

A Short Review on the Utilization of Sugarcane Bagasse Ash in the Manufacture of Concrete Block in Thailand

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Abstract This paper presents the use of sugarcane bagasse ash (SCBA) as a pozzolanic material for producing concrete block in Thailand. Sugarcane bagasse ash is a silica rich material that can play the role of an effective pozzolan leading to enhance pozzolanic reactions resulting in better performance of building materials. The literature review reveals that it has been utilized in the manufacture of concrete blocks as well as tiles in form of an auxiliary additive as well as a primary stabilizer. However, the use of concrete block has been more popular compared to sintered blocks due to higher energy consumption in the latter. To summarize, sugarcane bagasse ash not only has improved capability of concrete block in most of the cases but also has lowered the cost of the materials, leading to the conclusion that it's a sustain and profoundly productive responsiveness for waste management as well as cost economy.

Keywords: Sugarcane Bagasse Ash, pozzolanic, concrete block, Thailand

1. Introduction

The demand for construction materials has been continuously growing with the increasing consumption in buildings, both in rural and urban areas. It has been clearly seen that traditional materials that are being used are still very popular. However, due to the limitation of natural resources such as soils with high clay contents, limestone, marble, granite, sandstone and other durable rocks, it has become necessary to think over this problem seriously and to provide some sustainable solutions to make the alternative

materials available. Consequently, the use of an alternative and cheaper building material to replace the ones being traditionally used may facilitate solving the problems relating to building materials [1]. Many researchers from various countries have made experimentation in utilizing the sugarcane bagasse ash (SCBA) as a partial replacement materials in concrete mostly replacing cement and fine aggregate [2]. Sugarcane bagasse ash is a byproduct of sugar factories found after burning sugarcane bagasse which is found after the extraction of all economical sugar from

sugarcane [3]. Bagasse ash consists of both bottom ash collected from the boilers and fly ash collected from the gas washers. The ashes are composed of both organic and inorganic fractions but fly ash consists of more organic content compared to bottom ash [4]. Approximately more than 200,000 tons of bagasse ash are produced every year in Thailand. The major advantages of the bagasse ash is that it is cheaper to produce and ready to use because it is produced by the existing facilities [5]. Thailand produced 130 million tons of sugarcane in the year 2017-18, which was about 30% higher than the previous time [6]. Sugarcane bagasse ash is one such solid waste generated in huge quantities in Thailand, a leading sugar producer. Presently, Thai sugar production heavily relies on export - as high as 70-75% of total domestic sugar output with the capacity of 105.96 tons of sugarcane or equivalent to sugar output of 11.34 million tons [7]. Thailand is one of the leading producers of sugar. The bagasse ash waste is generated in huge quantities in the country leading to potential disposal problems without effective management techniques. However, the economic importance of this solid waste has been realized with several applications like sealing materials, pozzolanic material, blocks and soil amendment. There is only limited research available on the utilization of SCBA as cement replacement material in concrete as compared to other popular pozzolans. In this study, a short review on the use of sugarcane bagasse ash in the

manufacture of concrete block in Thailand was conducted.

2. Sugarcane Bagasse Ash

Sugarcane bagasse ash (SCBA) is a solid waste generated from the sugar manufacturing industry. The sugar manufacturing process generates sugarcane trash, bagasse, bagasse fly ash, press mud, and spent wash [8, 9]. The economic wastes are bagasse, molasses, and filter press mud [10]. Sugar cane is typically used to produce sugar and ethanol. Bagasse is commonly used as a fuel in cogeneration to produce steam and generate electricity. In this process, SCBA remains as the final waste in the sugar production chain. Each ton of burnt bagasse may generate 25-40 kg of bagasse ash [11] and, subsequently, a considerable amount of SCBA could be generated. With the increasing demand for more sugar and ethanol production in recent years, SCBA outputs have substantially increased.

Around the world, approximately 1,500 Mt of sugarcane is annually produced, which yields approximately 40-45% bagasse after juice extraction in sugar mills [12]. In many of sugarcane industries, the bagasse generated is usually used as fuel while also reducing its volume for disposal. These residual ashes generated from burning or incineration are called bagasse ashes inclusive of both bottom and fly ashes. In most modern plants, the bottom ash gets mixed with fly ash in the water channel that comes from the gas washer [13]. This waste is typically disposed into sumps and is also applied on land as soil

amendment in some purposes [8]. It was widely recommended to consider bagasse ash as a nonhazardous waste material. However SCBA is an agro-industrial residue available in many countries, and it was proved by previous comprehensive studies that its use generally improves the behavior of the cementitious construction materials [14]. SCBA has been incorporated into concrete as a pozzolanic material, such as conventional concrete [15, 16], high-performance concrete [17], self-compacting concrete [18, 19], and recycled aggregate concrete [20]. However, being nonhazardous does not exactly mean it has actually no impact on the environment. SCBA is generally used as a fertilizer or is disposed of in landfills, which has led to

3. Chemical composition of bagasse ash

The chemical composition of bagasse ash reveals that it consists of silica, alumina, and iron oxide etc. In Thailand, the chemical composition of bagasse ash reported by various researchers has been compiled in Table 1. It can be seen that the major component of the chemical composition of bagasse ash is silica. Alumina and calcium, though significantly lesser when compared to silica, together make up a major portion of bagasse ash composition, which contribute to pozzolanic reaction.

However, the pozzolanic activity of bagasse ash depends on calcination temperature of the ash [22, 23]. According to Cordeiro et al., 600°C for three hours is the optimal calcination condition for achieving ash of high pozzolanic activity [22]. According to ASTM C618 [24], the minimum requirement of silica, alumina, and iron oxide for natural pozzolans is 70%.

intensified environmental concerns [21]. Fig.1 shows the sugarcane bagasse ash after passing through 300 μm sieve.



Fig.1 sugarcane bagasse ash after passing through 300 μm sieve

It can be seen that, in almost all of the studies reported in Table1, bagasse ash meets this requirement. Another requirement for natural pozzolan is that SO_3 content should be less than 4%. This criterion is also met by almost all the studies for which SO_3 data has been reported. However, Pourkhorshidi et al. reported that pozzolanic performance evaluated based on ASTM C618 showed disparities when compared to actual pozzolanic performance [25]. Mineralogical characterization has indicated that bagasse ash is outstandingly composed of quartz and cristobalite, both of which are silica minerals, followed by calcite which is agreed upon by most of the researchers.

4. Bagasse ash research in Thailand

A number of researchers have worked on the compressive strength and water absorption of the concrete blocks. However, concrete blocks have been known to be less durable. Hence, durability of concrete blocks is an important aspect that

needs to be focused upon to increase the acceptability of concrete blocks in practice. The themes analyzed in the bagasse ash literature are listed in Table 2.

In 2006, S. Dumrongsil and Thepwong R. [26] studied the strength and microstructure of cement mixed with bagasse ash and fly ash in order to develop the bagasse ash as a construction material. They used the ratio of cement mixed with bagasse ash and fly ash as 70:30:10 by weight, respectively. The result showed that the strength of cement mixed with bagasse ash and fly ash was comparable to the Portland cement. It can be used as a construction material.

S. Suvimol and C. Daungruedee (2008) [28] reported the potential as cementitious material of grinding bagasse ash. Ashes from two different sources were studied for chemical composition and basic performance. Then, the ash from the major source was investigated in detail and used as cement replacement in the range of 20 - 40%. A slight difference in chemical composition of ashes from two sources was found, however, pozzolanic reactivity of both sources corresponded with ASTM suggestion limit.

Table 1: Chemical composition of bagasse ash from various researchers.

Author(s)	SiO ₂	Al ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	MgO	P ₂ O ₅	Na ₂ O	SO ₃	LOI
S. Dumrongsil & Thepwong R. (2006) [26]	76.6	3.1	1.9	1.3	DNR	DNR	DNR	DNR	1.6	8.9
Dumrongsil, S. & Sujjavanich S. (2007) [27]	70.6	3.8	2.8	0.7	DNR	DNR	DNR	DNR	0.2	15.4
Suvimol, S. and C. Daungruedee (2008) [28]	83.27	2.7	7.27	2.85	DNR	DNR	DNR	DNR	0.31	9
Chusilp, N., Jaturapitakkul, C., & Kiattikomol, K. (2009) [29]	64.88	6.40	10.69	2.63	DNR	1.55	DNR	DNR	1.56	8.16
Worathanakul, P. et al. (2009) [30]	75.14	0.61	16.14	1.41	0.90	DNR	1.2	DNR	3.74	DNR
Somna, R. & Jaturapitakkul C. (2011) [31]	55.0	5.1	11.0	4.1	1.2	0.9	DNR	0.2	2.2	19.6

Muangtong, P. et al. (2013) [32]	64.11	5.26	5.75	2.78	2.59	1.28	1.37	0.32	0.41	15.09
Tonnayopas, D. (2013) [33]	38.31	2.84	10.76	3.36	1.77	0.94	0.90	DNR	0.45	40.21
Patel, J. A., & Raijiwala, D. (2015) [34]	68.42	5.81	2.56	0.218	DNR	0.57	1.28	DNR	4.33	15.90
San, E. E., & Phueakphum, D. (2017) [35]	76.82	6.25	2.78	6.28	3.25	1.99	DNR	1.91	0.72	DNR
Janbuala S. & Wasanapiarnpong T. (2017) [36]	58.0	2.10	4.01	1.30	4.21	1.25	3.31	DNR	DNR	14.5

Table 2: Thematic analysis of some literature on bagasse ash in Thailand.

Author(s)	High-performance concrete	Heat evolution	Recycled aggregate concrete	Strength of cement mixed	Silica source extracted
S. Dumrongsil and Thepwoong R. (2006) [26]			✓	✓	
Dumrongsil, S. & Sujjavanich S. (2007) [27]			✓	✓	
Suvimol, S. and C. Daungruedee (2008) [28]			✓	✓	
Chusilp, N., Jaturapitakkul, C., & Kiattikomol, K. (2009) [29]	✓	✓		✓	
Worathanakul, P. et al. (2009) [30]		✓			✓
Somna, R. & Jaturapitakkul C. (2011) [31]			✓	✓	
Muangtong, P. et al. (2013) [32]			✓	✓	

Tonnayopas, D. (2013) [33]		✓	✓	✓	
San, E. E., & Phueakphum, D. (2017) [35]	✓			✓	
Janbuala S. & Wasanapiarnpong T. (2017) [36]		✓		✓	

Detailed investigation suggested that the coarsest yielded pozzolanic reactivity of about 84-87% while of the fine ash ranged between 99-108%. For low cost material, there was a potential of cement replacement between 30 % and 40%.

Chusilp, N. et al. (2009) [29] studied the physical properties of concrete containing ground bagasse ash (BA) including compressive strength, water permeability, and heat evolution. The process started with preparing bagasse ash from a sugar factory, then used as a replacement for Type I Portland cement at 10, 20, and 30 wt% of binder. The results showed that, at the age of 28 days, the concrete samples containing 10-30% ground bagasse ash by weight of binder had greater compressive strengths, while the water permeability was lower than the control concrete. Concrete containing 20% ground bagasse ash had the highest compressive strength at 113% of the control concrete. The water permeability of concrete decreased as the fractional replacement of ground bagasse ash was increased. For the heat evolution, the maximum temperature rise of concrete containing ground bagasse ash was lower than the control concrete. It was also found that the maximum temperature rise of the concrete was reduced up to 33% as compared with the control concrete when the cement was replaced by ground bagasse

ash. The results indicated that ground bagasse ash can be used as a pozzolanic material in concrete with an acceptable strength, lower heat evolution, and reduced water permeability with respect to the control concrete.

Worathanakul, P. et al. (2009) [30] found that silica had been successfully extracted from bagasse ash. They reported a mass composition from XRF, XRD spectrum peak, morphology and chemical bonding. The synthesis conditions were optimized to obtain the bagasse ash with the maximum silica content. The silica content of 91.57 percent was achieved from heating of bagasse ash at 600°C for 3 hours under oxygen feeding and HCl treatment. The result can be used as value added for bagasse ash utilization and minimize the environmental impact of disposal problems.

Muangtong, P. et al. (2013) [32] investigated the appropriate ratio of replacing clinker by SCBA to produce the cement and w/c ratio of the resultant cement. The result confirmed that replacing clinker with 20% SCBA was appropriate for production in laboratory scale and w/c ratio of 0.735 was suitable on workability of the resultant cement. It presented the highest compressive strength comparing to all ratios (0-40% SCBA) of resultant cements and near that of commercial cement. The

appropriate w/c ratio was 0.735:1 for good mortar flow ($110\pm 5\%$) at 80 % cement and 20% SCBA. It was ensured that increasing amount of SCBA influenced the increase of w/c ratio. Moreover, this cement mixture was possible for cement preparation in laboratory and would lead to industrial production in the future.

Sua-iama, G. and Makul N. (2013) [19] examined the effect of adding limestone powder to self- compacting concrete mixtures in which large amount of bagasse ash was employed as a fine aggregate replacement. A Type 1 Portland cement content of 550 kg/m³ was kept in all samples. The fine aggregate was replaced with 10, 20, 40, 60, 80, and 100% bagasse ash and limestone powder by volume. Mixtures were designed to yield a slump flow diameter of 70 ± 2.5 cm. The workability (slump flow, T50cm slump flow time, V-funnel flow time, and J-ring flow) and hardened properties (ultrasonic pulse velocity and compressive strength) of each mixture were collected, and blocking assessments were performed. The volumetric percentage replacement of 20% limestone powder in fine aggregate incorporating 20% bagasse ash effectively enhanced the workability and hardened properties of self-compacting concrete.

P. Promsawat and B. Chatveera. (2017) [37] studied flow loss of self-leveling mortar by using bagasse ash and fly ash from power plant as pozzolanic. Bagasse ash and fly ash were used to replace Portland cement at 10, 15 and 20% by weight of binder. Flow characteristic and 28-days compressive strength were examined. The results demonstrated that flow loss of mortar was increased when increasing the

bagasse ash. Conversely, it decreased with the increasing of fly ash replacement due to the improvement of flow characteristics of fly ash. Finally, fly ash had negative effect on setting time and compressive strength of self-leveling mortar because of incomplete hydration reaction.

San, E. E., & Phueakphum, D. (2017) [35] investigated the utilization of sugarcane bagasse ash (SCBA) mixed with Portland cement, bentonite and crushed salt as sealing materials to reduce the subsidence in salt and potash mine. The ratio of SCBA-to-cement (cementitious materials) was 20:80 by weight and bentonite-to-crushed salt (bentonite crushed salt mixture) was 30:70 by weight. The mixture ratio of cementitious materials to bentonite-crushed salt was 1:2 (CPB-1) and 1:3 (CPB-2). The constant saturated brine-to-mixed materials ratio of 0.4 was used for blending. The uniaxial compressive strength (UCS) test, triaxial compression (TRI) test and Brazilian tensile strength (BZ) test were performed for each curing period of 3, 7, 14 and 28 days. The test results were used in FLAC program to simulate the time dependent behaviors of salt and potash mine with sealing materials. The results clearly showed that CPB-1 mixture can produce more strength than CPB-2 mixture. From the numerical analysis, the result obtained from the mine opening with the CPB-2 sealing can reduce the magnitude of subsidence about 46% as compared with that without backfills.

Vimuttasoongviriyaya (2017) [38] studied the behavior of bagasse ash with cement and fine stone (BCS) in terms of density, absorption and compressive strength, respectively. Three experimental groups - general cement with fine stone,

BCS in non-compressive mold and BCS in compressive mold - were used in this study. The test results showed that the density decreased as fine sand mixed increased. The specimens without fine stone had maximum water absorption. Moreover, BCS in compressive mold had higher water absorption than BCS in non-compressive mold. In case of compressive strength, most of experimental groups were higher than 25 kg/cm² as the non-bearing interlocking block standard. However, the compressive strength of the specimen increased while the bagasse ash decreased.

Many researchers have intended to characterize bagasse ash and have more or less concluded that it is a waste material that is rich in silica and can contribute to pozzolanic reactions due to the high amount of silica, alumina, and iron oxide present in it, a requirement stipulated by ASTM for natural pozzolans. The pozzolanic activity of the ash depends on the amorphous silica rather than crystalline silica, which is dependent on the calcination temperature of the ash. Preparation of the ash by sieving can grind its particle size and, thus, enhance its reactivity. Microstructure of bagasse ash from various sources reveals both crystalline forms and individual fibers with pores, which corresponds with the fact that bagasse ash consists of both organic and inorganic crystalline fractions.

5. Conclusions

The paper aims to give an overview of the characterization and utilization of bagasse ash in manufacture of stabilized concrete blocks in Thailand. Based on the literature review that concentrates on the utilization of bagasse ash in the manufacture of concrete blocks, the following points can be concluded:

(a) Bagasse ash utilization in soil engineering activities has increased in recent years with it gaining prominence in stabilized concrete blocks. The utilization of bagasse ash in concrete blocks has been adopted in two modes as auxiliary additive/replacement to primary stabilizers like lime or cement or as additive to soil in the manufacture of concrete blocks. The common tests adopted in investigations dealing with stabilized concrete blocks include compressive strength, water absorption, and to a lesser extent efflorescence of blocks.

(b) The literature shows that addition of bagasse ash results in an improvement in the strength of stabilized blocks in most of the cases. Addition of bagasse ash to cement as auxiliary additive results in an enhanced performance of the concrete blocks. However, it has been reported that bagasse ash performs better at lower cement contents when compared to higher cement contents. When bagasse ash is added as standalone stabilizer in manufacture of blocks, it results in an improved performance when compared to unstabilized blocks but their performance is lower when compared to cement/lime stabilized blocks amended with bagasse ash. Practically, most of the investigations reported the increase of water absorption in the stabilized blocks due to addition of bagasse ash.

(c) The utilization of bagasse ash has been found to reduce cost either in saving virgin material when adopted in concrete blocks or in the form of savings due to process optimization in the case of sintered tiles or blocks.

Hence, it can be summarized that bagasse ash is actually silica rich material that can contribute to improve the performance of stabilized soil blocks while

still having unrealized potential in further making sintered soil blocks more durable and acceptable for use in commercial applications.

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