การวิเคราะห์สมบัติทางกายภาพและเชิงกลของคอนกรีตบล็อกกลวงผสมเถ้าชานอ้อย
Analysis of the physical and mechanical properties of concrete masonry units mixed with sugarcane bagasse ash

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บทคัดย่อ

งานวิจัยนี้จัดทำขึ้นเพื่อหาอัตราส่วนซีเมนต์ต่อเถ้าชานอ้อยที่มีผลต่อสมบัติทางกายภาพและสมบัติเชิงกลของคอนกรีตผสมเถ้าชานอ้อย ใช้อัตราส่วนซีเมนต์ต่อเถ้าชานอ้อยปริมาณร้อยละ 0 10 20 30 40 และ 50 โดยน้ำหนัก บ่มน้ำเป็นเวลา 3 7 และ 28 วัน ควบคุมค่าการไหลแผ่ที่ 110±5% ผลการวิเคราะห์โดยเครื่องวิเคราะห์ตัวอย่างโดยเทคนิคการเรืองรังสีเอกซ์ พบว่า เถ้าชานอ้อยประกอบด้วยซิลิกอนไดออกไซด์ เป็นสารประกอบหลักสูงถึงร้อยละ 50 โดยน้ำหนัก ผลการทดสอบทางกายภาพด้วยกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด พบว่า อนุภาคเถ้าชานอ้อยมีรูปร่างไม่แน่นอนและมีรูพรุนมาก จัดเป็นวัสดุปอซโซลานใกล้เคียงคลาสซี มีค่าความถ่วงจำเพาะเฉลี่ย 2.21 ค่าการสูญเสียน้ำหนักเนื่องจากการเผา ร้อยละ 10.85 โดยน้ำหนัก ผลการทดสอบทางกลพบว่ากำลังรับแรงอัดของมอร์ตาร์ผสมเถ้าชานอ้อยที่ร้อยละ 10 20 30 40 และ 50 โดยน้ำหนัก ลดลงตามลำดับที่ 247.59 230.75 193.30 159.53 และ 149.44 กก./ซม.^{2} การขึ้นรูปของคอนกรีตที่อัตราส่วนมอร์ตาร์ต่อมวลรวมหยาบ (หินเกล็ด) สามารถเริ่มต้นขึ้นรูปได้ที่อัตราส่วน 1:1.5 ผลการทดสอบกำลังรับแรงอัดของคอนกรีตได้ค่าดีที่สุด เมื่อใช้เถ้าชานอ้อยแทนที่ปริมาณซีเมนต์ในมอร์ต้าร์ ร้อยละ 10 ได้ค่าเฉลี่ย 33.74 กก./ซม.^{2} ซึ่งผ่านมาตรฐานอุตสาหกรรมคอนกรีตบล็อกผนังแบบไม่รับน้ำหนักตามมาตรฐานผลิตภัณฑ์อุตสาหกรรม มอก.58-2560 จากผลการวิจัยแสดงให้เห็นว่าเถ้าชานอ้อยสามารถนำมาใช้เป็นวัสดุทดแทนซีเมนต์ได้บางส่วนเพื่อช่วยลดต้นทุนในการผลิต สิ่งสำคัญที่ต้องคำนึงถึงคือการเลือกใช้วัสดุเชื่อมประสานจากเถ้าชานอ้อยด้วยสัดส่วนที่พอเหมาะ เพื่อให้เกิดประโยชน์ทั้งในด้านคุณภาพและราคา

คำสำคัญ: เถ้าชานอ้อย, ชีวมวล, สมบัติเชิงกล, กำลังรับแรงอัด

Abstract

This study set out to determine how cement to sugarcane bagasse ash (SCBA) ash ratios affected the physical and mechanical properties of SCBA-concrete mixes. Cement to SCBA ratios of 0, 10, 20, 30, 40, and 50% by weight of binder were used in the trials. Examples of concrete were cast, and were subsequently cured in water for 3, 7, and 28 days while keeping a slump flow percentage of 110±5%. Data from test results were quantitatively and comparably analyzed. The results from X-ray fluorescence showed that half of the composition in SCBA was SiO_2. Using a Scanning Electron Microscope it was found that the bagasse ash particles had an irregular shape with highly porous texture; it was classified as nearby Class C pozzolan, with an average specific gravity of 2.21. Bagasse ash sample

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lost 10.85 % of its weight during ignition. Mechanical tests of the compressive strengths of mortar blended with bagasse ash at 10, 20, 30, 40, and 50 % by weight were 247.59, 230.75, 193.30, 159.53, and 149.44 kg/cm^2 ,respectively. To make concrete masonry units, it was possible to combine mortar and coarse aggregate (chipped stone) in a 1:1.5 ratio with 10% bagasse ash substitution, which produced the best results. The concrete masonry unit had an average compressive strength of 33.74 kg/cm^2, making it a hollow non-load-bearing concrete masonry unit, in accordance with TIS 58-2560 (Thai Industrial Standards Institute). The results demonstrate that SCBA can assist lower production costs by serving in some cases as a cement substitute. To profit from advantages in both quality and cost, it is crucial to take into account the selection of binders from SCBA as biomass.

Keywords: Sugarcane bagasse ash, biomass, mechanical properties, compressive strengths

Introduction

With increased construction of buildings in both urban and rural areas, there has been a constant increase in the need for construction materials. There is no denying the continued popularity of conventional building materials. Sandstone, limestone, marble, granite, and soils rich in clay are among the available natural resources. It is therefore essential to give this problem careful thought and to propose some sustainable solutions in order to make alternative materials available to address it. The construction sector consumes a significant portion of the world's yearly resource consumption—nearly 50; which places a strain on the environment, ecosystems, and natural resources (Meglin *et al*., 2022). Many scientists from different nations have experimented with using sugarcane bagasse ash (SCBA) as a partial replacement for cement and a small amount of fine aggregate in concrete (Thomas *et al*., 2021; Khalil *et al*., 2021; Batool *et al*., 2020; Yogitha, 2020). After burning sugarcane bagasse, is left behind after all of the economically viable sugar has been extracted from sugarcane, sugar factories produce sugarcane bagasse ash (Minnu, *et al*., 2021). Bottom ash from the boilers and fly ash from the gas washers are also parts of bagasse ash. Both organic and inorganic components make up the ashes, however fly ash has a higher percentage of organic material than bottom ash. Alumina and silica around the sugar mills are reported to contribute to environmental problems brought on by the disposal of this material (Lathamaheswari *et al*., 2017). In Thailand, more than 200,000 tons of bagasse ash are produced annually. The primary benefits of bagasse ash are that it is ready for use and less expensive to produce because it is produced by already-existing plant (Athira *et al*., 2021). Thailand is one of the world's top producers of sugar; the country produces enormous amounts of garbage, which could cause disposal issues if proper management practices aren't used (Gheewala *et al*., 2019). SCBA, or sugarcane bagasse ash, is a type of solid waste produced by the sugar processing sector. Each ton of bagasse burned may produce 25–40 kg of bagasse ash (Amin *et al*., 2022), and as a result, a sizeable amount of SCBA may be produced. Globally, 1,500 Mt of sugarcane are produced each year, and once the juice is extracted in sugar mills, 40–45% of that crop is bagasse (Shafiq *et al*., 2016). Bagasse ashes refer to both bottom and fly ashes that are produced as byproducts of burning or incineration. In most modern plant, fly ash and bottom ash are combined in the water channel that exits the gas washer (Prasad *et al*., 2022). This waste is often dumped into sumps and, in certain cases, applied to the ground as a soil amendment (Kishor *et al*., 2022). It has been commonly advised to take bagasse ash into consideration as a nonhazardous waste item (Khawaja, *et al*., 2021; Thomas *et al*., 2021). The use of SCBA, an agro-industrial residue available in many nations, has been shown to typically improve the behavior of cementitious construction materials, as shown by earlier comprehensive investigations (de Sande *et al*., 2021). Concrete, including cementitious material (Quedou *et al*., 2021), recycled aggregate concrete (Yashwanth *et al*., 2019), high-performance concrete (Wu *et al*., 2022; Murugesan, *et* *al*., 2020), and ordinary concrete (Loganayagan *et al*., 2021; Abbas *et al*., 2020), have utilized SCBA as a pozzolanic ingredient. Being nonhazardous, however, does not necessarily imply that it has no effect on the environment. Due to the common use of SCBA as fertilizer or its disposal in landfills, environmental issues have grown more serious (Xu, *et al*., 2018). However, with numerous applications, including sealing materials, pozzolanic material, blocks, and soil amendment activities, the economic significance of this solid waste has been realized. Compared to other common pozzolans, there has been relatively little study of the use of SCBA as a cement replacement material in concrete.

Based on the feasibility of SCBA as a cement replacement material, this study has sought to replace the cement in the concrete mixture to the extent of 0, 10, 20, 30, 40, and 50% by weight. The results of multi0ple tests are presented. Morphology, elemental make-up, and physico-mechanical properties including compressive strength, mortar test, and water absorption are all considered throughout the inspection. Additionally, the concrete sample's forming test and Vebe test were examined.

Materials and methods

Materials

The sources of the materials used in this investigation were as follows

Cement. Type I ordinary Portland cement is the most widely used type of cement. Numerous tests were performed including standard consistency tests, setting time tests, etc.

Fine Aggregate. Sand is typically used as the fine aggregate. A minimum void ratio should be achieved by the sand particles; a greater void ratio necessitates the use of more mixing water.

Coarse Aggregates. Crushed aggregates wew normally employed and in this work were nominally evaluated at a maximum size of 9.5 mm.

Water. Water from the Metropolitan Water Supply that complied with ASTM C192/C192M for water for concreting and curing materials was used.

Sugarcane Bagasse Ash. The sugarcane bagasse was collected at the Kornburi Sugar Plant in the Nakhon Ratchasima area of Thailand. Subsequently, SCBA was sorted using a standard sieve No. 16 (1.18 millimeter in diameter) with a hold size of No. 200 (75 micrometers in diameter) to remove big particle pollutants caused by the incomplete combustion process. In the mixture, SCBA was used as a pozzolanic material to replace cement to the extent of 0, 10, 20, 30, 40, and 50% by weight of the binder.

Mortar and concrete mixes design

This section briefly describes an assessment of the mortar and concrete in addition to the SCBA types that were used. The preparation of materials and testing material properties were evaluated at the Material and Testing Laboratory, Department of Civil Engineering, Southeast Asia University.

1. Concrete masonry was made using a hand-pouring mold that was suggested by a seller of concrete masonry molds. In summary: the mixture was pushed firmly into the framework using a stick until it reached approximately a third of the way up the mold The mold was then filled to approximately 2/3 full with the mixture. The final layer of mixture was added into the mold with a forceful push. Finally, the mold was, disassembled after giving the surface a firm push to level it.
2. To evaluate the water content of the mortar, bagasse ash was used in place of cement at weight ratios of 0, 10, 20, 30, 40, and 50%, with flow control set at 110±5% in line with ASTM C1437.
3. To produce a concrete masonry unit in accordance with ASTM C109, the first two ratios with the highest compressive strength were chosen, and the mortar's compressive strength was tested at days 3, 7, 14, and 28. An experiment was conducted to determine the results of the ASTM C 311-02 compliant mortar test for the Strength Activity Index.
4. The concrete masonry mixture was made using a 1:2.75 cement to sand ratio in accordance with ASTM C230. After much trial and error, a mortar: coarse aggregate ratio of 1:1.5 was used for the forming process, with bagasse ash being used in place of one part of cement at weights of 0, 10, and 20%,.

5. Concrete utilized for the shaping of concrete masonry units was mostly slump-free and relatively dry. The ASTM C143 slump test was not appropriate in this case since it cannot identify the mixes for concrete masonry unit forming and we employed pozzolanic elements in the mortar. Instead, the researcher determined the appropriate water to binder ratio using Vebe testing in line with BS EN 12350-3. Vebe is a useful laboratory test that benefits from having a treatment of concrete that is relatively similar to the manner of placement in practice (Shamsaei *et al*., 2019). A typical slump cone is put within a 305 mm diameter cylinder, which is rigidly attached on a flow table and adjusted to provide a drop. After the slump cone has been properly filled and removed, the concrete is covered with a disc-shaped rider. When the glass plate rider is entirely covered in concrete and all crevices in the concrete's surface have vanished, the remolding is thought to be finished. The time in seconds, known as the Vebe time, needed for the remolding to be completed is considered to be a measure of the mix's workability and is stated as the input of energy required for compaction.

6. Concrete masonry unit formwork testing using a trial-error ratio for the cement mortar to coarse aggregate ratio. Once the appropriate ratio for forming had been established, the compressive strength of the concrete masonry unit was then tested based on significant criteria, with reference to the Thai Industrial Standard (TIS 57-2533 and TIS 58-2533) and the American Society for Testing and Materials (ASTM C140, ASTM C90 and ASTM C129).

Analytical methods

The data analysis is organized into three sections. The first section examines mortar by investigating the impact of water content on flow values and compressive strength of mortar that mixes bagasse ash in a variety of ratios. The second section examined the impact of concrete using the test-derived mortar to coarse aggregate ratio of 1:1.5, controlled by the slump value at 0, and then the VB duration was determined and a compressive strength test was performed after 28 days. The type of concrete blocks that were produced from the study are evaluated in the last section of this report by comparing the compressive strength of concrete blocks to TIS criteria.

Results and discussion

Physical characteristics of materials

Cement: The specific gravity of cement is 3.17 as per ASTM C118-16.

Fine Aggregate. Specific gravity and fine aggregate adsorption in this investigation were 2.54 (per ASTM C128) and 1.01 (per ASTM C29), respectively. Fine aggregate is defined as fractions between 4.75 mm and 150 microns, and its unit weight in its loose state is 1,620 kg/m^3.

Coarse Aggregates. The specific gravity of coarse aggregate was 2.68 as per ASTM C127, the adsorption of coarse aggregate was 2.05 as per ASTM C29. In its loose state, coarse aggregate had a bulk density of 1,540 kg/m^3.

Sugarcane Bagasse Ash The specific gravity of SCBA was 2.21 as per ASTM C118-16.

Chemical composition of Portland cement and SCBA. The chemical composition of Portland cement and raw SCBA was investigated using a wavelength-dispersive X-ray fluorescence spectrometer (XRF) at the Materials Technology Laboratory, School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi. The results are listed in Table 1.

The percentage of pozzolanic oxide (SiO_2+Al_2O_3+Fe_2O_3) in SCBA's total composition was 55.65 %. Because of its high amount of SiO_2, SCBA has been shown in several investigations to have a chemical composition that is ideal for usage as a pozzolanic mineral (Zaheer, & Tabish, 2023; Lyra *et al*., 2021).

Table 1 Chemical composition of Portland cement and SCBA, in wt%.

Chemical composition of the binder	Portland cement (%)	SCBA (%)
Silicon Dioxide (SiO_2)	20.9	50.0
Aluminium Oxide (Al_2O_3)	4.8	3.16
Calcium Oxide (CaO)	65.4	2.93
Ferric Oxide (Fe_2O_3)	3.4	2.49
Potassium Oxide (K_2O)	0.4	2.27
Phosphorus pentoxide (P_2O_5)	-	1.21
Magnesium Oxide (MgO)	1.3	1.05
Sulfur Trioxide (SO_3)	2.7	0.48
Sodium Oxide (Na_2O)	0.3	0.21
Loss on ignition (LOI)	1.0	10.85

Morphological Aspects

Scanning electron microscopy (SEM) has been widely utilized by researchers to examine the microstructure of SCBA concrete because it can show how the material transforms morphologically from raw components to hydrated forms (Zaheer & Tabish, 2023; Li *et al*., 2022). The surface micrographs of the particles are provided by the SEM analysis. The carbon particles of SCBA have been found to be similar to elongated oval shapes (columnar fibrous structure), which have a variety of sizes and shapes (Jagadesh *et al*., 2020). Additionally, there are prismatic (tetrahedral) particles present, which are similar to crystalline silica and have a well-structured edge. For partially burned particles, it has also been reported that they have a high percentage of porosity and a cellulose sheet-like pattern (Jagadesh *et al*., 2020). The cellular sheet patterns found in SCBA have been linked in some studies to the imperfect development of crystalline phases that accumulate as meta-stable crystalline particles, making them water-absorbent (Zaheer & Tabish, 2023; Jagadesh *et al*., 2020). As previously mentioned, SEM reveals the SCBA particles to have surface holes and having a cellular sheet pattern, oval forms, elongated layered shapes (fibrous structure), and prismatic tetrahedral shapes (crystal silica structures) (incomplete crystallinity). Raw SCBA was tested SEM at the King Mongkut's University of Technology Thonburi's Materials Technology Laboratory and its properties matched those of cristobalite silica. Figure 1 depicts the particle shape of the SCBA used in this study. SEM imaging, which has improved contrast and spatial resolution, makes it possible to identify cementitious materials in SCBA and provides supplementary capabilities for element analysis. The pozzolanic activity of SCBA can be lowered by the raw SCBA, which typically burns inefficiently and contains a lot of fiber particles with a high amount of amorphous carbon (Li *et al*., 2022). Cristobalite particles have a well-structured edge with a smooth surface, as seen in Figure 1(a). Even after burning, SCBA, which is only made up of fibers, may still produce particles with prismatic or elongated layered morphologies or fibrous structures, as indicated by the fibers in Figure 1(b). The crystalline phases are shown in Figure 1(c), while the surface pores that still plainly exist are shown in Figure 1(d). Figure 1(e) depicts a high proportion of porosity in the SCBA structure, while Figure 1(f) displays tetrahedral forms, crystal silica structures, and imperfect crystallinity particles.

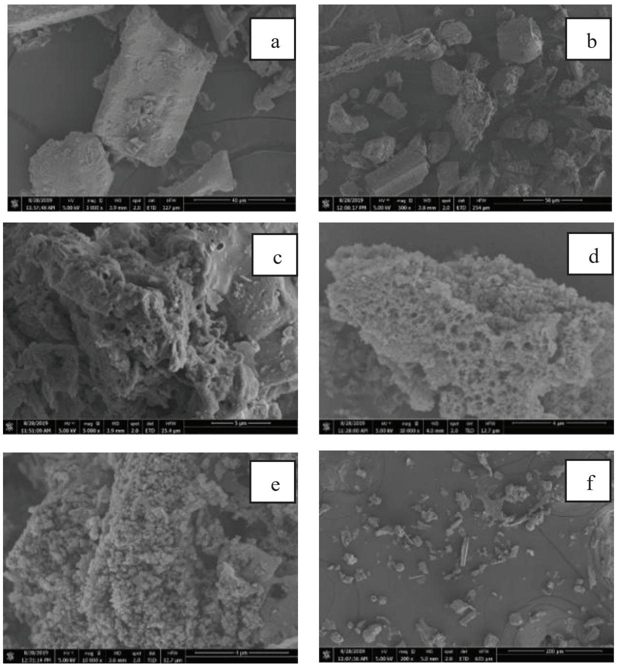

Figure 1 Morphology of SCBA's particle; well-structured edge (a), elongated layered shapes (fibrous structure), and prismatic (b), crystalline phases (c), surface holes (d), high percentage of porosity (e), and tetrahedral shapes, crystal silica structures, and incomplete crystallinity (f).

Mortar test results

1. According to ASTM C230 standard, a flow table test was used to gauge how much water the mortar mixture needs in order to flow properly. Prior to casting into a test bale for additional compressive strength testing and use as the starting mix ratio, a test to determine the amount of water to establish the percentage flow (Percent Flow) must be between 110±5%. The flow test was carried out to determine the quantity of water required in the mortar mixture. Since it is acceptable for concrete of high and very high workability, including flowing concrete that would demonstrate a collapse slump, the flow test has grown in popularity in recent years (Shamsaei *et al*., 2019). The test's outcomes are described in full below. The Khonburi Sugar Factory's bagasse ash was sieved using a standard No. 16 sieve to remove large particle contaminants caused by incomplete combustion before being subjected to an ASTM C230 test to determine its water content. With a flow control of 110±5%, bagasse ash concentration of 0, 10, 20, 30, 40, and 50 % cement displacement. The ASTM C109 standard was followed while measuring compressive strength.

2. Table 2 lists the top two ratios that had the maximum compressive strength after the mortar from the combination was tested at age 3, 7, 14, and 28 days. These ratios were chosen to be further molded into concrete masonry units.

It was found that the flow rates of both the conventional mortar and the bagasse ash-mixed mortar were between 105 % and 115 %. The amount of water needed for the bagasse ash mortar was discovered to be 75.70, 88.38, 85.29, 92.01, 95.15, and 103.91 % at 3, 7, 14, and 28 days respectively. These values were higher than those for the normal mortar by percentages of 16.75, 12.67, 21.55, 25.69, and 37.27, respectively.

Table 2 Flow test results according to ASTM C230 and compressive strength tests of mortar according to ASTM C109

Amount of SCBA (percent)	W/C	Percent Flow (%)	Compression strength test (ksc.)			
			3 days	7 days	14 days	28 days
0	0.75	110	71.94	167.86	193.76	337.53
10	0.88	110	62.79	146.52	165.26	270.25⁽¹⁾
20	0.85	110	38.44	89.7	130.15	238.94⁽²⁾
30	0.92	110	30.46	71.07	99.49	202.52
40	0.95	110	21.49	30.45	50.15	167.79
50	1.03	110	11.96	13.05	27.45	149.43

Note: (1) the first rank of compressive strength,
(2) the second rank of compressive strength

When the amount of bagasse ash increases, it has an impact on the pourability (Workability) and a tendency to require more water. According to the literature, the application of SCBA might alter the workability of concrete depending on factors including slump, water demand, and superplasticizer content. In general, replacing cement in concrete with SCBA will cause the concrete to slump less and require more water and superplasticizer (Chi, 2012)., Using the results of the mortar test, the Strength Activity Index was calculated in accordance with ASTM C 311-02 when pozzolanic materials were being used. The test findings matched Table 3's calculations of the strength index when pozzolanic materials were used.

Table 3 Strength Activity Index at day 28th in accordance with ASTM C 311-02.

Amount of SCBA (percent)	Strength Activity Index (percent)	Remark
0	100	Standard
10	80.07	1st rank
20	70.79	2nd rank

Vebe Test Results

According to the Vebe test findings, fresh mixes were made using the same components and mix ratios for the Vebe test. A digital stopwatch was used to measure the passing of the Vebe test after 15 minutes since the addition of water. The mean time found by testing was 493 seconds for 0% of SCBA replacement, 227 seconds for 10% of SCBA replacement, and 127 seconds for 20% of SCBA replacement. The amount of bagasse ash added contributed to the increased pourability by forming, since it was discovered that the amount of bagasse ash displaced to cement resulted in a shorter period.

Trial-Error Forming Test

The ability to create concrete masonry units from different mixtures of cement mortar and coarse aggregate was investigated. Based on the findings of an early molding test, the trial-error forming test was undertaken. When the proportion of coarse aggregate in concrete is low, a problem arises from the aggregate being too dry, which prevents it from forming because it absorbs too much water. However, if there is an excessive amount of coarse aggregate present, it may interfere with the concrete forms. Even after double the amount of coarse aggregate was used, there was still not enough mortar. As a result, it never forms. Reducing the amount of coarse aggregate will result in more mortar being required to keep the shape. The formability of concrete masonry units were was using a cement mortar to coarse aggregate ratio. The test findings showed that even with 10% bagasse ash in place of cement, the sample may not have formed perfectly, but it was still sufficient to form, if imperfectly. In a test on the formability of concrete masonry units, 600 samples were initially molded using different binder ratios; the best ratio, albeit with a reasonable amount of formability, was discovered to be 1:1.5. Figure 2 illustrates the crack that existed before the test, necessitating the casting of additional test specimens to provide enough cubes for the compressive strength test.


a) unformable b) formable

Figure 2 Forming effect of mortar to coarse aggregate.

Concrete masonry unit test results

Several factors, including SCBA properties, curing time, and replacement amount, have major impacts on the development of SCBA concrete's compressive strength (fineness, silicon and aluminum oxide content and loss on ignition) (Li *et al*., 2022). We tested the compressive strength of concrete masonry units following the initial molding test. It was discovered that some samples shrank when dried, causing cracks to form before compressive strength was evaluated. The preliminary results of the compressive strength test agreed with Table 4.

Table 4 Results of tests comparing the compressive strength of concrete masonry units at 7, 14, and 28 days.

Mortar* to coarse aggregate ratio	Amount of SCBA (percent)	Compressive strength of concrete masonry unit (ksc.)		
		7-day	14-day	28-day
1:1.5	0	38.30	53.79	66.90
1:1.5	10	31.29	48.07	62.86
1:1.5	20	32.53	36.57	37.12

Note: *Mortar (Cement:Sand) 1:2.75 from ASTM C109.

The test findings for compressive strength from Table 4 demonstrate that the non - load bearing block standard was met. The crucial requirements outlined above are based on American standards ASTM C90 and ASTM C129, and the relevant Thailand Industrial Standards are TIS 57-2533 and TIS 58-2533. Walls made of concrete masonry units are not load-bearing. By outlining two crucial concrete masonry unit requirements, namely that the average compressive strength of five blocks of concrete be at least 25 ksc. In accordance with ASTM standards, the tolerance cannot be greater than 2 mm. The average was not less than 42.22 ksc. when the parameters for compressive strength of concrete masonry units are specified. On the other hand, the walls formed of concrete masonry units do not exceed the requirements stated in the aforementioned standard because they have an average compressive strength of at least 140.72 ksc. Results of tests on mixtures that meet the concrete masonry unit standard, but not load-bearing walls, showed that the ash mixture was between 0 and 10% at 14 days of age. The first ratios discussed above ranged in average from 48.07 ksc. to 66.90 ksc, which were greater than the necessary standard. No mixtures met the required standards when they were 7 days old, and no mixtures met the required standards when the 20% cement substitute mixture was tested. From the standpoint of development, it is evident from Table 4 that swapping out bagasse ash preserves the pattern of growth of compressive strength. The problem, however, was with the slurry that was created by the flow of the mortar. For all mix ratios, the concrete cubes' compressive strength increased with curing age and decreased as SCBA content rose. At 28 days of age, the percentages of compressive strength that were reduced for cement replacements of 10% and 20% with SCBA as opposed to controls were 6.08% and 44.51%, respectively.

Concrete masonry units mixed with sugarcane bagasse ash was tested for their fresh characteristics by Subramaniyan and Sivaraja (2016) who reported that the workability of concrete depends on the SCBA concentration and increases with its presence., Patel and Raijiwala (2015) also carried out experimental work on SCBA concrete. All of the SCBA mixes under consideration exhibited high slump values, according to their results, with the exception of the concrete with 0% SCBA. For M20 grade concrete, Srinivasan & Sathiya (2010) evaluated the impact of SCBA as a cement substitute. In their study, cement weight was used in place of 5–25% SCBA. According to authors, concrete with 5% SCBA is the best alternative for M20 grade concrete, and concrete with 10% SCBA has a compressive strength that is higher than the recommended mix. Likewise, Kiran & Kishore (2017) prepared the concrete with up to 25% SCBA. The authors deduced from test findings that 5% is the ideal replacement, and that concrete containing 15% SCBA produced a compressive strength that was higher than that of the reference mix. In the study by Hussein *et al*. (2014), they carried out experimental work on bagasse ash concrete in which cement is substituted for 5–30% of the SCBA. Bagasse ash was sourced from a sugar mill and pulverized in a Los Angeles abrasion machine until more than 95% of the particles passed through a 45-mesh filter. The findings demonstrated that adding bagasse ash to concrete up to 20% enhanced its compressive strength significantly. The highest compressive strength, according to the authors, was attained with a SCBA replacement rate of 5%. Mangi *et al*. (2017) performed an experimental analysis on M15 concrete. When SCBA is used in place of cement in concrete at a rate of 5%, as was done in the compressive strength test, the average amount of compressive strength will rise by around 11.50% compared to concrete of normal strength. Additionally, the compressive strength of both grades of concrete (M20 and M15) containing SCBA was shown to be reduced at the early ages but considerably increases with longer curing times.

Conclusion and suggestions

This section is based on an overview of recent research that examined the impact of SCBA as a cement substitute on specific properties of concrete. Concrete containing SCBA is described along with its mechanical, fresh, and durability features, as well as its advantages for the environment. The conclusions are as follows.

1. Pozzolanic activity exists in SCBA, which can be used as supplementary cementitious materials in concrete. The raw SCBA frequently has a rough surface, a large particle size, and a high loss on ignition, making it inappropriate for use directly in concrete and necessitating correct treatment. Sieving, burning, grinding, and chemical treatment are frequent treatment techniques that can enhance SCBA's pozzolanic activity. Additionally, the effectiveness of the treatment might be increased more by combining different approaches.

2. According to SEM, the microstructure of processed SCBA particles and SCBA-containing concrete is consistent and compact. In general, SCBA can reduce concrete's porosity, however due to variations in the material's qualities and treatment approaches, porosity in some cases will rise. However, the addition of SCBA to concrete transforms the bigger pores into tiny ones and enhances pore distribution. The shape and pore structure

of SCBA concrete are thinner due to the dense hydration products and decreased wall effect.

3. The compressive strengths of concrete containing SCBA develop roughly as they would with no SCBA added after a 10% SCBA cement substitution. Numerous experiments have demonstrated how Portland cement replacements using 10% by weight of SCBA can produce concrete with exceptional mechanical properties and durability. Strength declines at early curing age because of the diluting effect and the delayed influence of high loss on ignition on the hydration process. However, strength rises as pozzolanic reactions become more intense with later cure ages. Concrete with a high silicon aluminum oxide content, concrete with a low level of SCBA loss on ignition, and pretreatment methods that produce tiny particles all enhance the mechanical properties of concrete containing SCBA.

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