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Study on Bagasse Ash As Partial Replacement of Cement in Concrete

Lathamaheswari, R., Kalaiyarasan, V andMohankumar, G
Department of Civil Engineering, Arunai Engineering College, Tiruvannamalai.
(Affiliated To ANNA University)

ABSTRACT: Today, the increasing demand and scarcity of construction materials like cement make the researchers all over the world to focus on finding ways of utilizing either industrial or agricultural wastes as a source of raw materials and ecofriendly substitutes or alternatives. These wastes utilization would, not only be economical, but may also help to create a sustainable and pollution free environment as the disposing of such wastes is tedious but, promoting towards waste management. Sugar-cane bagasse is one such fibrous waste product of the sugar mills and sugar refining industry. The bagasse ash with alumina and silica, creates disposaland environmental problems around the factories.The use of such ash in concrete by partial replacement of cement, not only reduces the cost of making concrete, but also improves the properties of concrete and reduces environmental pollution. This paper presents the attempt made in making concrete with partially replacing cement by 2.5, 5.0, 7.5,10 and 12.5 % of bagasse ash. Mix design is made for conventional M20 grade, conventional and ash based concrete prepared, the workability, strength and durability characteristics are determined through proper testing and the results are compared.The optimum level of cement replacement with bagasse ash is observed to be 7.5 percent.

Keywords:bagasse ash, cement replacement, mix design, workability, strength, durability.

I. INTRODUCTION

In any industry the difference between the products and the wastages is the way of using them and with a small investment, most of the wastages can be used and can be treated as by-products. In this line the industrial and agricultural wastages are recycled and reused in construction industries. One such potential usage is often recognized by many researchers from the agricultural waste called sugarcane Bagasse of sugar industries which by burning results in sugarcane Bagasse ash (SCBA). Sugarcane is one of the most important agricultural plants that grown in hot regions. Brazil and India are the world’s major sugarcane producing countries with Brazil having over of 719 million tons and recorded one-third of the world’s total sugarcane production. Nigeria produces over 15 milliontons of sugarcane. The total sugar production capacity of India is over 30 million tons per annum. The sugarcane value chain is shown in figure 1(AmitBhardwaj, 2013). Despite the variety use of bagasse, for production of wood, papers, animal food and thermal insulation materials, a large quantity of bagasse are remained unused and hence the ash. If utilized properly, use of SCBA can promote for the green technology.

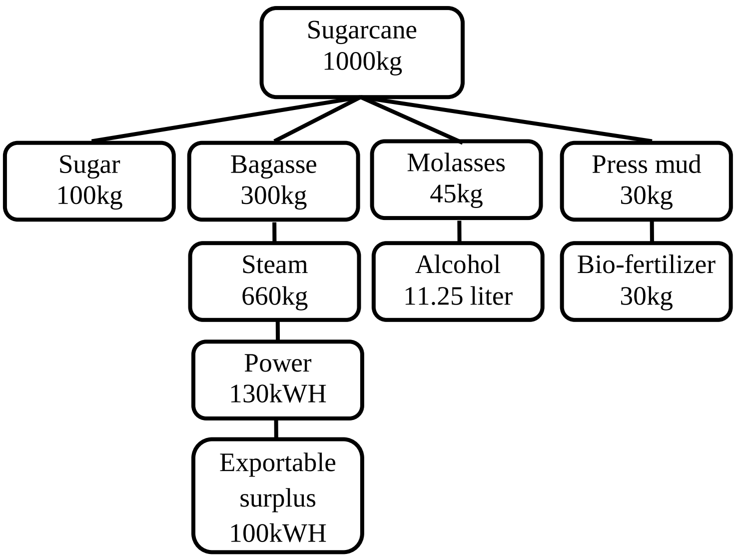

Fig.1 The sugarcane value chain (AmitBhardwaj, 2013)

The main composition of SCBA is siliceous oxide that reacts with free lime from cement hydration but only crystal silica oxide has reactive properties that can be obtained by burning bagasse in 700^{o}C for 90 minutes and also 800^{o}C at time of 15 minutes. It is observed that one ton of sugarcane to generate 26% of bagasse and 0.62% of residual ash (SnehithDevasani and Kaushik, 2015). Mostly when a quantity of bagasse is burnt, only 7-10% of ash is got. In India, SCBA is commonly obtained by bagasse carbonation, in which bagasse is packed in graphite crucible air tight, placed in electrically controlled furnace and burnt at 1200^{o}C for five hours. The carbonated bagasse is collected and burnt at 600^{o}C for 6 hours and a further burning for three hours at 700^{o}C. The cooled ash is used as SCBA in concrete.

There is only limited research available on the utilization of SCBA as cement replacement material in concrete as compared to other popular pozzolans. Having a good quantum of availability of bagasse, SCBA being high in silica content can be easily produced and used as an alternative cement replacement material in concrete products. The prime aim of this study is to realize the use of SCBA from waste and experimental investigations performed for studying the effect of partial replacement of cement with SCBA.

II. LITERATURE SURVEY

Many researchers from various countries have made experimentation in utilizing the SCBA as replacement materials in concrete mostly replacing cement and few on fine aggregate.George Rowland Otoko (2014) reported thatup to 2% of cement only can be replaced by the SCBA without adverse effect. Hailu and AbebeDinku (2012) reported that up to 10% replacement of cement by bagasse ash results in better concrete properties.Srinivasan and Sathiya (2010)bypartially replacing with SCBA up to 25% by weight of cement reported that the strength of concrete increased as percentage of replacement increased. Abdolkarim Abbasi and Amin Zargar (2013) reported that Replacing cement by 10% of bagasse ash, the workability and flowability are optimized and the compressive strength at 28 days is increased by 25% compared with normal concrete. Abdulkadir, et al (2014) concluded that 10% replacementof SCBA has the highest PAI and also, based on the compressive strength results 10% and 20% replacement of SCBA with compressive strengths of 22.3N/mm^2 and 20.1N/mm^2 are recommended for concrete.Kawade et al (2013) characterized SCBA and partially replacedcement with bagasse and observed that the strength of concrete increased up to 15% SCBA replacement.

Asma AbdElhameed Hussein et al (2014) and Sagar Dhengare et al (2015) examining on workability, strength of concrete reported to have optimum of 15% replacement level. Núñez-Jaquez et al (2012) studied the corrosion rate of steel by polarization resistance method, embedded in concrete having cement replaced with bagasse ash by 20% and found some beneficial effect on protection of steel rebar from corrosion. Amin, N (2011) reported that with the optimal replacement ratio of 20% cement reduced the chloride diffusion by more than 50% without any adverse effects on other properties of the concrete.

Almir Sales and Sofia Araújo Lima (2010), Prashant Modani and Vyawahare (2013), Subramani and Prabhakaran (2015) and Vinícius et al (2013) tried to replace sand partially with SCBA and concluded that SCBA can be a suitable replacement to fine aggregate.SadiqulHasan et al. (2014) investigated the properties of recycled aggregate concrete andSCBA as the partial replacement of cementobserved that the strength is enhanced up to 10%. Details of certain common compounds of SCBA from various countries used by several authors is given in Table1(No.1-8) and also compared with cement and flyash.As the chemical composition varies, the characterization of bagasse ash is to be done before making decision on using it in concrete. It is observed that SCBA has been tried up to 40% and the optimum level is a variant.

Table 1 Comparison Of The Chemical Composition Of Bagasse Ash

No	Authors and Country	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3/ SO_4	K_2O	LOI
1	Abdolkarim and Amin, 2013(Iran)	44.70	2.90	2.40	14.9	3.50	NA	4.40	16.7
2	Abdulkadir, et al., 2014 (Nigeria)	72.85	6.96	1.08	9.97	6.49	NA	6.77	4.23
3	Asma et al., 2014(Sudan)	77.25	4.21	6.37	4.05	2.61	0.11	2.34	1.40
4	George, 2014 (Nigeria)	41.15	2.70	7.00	3.20	0.12	0.03	8.75	17.7
5	Kawade et al.,2013(India)	66.89	29.18		1.92	0.83	0.56	NA	0.72
6	Prashant and Vyawahare, 2013(India)	62.43	6.98	4.28	11.8	2.51	1.48	3.53	4.73
7	Sagar et al., 2015 (India)	87.59	0.67	0.51	2.59	1.65	0.03	3.64	NA
8	Present study	67.82	2.56	6.33	1.54	2.03	-	2.87	2.31
9	Flyash- F (Mettur, India)	54.40	11.32	25.6	2.03	0.92	1.70	0.73	1.32
10	Flyash- C (NLC, India)	47.60	07.80	21.4	11.9	1.80	2.80	0.82	3.30

11	Cement	20.24	4.61	2.89	66.7	1.63	2.31	0.29	1.43

III. EXPERIMENTATION

The experimental part of the work consists of procuring the materials, determining the physical properties and chemical composition, designing a M20 mix, making concrete with different replacement levels(0,2.5, 5, 7.5, 10 and 12.5%) of cement with SCBA and finallydetermining their workability, strength and durability characteristics. The SCBA collected from Madras Sugar factory located in Thirukovilur, Villupuram District shown in figure 2 is used. The properties of basic constituents and the concrete are presented in Table 2.

Fig.2 View of Bagasse ash used

Table 2 Properties of concrete constituents

No	Materials	Properties	Values
1	Cement	Fineness	7% retained in 90μ sieve
2		Specific gravity	3.13
3		Consistency	34%
4		Initial setting time	46minutes
5		Final setting time	199minutes
6	Bagasse ash	Specific gravity	2.65
7		Size	75 microns
8	Fine aggregate	Specific gravity	2.65
9		Fineness modulus	2.73
10		Grading zone	II
11	Coarse aggregate	Maximum size	20mm
12		Specific gravity	2.67
13		Fineness modulus	7.10
14	Concrete grade of M20	Mix ratio	1: 1.80 : 2.96, w/c=0.5
15		7^{th} day strength	14.9 MPa(trial mix)

The quantity of concrete constituents required for each replacement level is weighed and hand mixed.Slump and compaction factor tests are conducted and the values are compared in figure 3. Specimens of concrete like 150mm cubes, 150×300mm cylinders and 100×100×500mm prisms are cast by compacting on a vibrating table. After 24 hours of casting, the specimens are demoulded and kept for pond curing until testing. Strength in compression, indirect tension and flexure, and modulus of elasticity of concrete are determined using the respective specimens. The comparison of rate of gain of compressive strength is shown in figure 4 and other properties are compared in figure 5.

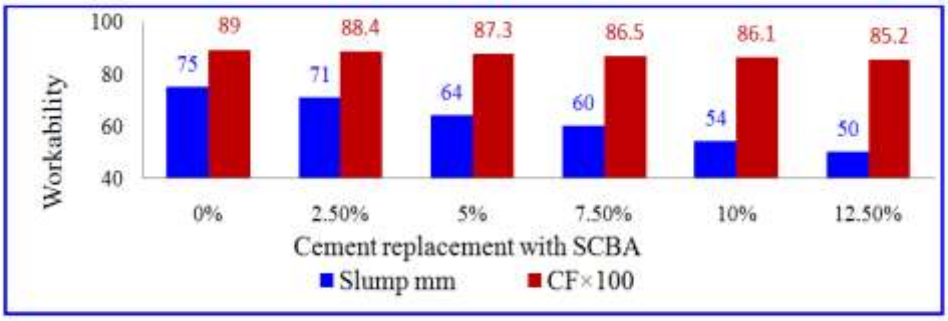

Fig. 3 Comparison of the workability characteristics

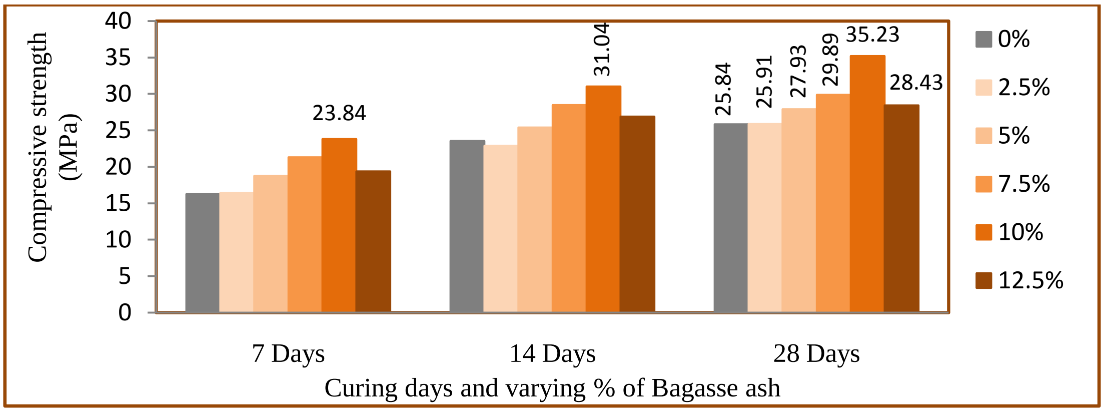

Fig.4 Comparison of rate of gain of compressive strength

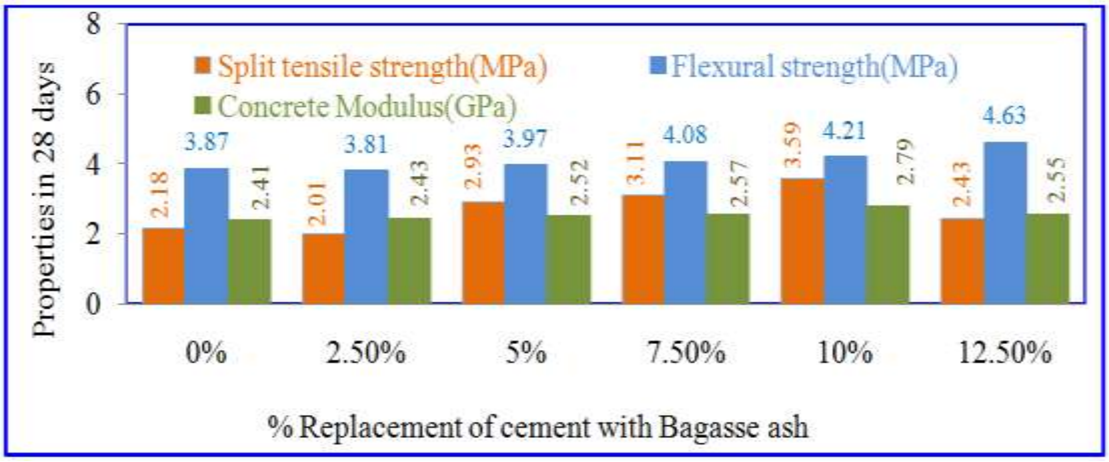

Fig.5 Comparison of flexural and tensile strength and concrete modulus

Acid resistance and sulphate resistance are also determined for every mix. Two sets of concrete cubes based on the six types are immersed in 5% dilute HCl and 5% sodium sulphate solutions respectively. After 90 days of immersion, the specimens are taken out and wiped off the surface wetness. The weight loss if any and the residual compressive strength are obtained for all the specimens. The weight loss and the strength loss are respectively compared in figures 6 and 7.

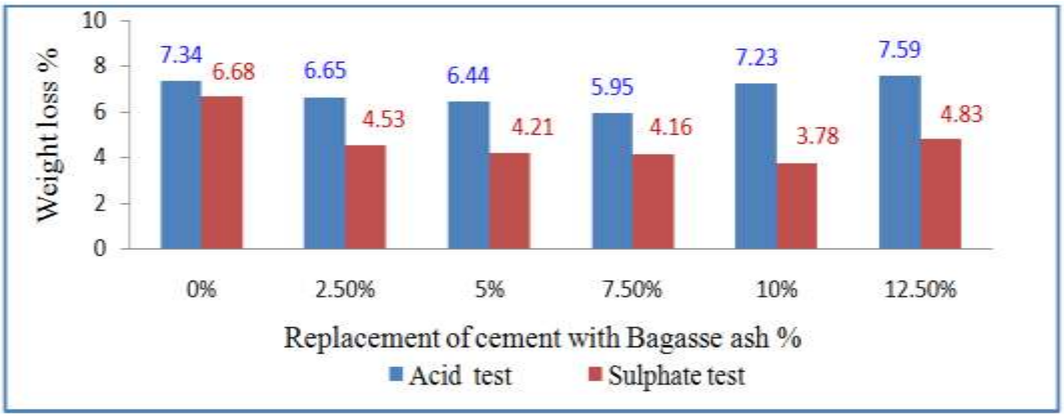

Fig.6 Comparison of weight loss by Acid and Sulphate attack

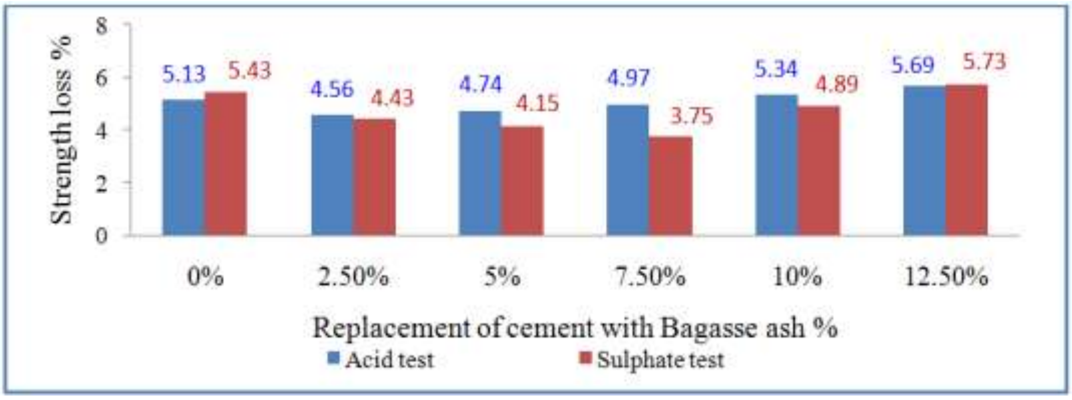

Fig.7 Comparison of strength loss by Acid and Sulphate attack

IV. DISCUSSION OF RESULTS

SCBA has been tried up to 40% by many authors and the optimum level of replacement for cement with SCBA is a variant. The cement replacement with SCBA slightly decreased the workability for the same amount of water for the present study. The compressive strength and tensile strength increased with the increase in the replacement level up to 10%. But the modulus of rupture (flexural strength) increased for all the replacement levels (up to 12.5%). The elastic modulus of concrete obtained as the tangent modulus is also increased up to 10% replacement level. For all the four properties, the increase is significant from 5% level only.

In general, the weight loss is comparatively more in acid test than the sulphate test. The weight loss by acid resistant test decreases compared to cement concrete for increase in the cement replacement with SCBA upto 7.5% and thereafter increase. The weight loss is less for all replacement levels, compared to cement concrete. The weight loss by sulphate resistance test decreases compared to cement concrete for increase in the cement replacement with SCBA upto 10% and thereafter increase.

In case of the strength loss, controversially, it is comparatively more in sulphate test than the acid test. The strength loss by acid resistant test decreases compared to cement concrete for increase in the cement replacement with SCBA upto 7.5% and thereafter increase. The strength loss by sulphate resistance test decreases compared to cement concrete for increase in the cement replacement with SCBA upto 10%.

V. CONCLUSIONS

The workability of concrete is not much affected by the increasing percentage of replacement of cement with SCBA.

- Concrete with cement partially replaced has shown increased strength in compression, tension and flexure and modulus of elasticity compared to concrete without SCBA.
- As for as the strength properties are concerned, the optimum level of replacement is 10%.
- The sulphate resistance is more for SCBA based concrete compared to acid resistance.
- In case of acid resistance test, the weight loss is least at 7.5% replacement and for all replacement levels and the weight loss is less compared to cement concrete.
- In case of sulphate resistance test, the weight loss is least at 10% replacement level.
- The strength loss is least in both cases at 7.5% level of replacement.
- The optimum level of cement replacement is 7.5% by weightwith SCBA.

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