattern of cost reduction from OPBA-0 between brickwork and plaster were almost same. In both civil works for mortar showed similar cost reduction scenario for different replacement of OPC-SCBA mortar.

The pattern of cost reduction from PCBA-0 between brickwork and plaster was found similar also and it was shown in figure 7.

4 Conclusions and Recommendations

4.1 Conclusions

Based on the experimental results, following conclusions were drawn:

- The compressive strength of OPC-SCBA mortar met the BNBC code up to 30% replacement by the SCBA.

For PCC-SCBA mortar the replacement was up to 27.5%.

- It was also cost effective too by replacing with different percentage of SCBA for mortar. For OPC-SCBA mortar the cost was reduced over 20%. On the other hand, the cost was reduced almost 20% for PCC-SCBA mortar.

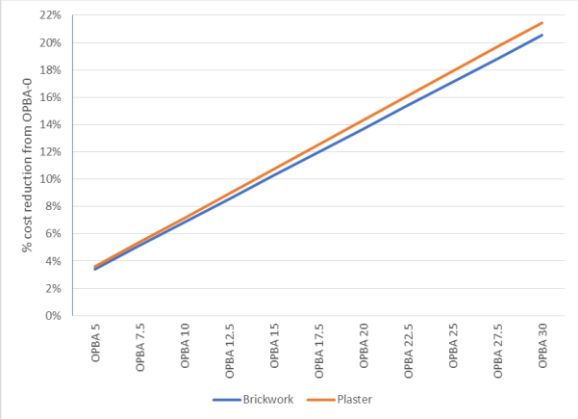

Figure 6: Comparison of % cost reduction from OPBA-0 between brickwork and plaster

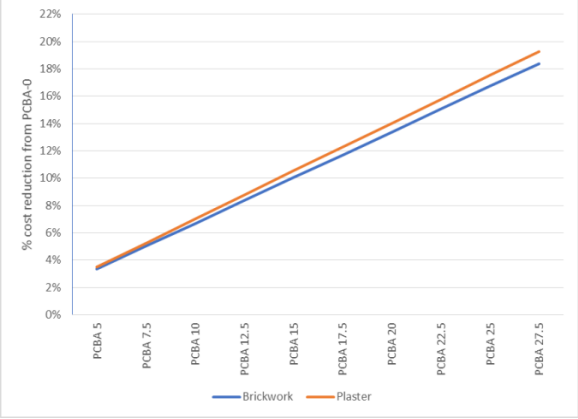

Figure 7: Comparison of % cost reduction from PCBA-0 between brickwork and plaster

4.2 Recommendations

SCBA can be used as a partial replacement material with OPC and PCC in mortar. It will save the uses of cement. Concerned stakeholder can use different replacement of SCBA as per their required mortar strength. The concerned authorities like sugar industries, cement industries and relevant government institutions, higher education institutions should be aware about this issue.

Acknowledgment

Author is very grateful to all the teachers, employees and other stuffs of The University of Asia Pacific and Bangladesh Standard and Testing Institution (BSTI) for their cordial help and lab support. Author also thankful to the Natore sugar mills factory for providing SCBA as raw materials.

References

1. ASTM C109 / C109M-16a, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens), ASTM International, West Conshohocken, PA, 2016, www.astm.org.
2. ASTM C150 / C150M-18, Standard Specification for Portland Cement, ASTM International, West Conshohocken, PA, 2018, www.astm.org.
3. ASTM C595 / C595M-18, Standard Specification for Blended Hydraulic Cements, ASTM International, West Conshohocken, PA, 2018, www.astm.org.
4. BNBC, 2006. Bangladesh National Building Code, *Housing and Building research Institute, Bangladesh*.
5. Cordeiro, G.C., Toledo Filho, R.D., Tavares, L.M., Fairbairn, E.M.R., 2008. Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars. *Cement and Concrete Composites, 30 (5), 410-418.*
6. Habibullah, M. and Rahman, G. M. M., 2014. Sugar Industry. *Banglapedia, Retrived from: www.en.banglapedia.org*
7. Griffin, 1987. *IPCC Second Assessment Report, Industry, chapter 20.*
8. Mahamud, M.R., and Gomes, D.J., 2012. Enzymatic Saccharification of Sugar Cane Bagasse by the Crude Enzyme from Indigenous Fungi. *Journal of Scientific Research, JSR Publications, 4 (1), 227-238.*
9. PWD, 2018. Analysis of PWD Schedule of Rates 2018 for Civil Works, 2018, *Public Works Department, Bangladesh*.
10. The Independent, 2018. Prices of construction materials mark rise, *The Daily Independent, published on 21st February 2018*. http://m.theindependentbd.com/printversion/details/138139 (Accsessed on 18 November, 2018)
11. Villar, E., Frías, M., and Valencia, E., 2008. Sugar Cane Wastes as Pozzolanic Materials: Application of Mathematical Model. *ACI Materials Journal, 105 (30), 58-64.*
12. Worrell, Ernst & Price, Lynn & Martin, Nathan & Hendriks, Chris & Ozawa-Meida, Leticia., 2001. Carbon Dioxide Emission from the Global Cement Industry. *Annu. Rev. Energy Environ. 26.303-29.10.1146/annurev.energy.26.1.303.*

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 7 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.