Silica Gel from Sugarcane Bagasse Ash as Cement Replacement Material: Effect of Burning Temperature of Pre-Treated Sugarcane Bagasse Ash

by

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Dissertation submitted in partial fulfilment of
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CERTIFICATION OF APPROVAL

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Approved by,

_____

Ir Dr Mohamed Mubarak B. Abdul Wahab

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2022

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

_____

Nur Aqila Binti Mohd Hamka

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ABSTRACT

It is essential to create a sustainable substitute to cement which aligns with the increase in demand and utilization due to the growth of construction industry. Taking into consideration that sugarcane bagasse (SCB) contains a high amount of silica, it is known to have a high pozzolanic reactivity which suits as an alternative for cement. The effect of burning temperature on the quality and quantity of silica gel extracted from pre-treated and raw SCB as cement replacement material was investigated. Pre-treated and raw ash was subjected to controlled burning for an hour at 600°C, 700°C and 800°C. The ash produced was characterized by X-ray Fluorescence and Diffraction. Concrete casting was conducted using the silica gel obtained and compressive strength test will be executed on all concrete cube specimens. Field emission scanning electron microscopy test was also performed on the specimens to observe the precise information on the composition and structure. The quality of silica gel and compressive strength test was then compared. XRF analysis found the content of silica dioxide and silica in the Pre-Treated 600℃ sample to be 28.8% and 18.7% respectively. Whereas the compressive strength at an early curing stage of 7 days for Pre-Treated burning samples of 600°C, 700°C and 800°C were 6.28 MPa, 6.44 MPa and 6.25 MPa respectively.

CHAPTER 1

INTRODUCTION

1.1. Background of Study

Concrete plays the role as an important material that have been known to be used in most development of infrastructure. Subedi, Arce, Hassan, Kumar, Barbato and Gutierrrez-Wing (2019) mentioned that during the production of a ton of cement, 0.7 to 0.9 ton of carbon dioxide will be released to the atmosphere. They found that 5% of the carbon dioxide emitted globally are caused by the production of cement itself. Over the years, the demand towards the production of cement has increased tremendously due to the rising of infrastructure. To meet these demands without leaving any further negative environmental impact, a sustainable substitute to cement is introduced.

FIGURE 1.1. Sugarcane

Figure 1.1 shows a picture of sugarcane. Sugarcane Bagasse ash (SCBA) is known to be an environmentally friendly alternative for cement. SCBA originated from the by-product of the ethanol industry. It is considered to be an abundant waste since most of the material would be dumped in landfills. Subedi et al. (2019) mentioned that raw SCBA contain high silica and aluminium oxide content which results in SCBA being

a highly potential partial replacement for cement in concrete. Setiawan and Chiang (2020) mentioned that out of all crop residues that have been reviewed by them, sugarcane leaves carry the most potential silica source.

This project will focus on the effect of burning the Sugarcane Bagasse (SCB) in different temperatures. The emphasis towards burning temperature in this project is due to the lack of studies on the optimum temperature needed to achieve a certain amount of silica gel. By studying this, the effect or varying burning conditions towards the performance of the final product can be identified. Figure 1.2 shows the sugarcane production and area of cultivation in 20 main countries according to Basika, E. et al (2021).

Country	Production (Tons/Year)	Area (Hectares)
Brazil	768,678,382	10,226,205
India	348,448,000	4,950,000
China	123,059,739	1,675,215
Thailand	87,468,496	1,336,575
Pakistan	65,450,704	1,130,820
Mexico	56,446,821	781,054
Colombia	36,951,213	416,626
Australia	34,403,004	447,204
Guatemala	33,533,403	259,850
United States of America	29,926,210	370,530
Indonesia	27,158,830	472,693
Philippines	22,370,546	410,104
Argentina	21,990,823	331,699
Cuba	18,890,972	442,307
Vietnam	16,313,145	256,322
Egypt	15,760,418	137,011
South Africa	15,074,610	246,937
Myanmar	10,437,058	163,650
Peru	9,832,526	87,696
Ecuador	8,661,609	104,661

FIGURE 1.2. Sugarcane production and area of cultivation in 20 main countries

1.2. Problem Statement

Throughout the centuries, cement has had an increase in demand and utilization due to the growth of construction and infrastructure. Manufacturing cement has contributed towards greenhouse gases through the production of carbon dioxide. There has been a constant search to make the production of concrete more sustainable to decrease the negative environmental impact. By utilizing agricultural waste such as sugarcane bagasse ash, partial replacement of cement using silica gel from sugarcane bagasse ash can be produced.

In this study, I will investigate the effect of burning duration of pre-treated SCB in producing silica gel for application as cement replacement material. The temperature and burning duration are variables that will determine the silica gel quality and performance of the concrete end product. The material Sugarcane Bagasse will be pre-treated before proceeding towards the incineration process. Embong, Shafiq and Kusbiantoro (2016) found that soaking the sugarcane bagasse with high concentration of hydrochloric acid was found as crucial in order to increase the level of Silica dioxide (SiO_2) extraction. The aim of this project is to achieve the time and temperature needed to produce silica gel.

Throughout the study pre-treated SCBA was burned at different temperatures and time to monitor the performance of the concrete. Towards the end of the project, various silica gel quality depending on the burning temperature of SCB was be obtained.

1.3. Objectives

This project aims to investigate the effect of burning duration of Pre-Treated Sugarcane Bagasse for the application of using the silica gel from Sugarcane Bagasse Ash (SCBA) as Cement Replacement Material.

To accomplish the aim for this project, the objectives below are to be achieved:

1. To investigate the burning time and temperature of Pre-Treated Bagasse
2. To investigate the quality and quantity of silica gel needed as cement replacement material

1.4. Scope of Study

To accomplish the objectives, the scope of the project includes:

1. Identify the optimum burning temperature based on the XRF and XRD analysis.
2. Analysis on silica gel extraction method and testing.
3. Evaluation of data comparison of silica analysis and design mix testing.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1. Sugarcane Bagasse Ash (SCBA) origin

Sugar cane bagasse ash (SCBA) is a product that can be found in a large quantity due to the abundant by-product of the sugar and ethanol industry. The research that has been done towards the SCBA has been directed towards the usage on construction materials as it contains pozzolanic characteristics (Xu et al., 2018). The figure below shows a flowchart of the process of SCBA in a sugar mill by Xu et al. (2018)

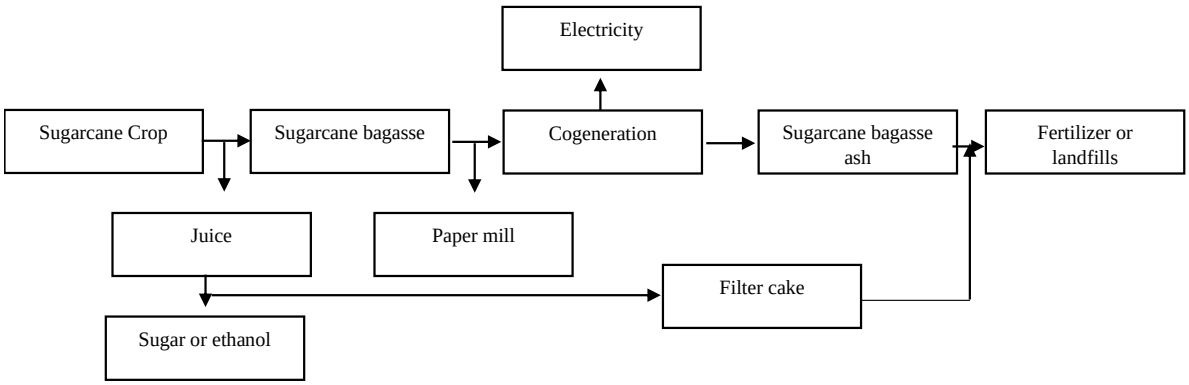


FIGURE 2.1. Flowchart of the process of SCBA in a sugar mill

According to Xu et al. (2018) the final product of the sugarcane crop, which is the SCBA would generally be utilized as fertilizers or dumped in landfills as shown from the flowchart above. They found that by using SCBA as fertilizers, it would leave a negative impact towards the environment is because it does not contain enough nutrient value as well as contains heavy metals that will later pollute the soil and groundwater.

Towards seeking other beneficial usage for SCBA, research have found that SCBA could be included in the production of several cementitious materials such as, glass-ceramic, geopolymers, raw material for ceramic, phillipsite zeolite synthesis and many more. According to Xu et al. (2018), SCBA are being studied as a pozzolanic material

(material consisting of siliceous or a combination of siliceous and aluminous material in a finely divided form that in the presence of moisture will react with calcium hydroxide, at ordinary temperatures, to form compounds possessing cement properties).

2.2. SCBA replacement in Concrete Mix

Regarding the increasing demand and utilization of cement, there has been a search for producing a suitable substitute of binding materials that are sustainable and ecologically friendly. Cement is an important component of concrete, being the second to most used material. In the production of cement, it is important to take note that carbon dioxide will be emitted to the atmosphere which is the leading cause of global warming. By utilizing the agricultural and industrial waste, negative environmental impact can be reduced. The table below shows the compressive, split tensile and flexural strength for SCBA (%) ranging from 0% to 25% by Bhargavi et al. (2018).

TABLE 2.1. Compressive, split tensile and flexural strength for SCBA (%) ranging from 0% to 25%

Percentage of SCBA (%)	Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)		Flexural strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
0	25.29	39.47	1.09	1.31	2.5	3.92
5	29.07	45.54	1.12	1.37	2.85	4.38
10	24.12	42.96	1.01	1.34	2.4	4.12
15	22.96	39.69	0.992	1.32	2.3	4.00
20	15.26	30.05	0.718	1.05	1.78	2.86
25	9.82	18.69	0.614	0.86	1.19	2.00

Bhargavi et al. (2018) studied a comparison for replacing cement material with 0% to 25% with SCBA by applying several tests such as compressive strength test, flexural strength test and split tensile strength for 7 days and 28 days. The table above shows the optimum percentage of SCBA and curing day that would result in a high performing concrete sample. Their findings revealed that at 28 days curing the compressive strength, split tensile strength and Flexural strength at 5% was at its peak 45.54 N/mm^2, 1.37 N/mm^2 and 4.38 N/mm^2. It can be concluded that SCBA can be utilized for partial replacement of cement up to 5% by weight of cement without any major loss in strength. The figure below shows the compressive strength versus curing time for all mortars by Corderiro et al. (2019).

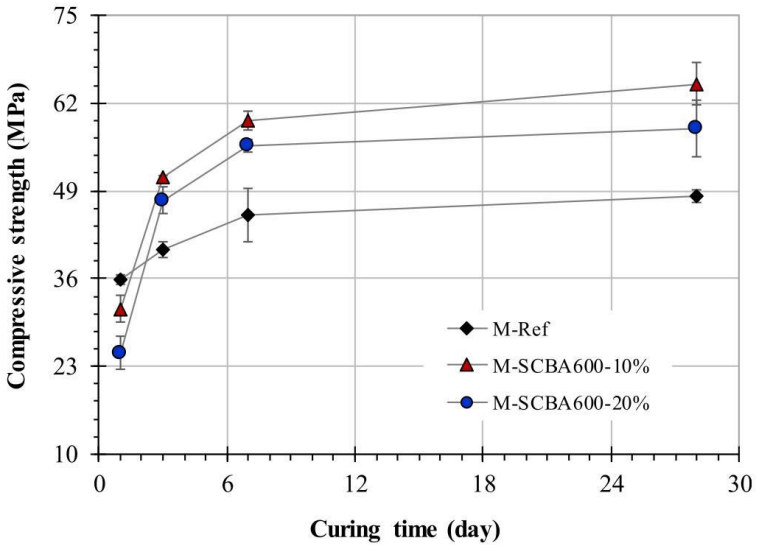


FIGURE 2.2 Compressive strength versus curing time for all mortars

Corderiro et al. (2019) studied a comparison for replacing 10% and 20% of cement with 600°C SCBA. The figure concludes that the compressive strength of SCBA at 10% cement replacement was showed to be the highest as compared to the controlled sample and 20% cement replacement at 28 days curing time. Their findings show that for 1 day curing time the SCBA concrete mix shows lower compressive strength than that of the controlled sample.

The figures below show the compressive strength of M20, M30 and M40 concrete with various percentage of silica gel as cement replacement by Kawade U. et al (2020).

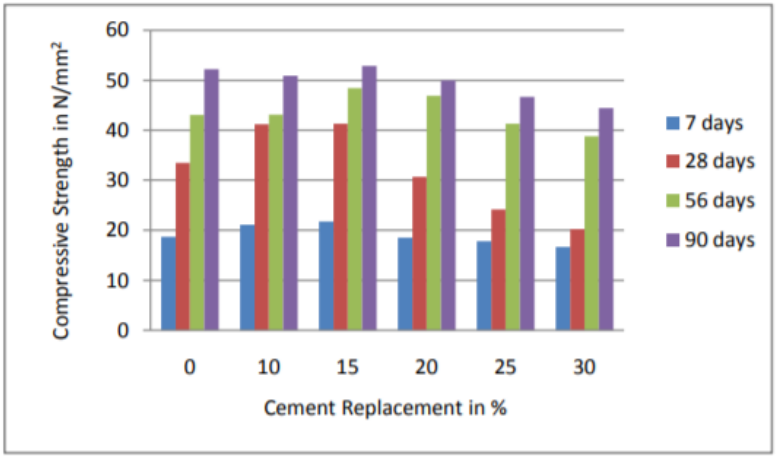


FIGURE 2.3 Compressive strength of M20 Grade concrete

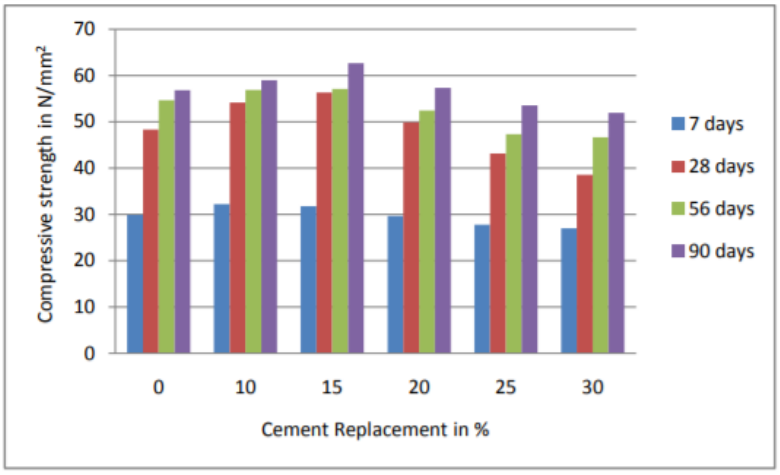


FIGURE 2.4 Compressive strength of M30 Grade concrete

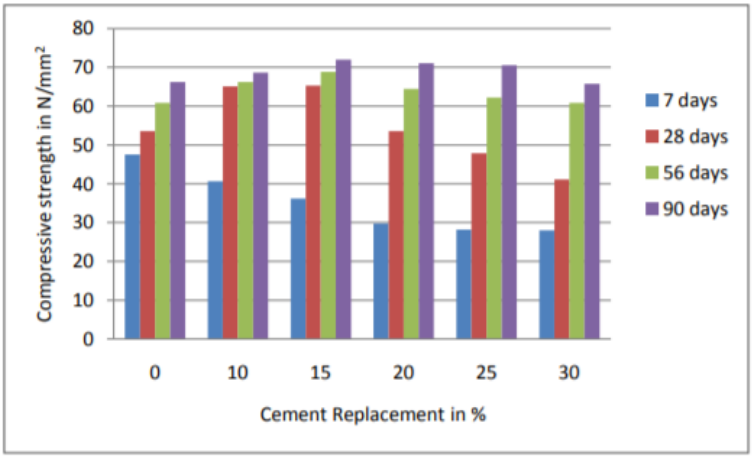


FIGURE 2.5 Compressive strength of M40 Grade concrete

Kawade et al. (2013) studied SCBA that has been chemically and physically characterized and partially replaced in the ratio of 0%, 10%, 15%, 20%, 25% and 30% by the weight of cement in concrete. The properties for fresh concrete are tested like slump cone test and for hardened concrete compressive strength at the age of 7,28,56 and 90 days. The test result indicates that the strength of concrete increase up to 15% SCBA replacement with cement.

They found that SCBA containing concrete had substantially higher compressive strength compared to the concrete without SCBA. The result shows that the cement could be strategically replaced with SCBA to a maximum limit of 15%. Although, the ideal level of SCBA content was achieved with 15 % replacement. Partial replacement of cement by SCBA increases workability of fresh concrete.

2.3. Pre-treatment and Burning of SCB

Worathanakul et al., (2009) concluded that by using high concentration of acid such as hydrochloric acid (HCL) at 1.0 M to 6.0 M, ideal concentration to remove alkali and alkaline metals such as Potassium (K^+), Magnesium (Mg^{2+}), and Calcium (Ca^{2+}) from SCB. They mentioned that by doing so, the extraction of SiO_2 improved almost 80% from SCBA.

According to Sahiron et al., (2016), using HCL will result in removing metallic ions and impurities. Besides that, pre-treatment using HCL will increase the level of Silica dioxide (SiO_2) extraction during hydrothermal process.

Embong et al., (2016) mentioned that the extraction of SiO_2 has enhanced when pre-treatment was done with 0.1 M HCL. They also found that a controlled burning of SCB at 800℃ for 1 hour has increased pozzolanic activity due to the avoidance of turning amorphous ash into crystalline phase. Thus, enforcing the methodology of the study to emphasis on burning the SCB at 600℃, 700℃, and 800℃.

2.4. Silica Extraction

Megawati et al., (2018) reported that silica content was at its peak (54% w/w) after heating on hot plate and washing with HCI solution. They mentioned that the silica production increased with NaOH concentration of 0.5 mol/L to 2 mol/L. Silica extraction was done with 1 mol/L NaOH, ratio of SCBA:NaOH = 1:10 w/v, volume = 100 mL; precipitated with 1 mol/L HCl solution). Comparison was made between the concentration of several compositions (such as Silica) for before and after washing SCBA with HCI solution. It was found that washing SCBA with HCI solution increases Silica content by around 25%.

2.5. X-ray Diffraction

The figure below shows the X-ray diffraction patterns of SCBA and SCBA 600 by Cordeiro et al. (2019).

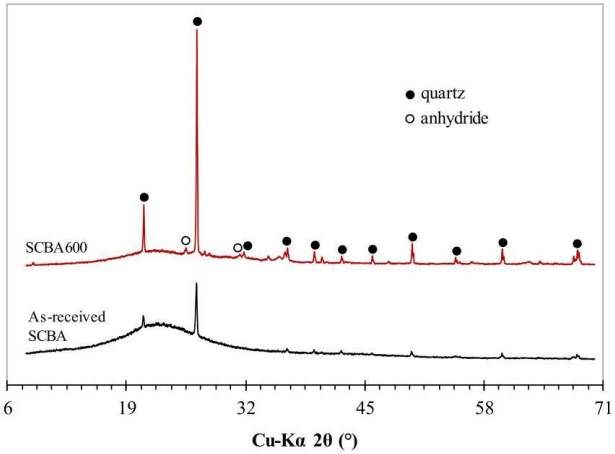


FIGURE 2.6. X-ray diffraction patterns of SCBA and SCBA 600

Cordeiro et al., (2019) found that the quartz was the main crystalline phase in SCBA burned at 600℃. They reported the presence of high silica content after burning two kilns, low loss on ignition. Silica content was found to be 63.3%.

2.6. X-Ray Fluorescence

The table below shows the chemical composition of bagasse ash for 500℃, 600℃ and 800℃ by Usman et al. (2014).

TABLE 2.2 Chemical composition of bagasse ash

T (℃)	Chemical composition (%)								
	SiO_2	Na_2O	CaO	K_2O	Al_2O_3	SO_3	MgO	Fe_2O_3	Others
500	76.168	0.379	2.521	3.498	11.079	0.701	1.455	3.700	Balance
600	76.292	0.395	1.963	3.660	11.410	0.534	1.507	3.739	Balance
700	77.286	0.381	2.088	3.159	10.951	0.487	1.489	3.660	Balance

Usman et al., (2014) found that the silica content for 500℃, 600℃ and 800℃ SCBA are 76.168%, 76.292% and 77.286% respectively.

The table below shows the chemical compositions of sugarcane bagasse ash from various publications.

TABLE 2.3 Elemental composition (%) of sugarcane bagasse ash from various authors

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	K_2O	Authors
62.1	5.42	5.54	1.0	1.12	-	2.22	(Basika, et al. 2015)
84.0	1.7	1.1	0.5	0.6	-	0.5	(Aboyade et al. 2011)
72.8	5.5	6.4	3.8	2.3	-	2.7	(Torres Agredo et al. 2014)
96.2	1.7	0.2	0.1	0.1	0.1	0.3	(Sales and Lima 2010)
31.41	6.02	7.57	16.06	1.07	0.78	1.58	(Castaldelli et al. 2013)
67.82	2.56	6.33	1.54	2.03	-	2.87	(Hariharan et al. 2014)
87.59	0.67	0.57	2.59	1.65	0.003	3.64	(Modani and Vyawahare 2013)
62.43	6.98	4.28	11.8	2.51	1.48	3.53	(Kawade, Rathi, and Girge 2013)
66.89	29.18	29.18	1.92	0.83	0.56	NA	(Hussein et al. 2014)
41.15	2.7	7.00	3.20	0.12	0.03	8.75	(Otoko 2014)
77.25	4.21	6.37	4.05	2.61	0.11	2.34	(Hussein et al. 2014)
72.85	6.96	1.08	9.97	6.49	NA	6.71	(Abdulkadir, Oyejobi, and Lawal 2014)
44.7	2.90	2.40	14.9	3.50	NA	4.40	(Abbasi and Zargar 2013)

The SCBA Silica dioxide content from several publication varies from 30% to 96%. It is important to note that this might be due to the different methodologies applied before or after the incineration process.

2.7. Summary of Literature Review

The studies performed in this field of agricultural waste consisted of high percentage of treated silica gel as cement replacement (10%, 15% and 20%). This created a research gap on the findings of low percentage untreated silica gel as cement replacement. Moreover, the application of lowering the content of silica gel would be efficient and optimised as the time taken to produce the sample would be lessened. The optimum temperature of burning was found to be 600℃. Whereas the most preferred pre-treatment and silica extraction method was by applying 0.1M of HCI solution on the bagasse and acid leaching respectively.

The quality of the ash produced can be determined by XRF analysis to study the content of Silica dioxide present. Previous study shows the amount of silica dioxide in SCBA can range from 30% to 96% depending on the methodologies applied before and after the burning process.

As a conclusion, the research gap for this area of study lacks untreated silica gel from SCBA as cement replacement material. Comparison between untreated and treated silica gel samples are crucial to identify the effect of pre-treatment on SCBA samples. To determine the quality and quantity of silica gel needed as cement replacement material, various amount of silica gel was added into cement mix. The concrete samples then undergone compressive strength test.

CHAPTER 3
METHODOLOGY

3.1. Pre-Treatment of Sugarcane Bagasse

After obtaining the raw sugarcane bagasse, it is crucial to wash the bagasse using a washer to remove any unwanted materials from it. The bagasse then needs to be rinse and dried before being able to burn using a furnace. The parameters that will be varied will consist of the temperature of burning ranging from 600℃, 700℃, and 800℃. Although, the constant variable will be the time of burning which is 1 hour.

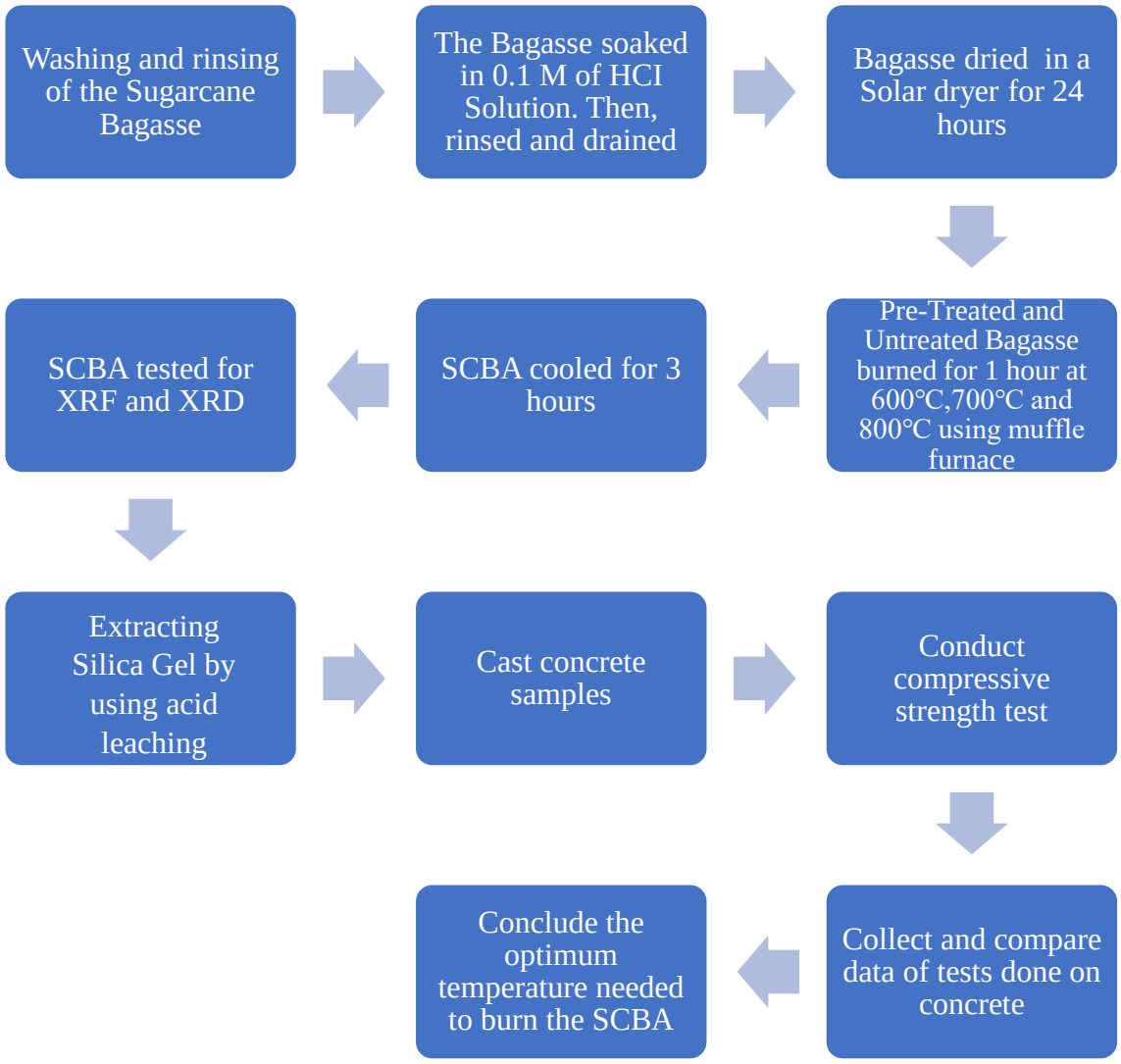


FIGURE 3.1. Flowchart of the methodology

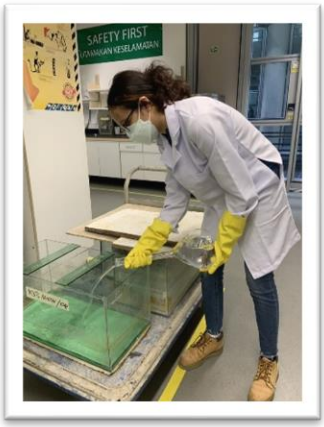


FIGURE 3.2. Filling 0.1 M of HCI in aquarium tank

The pre-treatment that will be done is by soaking the Sugarcane bagasse with 0.1 M concentration of hydrochloric acid solution in a glass aquarium for a duration of 1 hour. The preparation of 0.1M solution of HCI was using a 37% HCL stock bottle.

FIGURE 3.3. SCB in 0.1 M HCI solution

TABLE 3.1 Calculation of 0.1M HCI Solution

Preparation of 0.1M solution of HCI		
Stock bottle of 37% HCL. Determination of molarity of 37% HCL V/V 37 ml of solute/100 ml of solution.		
HCL	=	37% v/v.
Specific gravity: 1.19 g/ml 37ml/100 ml or 370 ml/1000 ml x 1.19 g/ml	=	440.3 g/L
HCL Molecular weight = 36.5	=	36.5
Molarity: 440.3 grams /36.5 grams	=	12.06 M
Compounding 1 litre of 0.1M Solution		
M1V1	=	M2V2
(0.1) (1000)	=	(12) (x)
x	=	8.3 ml
Therefore **8.3 ml** was added of 37% HCL to 1 litre of D5W or NS to create a 0.1M HCL solution.		

FIGURE 3.4. Pre-Treated SCB in drying chamber

3.2. Post Incineration of SCB

3.2.1. Silica Extraction

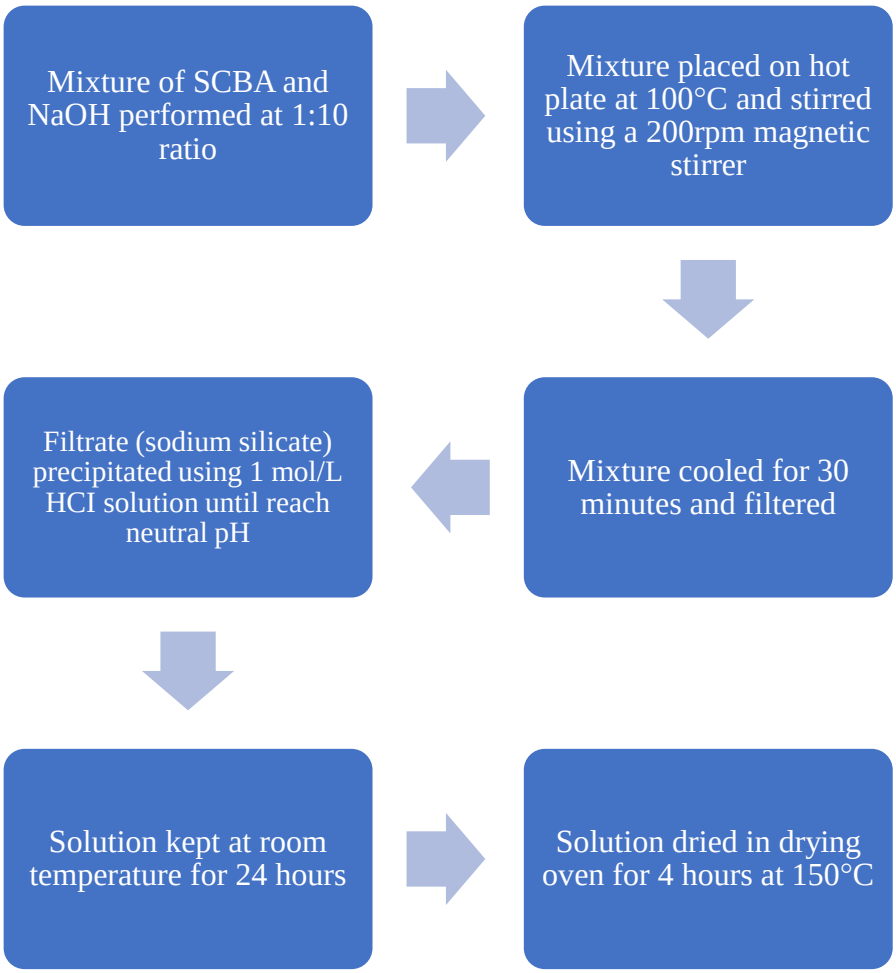


FIGURE 3.5. Silica Extraction process

3.2.2. Concrete casting

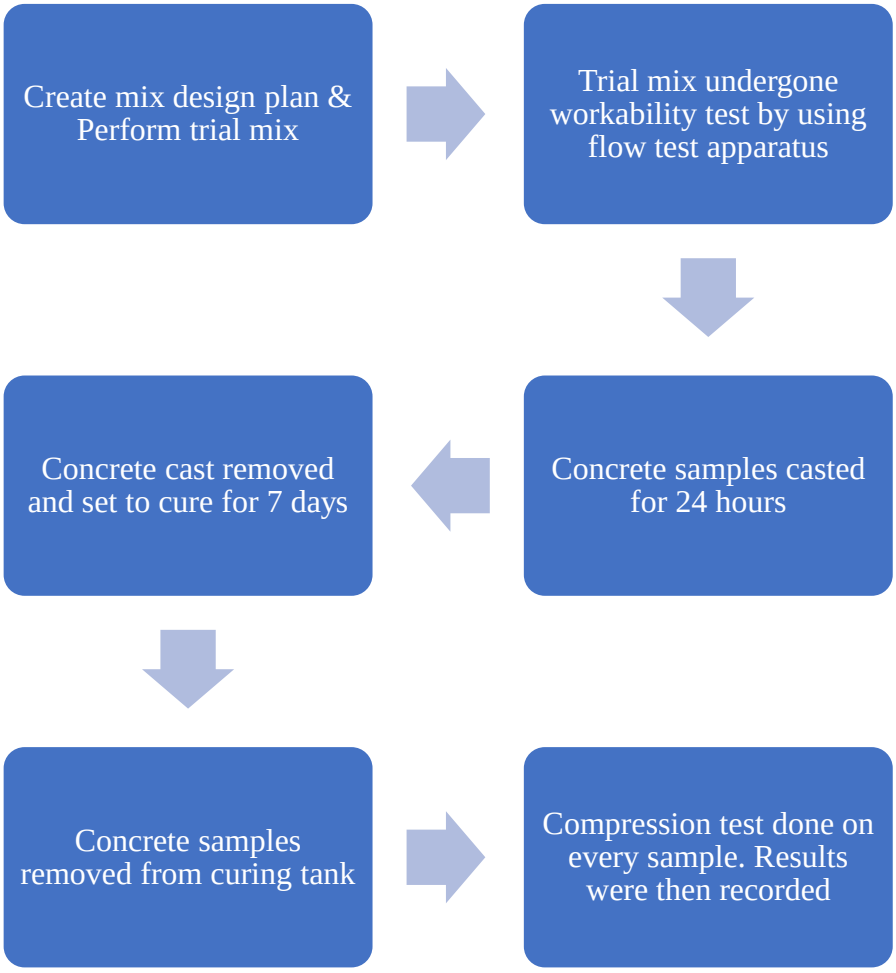


FIGURE 3.6. Concrete casting process

Concrete mix that will be used is determined by its workability using flow test. The cement to water ratio will define the amount of silica gel mixed in every concrete sample. 5% of cement will be replaced with silica gel throughout the casting process. In relation to that, controlled samples will also be casted to identify the difference in compressive strength test.

The method of testing that will be done to the final concrete product is the compressive strength test. The purpose of conducting a compressive test is mainly to evaluate the behaviour of concrete while it experiences a certain amount of compressive load. This is to assess the quality of concrete that will be used in the intended lifespan.

Compression test will be done using a compression testing machine. For every varying temperature, 3 concrete cubes will be casted. To determine the compressive strength for the concrete, the average compressive strength will be calculated for every varying temperature.

The compressive strength for every cube will be calculated using the formula 3.1:

$$Equation\ 3.1: Compressive\ Strength\ of\ Concrete = \frac{Maximum\ load\ applied\ on\ sample}{Surface\ area\ of\ the\ top\ of\ sample}$$

Equipment

The figure 3.7 and 3.8 below shows two equipment that will be used heavily throughout this study. Both equipment was found to be available in the civil engineering department block and Institute of Self Sustainable building (ISB).

FIGURE 3.7. Compression testing machine

FIGURE 3.8. Muffle furnace

3.3. Methods

Sugarcane Bagasse Ash (SCBA) Characterization

1) **Scanning electron microscopy (SEM)**

Physical characterization using microstructural characterization using scanning electron microscopy (SEM). This test will produce the findings of the surface topography, image identification and composition of the SCBA. Jagadesh et al. (2016) found that the result of SEM on SCBA shows that they are naturally porous and have irregular shape typical for morphology of fibres. SCBA has been proven to retain air bubbles indicating that they are in molten state. Jagadesh et al. suggests that combustion temperature reached in burning process will not produce the melting of volatile matter.

2) X-Ray Diffraction Spectroscopy (XRD)

X-Ray Diffraction Spectroscopy is a non-destructive test method used to analyse the structure of crystalline materials. Jagadesh et al. (2016) discovered that SCBA essentially consists of amorphous silica. Besides that, the burning of SCBA above 600℃ will cause an increase in the specific surface area and the burning of SCBA above 900℃ will convert it to crystalline.

3. X- Ray Fluorescence (XRF)

X-Ray Fluorescence is used to analyse inorganic elements of a material by the emission of fluorescent X-rays with high energy gamma rays. The chemical composition of the sample will then be observed and compared between the variations of burning temperature.

CHAPTER 4

RESULTS AND DISUCSSION

4.1. Sugarcane Bagasse Ash

TABLE 4.1. SCBA obtained after burning

Burning Temperature	Non-Pre-Treated	Pre-Treated
600°C		
700°C		
800°C		

TABLE 4.2. Mass of SCBA obtained

Burning Temperature (°C)	600	700	800
Pre-Treated (g)	15	10	12
Non-Pre-Treated (g)	11	9	7

4.2. X-ray Diffraction Analysis

X-ray Diffraction test was conducted on pre-treated ashes. The purpose of this test is to examine crystalline material structure. The figure below shows the outcome for 600°C, 700°C and 800°C burning temperature pre-treated samples.

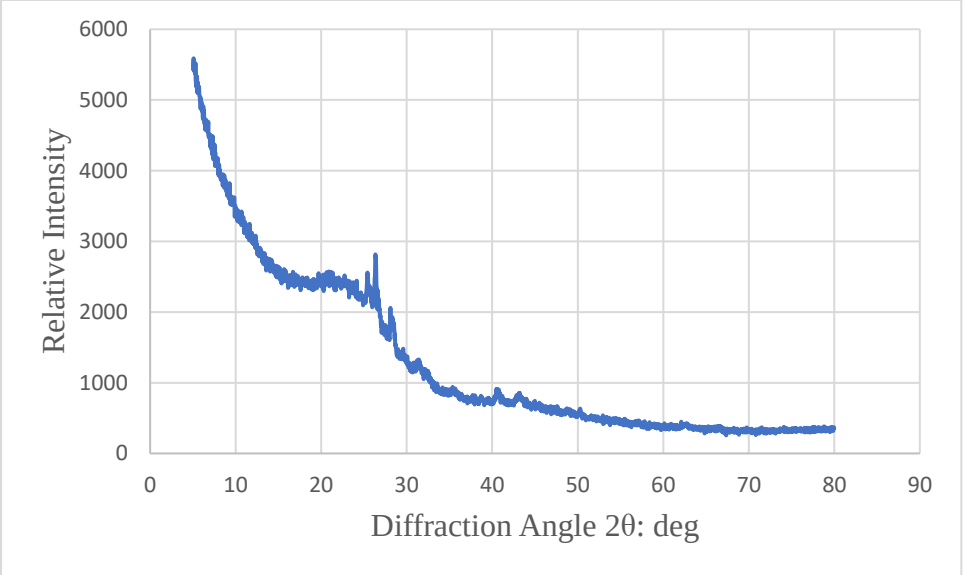


FIGURE 4.1. X-ray diffraction analysis of SCBA at 600°C burning temperature

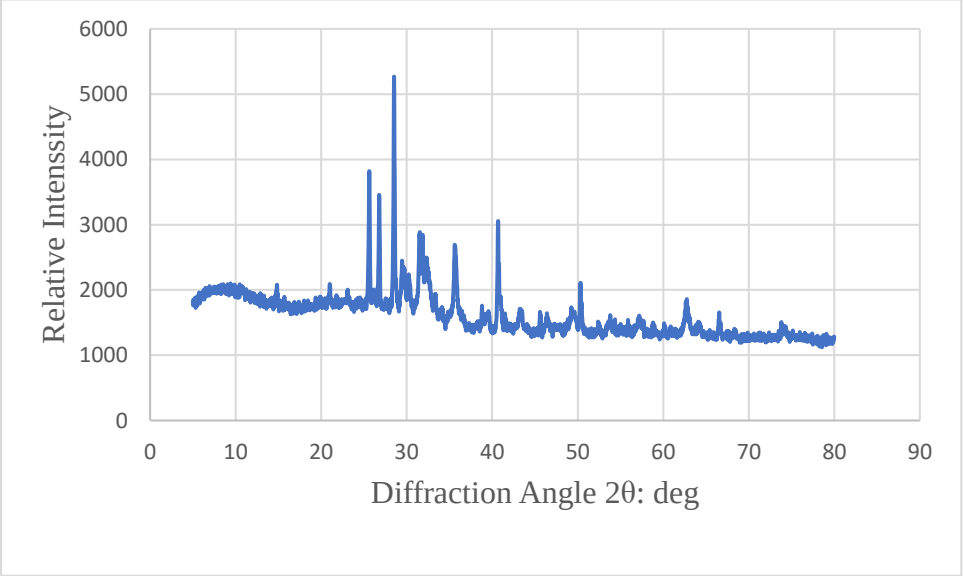


FIGURE 4.2. X-ray diffraction analysis of SCBA at 700°C burning temperature

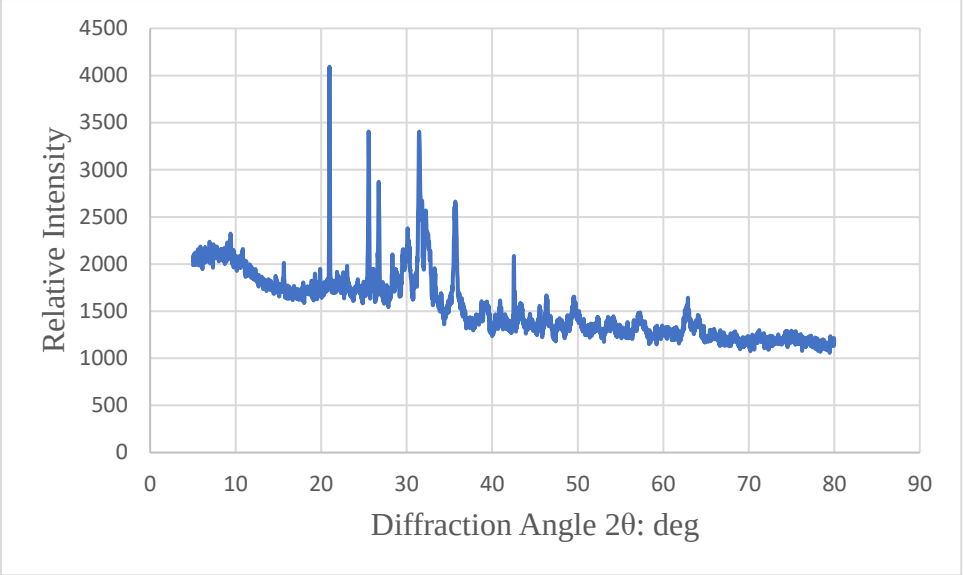


FIGURE 4.3. X-ray diffraction analysis of SCBA at 800°C burning temperature

4.3. XRF Analysis

TABLE 4.3 Chemical oxide composition of 600°C SCBA

Chemical oxide composition (%)									
SiO_2	P_2O_5	CaO	K_2O	Al_2O_3	SO_3	MgO	Fe_2O_3	Cl	Cr_2O_3
28.8	4.59	20.5	10.7	2.95	8.41	3.48	9.79	6.05	1.54

TABLE 4.4 Chemical element composition of 600°C SCBA

Chemical element composition (%)										
Mg	Al	Si	P	S	Cl	K	Ca	Cr	Fe	Zn
2.74	2.10	18.7	2.97	5.09	9.43	14.5	25.4	1.97	13.2	1.52

4.4. Silica Extraction

TABLE 3.5. Silica powder obtained after gelation process

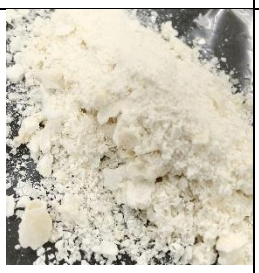
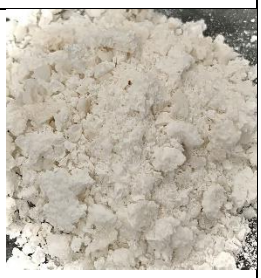
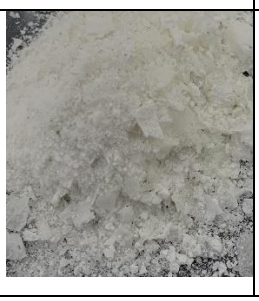
Burning Temperature	Non-Pre-Treated	Pre-Treated
600°C		
700°C		
800°C		

TABLE 4.6. Mass of silica powder obtained

Burning Temperature (°C)	600	700	800
Pre-Treated (g)	4.50	2.35	5.17
Non-Pre-Treated (g)	4.21	3.35	1.97

4.5. Concrete mix design

Trial concrete mix was conducted several times to ensure the workability of the mix passes above plastic limit during flow test.

TABLE 4.7. Cement trial mix

Concrete Mix	A	B	C	D
Cement (g)	87.5	87.5	87.5	87.5
Sand (g)	371	371	371	371
Water (g)	70	73.5	77	84

FIGURE 4.4. Flow test apparatus

After the flow table has raised and dropped 15 times, measurement of the concrete spread diameter was recorded in 3 different positions. The flow (%) was calculated using the equation below:

$$Equation\ 4.1: Flow\ (\%) = \frac{(Spread\ diameter\ in\ mm - 100)}{100}\ x\ 100$$

TABLE 4.8. Flow test results

Concrete Mix	A	B	C	D
Diameter (1)	133.61	144.45	154.91	165.22
Diameter (2)	133.85	144.79	157.53	163.84
Diameter (3)	125.66	144.94	152.7	167.82
Flow (%)	31.02	44.73	55.05	65.63

TABLE 4.9. Flow Test Standard

Flow (%)	0-20	20-60	60-100	100-120	120-150
Consistency	Dry	Stiff	Plastic	Wet	Sloppy

Concrete Mix D was chosen as the final mix due to the flow test exceeding 60%.

TABLE 4.10. Summary of Mixture Proportion

Mix Code	Cement (g)	Sand (g)	Water (g)	Untreated Silica Gel	Pre-Treated Silica Gel
Controlled Sample (CS)	87.5	371	84	0	0
PT 6	83.2	371	84	0	2.19
PT 7	83.2	371	84	0	2.19
PT 8	83.2	371	84	0	2.19
NPT 6	83.2	371	84	2.19	0
NPT 7	83.2	371	84	2.19	0
NPT 8	83.2	371	84	2.19	0

5 % of silica gel was added into the the concrete samples which was 2.19 g.

FIGURE 4.5. Pre-treated concrete sample (Left to Right: 600°C, 700°C and 800°C)

FIGURE 4.6. Untreated concrete sample (Left to Right: 600°C, 700°C and 800°C)

TABLE 4.11. Compressive strength test results

Burning Temperature (°C)	Untreated (MPa)	Pre-Treated (MPa)	Percentage increase (%)
600	4.82	6.28	30.29
700	5.96	6.44	8.05
800	5.88	6.25	6.29

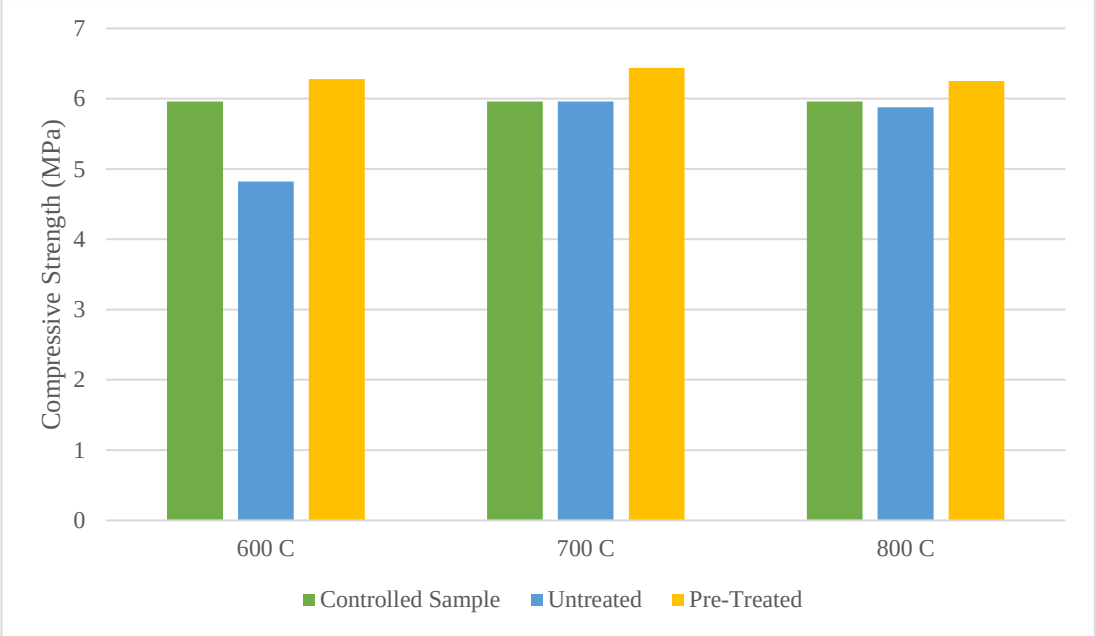


FIGURE 4.7. Compressive Strength Test of Samples

TABLE 4.12. Comparison of Controlled and Pre-Treated samples

Burning Temperature (°C)	Controlled Sample (MPa)	Pre-Treated (MPa)	Percentage increase (%)
600	5.96	6.28	5.36
700	5.96	6.44	8.05
800	5.96	6.25	4.87

4.6. Discussion

It can be observed from table 4.1 that there is a significant difference between the appearance of the ashes. At the lowest burning temperature (600°C), it can be noted that the ash was black in colour unlike 700°C and 800°C where the colour was light to dark brown. This could be due to the ash still containing unburned carbon.

As for XRD analysis figure 4.1 shows the peak of the graph is at 2θ=5' and 2θ=27'which suggests the presence of amorphous silica at a burning temperature of 600°C. Although in comparison of the value reported by Embong et al. which found that SCB burned at 600°C for an hour resulted in a sharp peak at 2θ=23'.

Whereas referring to figure 4.2 for 700°C burning temperature, the peak of the graph can be seen at 2θ=27', 2θ=28',2θ=29' and 2θ=41'. This indicates the transition of ash into crystallinity phase. Lastly, figure 4.3 shows the results of 800°C burning temperature. The peak was recorded at 2θ=21', 2θ=25',2θ=21' and 2θ=35'.

XRF Analysis was done on the 600°C pre-treated sample. This is due to the findings of the literature review that found 600°C burning temperature being the optimal temperature to burn SCB as it contains the most silica content. The content of silica dioxide and silica in this study was observed as 28.8% and 18.7% respectively. The content of Silica dioxide found in this study is similar to other types of agricultural waste such as Palm Oil Fuel Ash (POFA). According to Kamaruddin et al. (2018) the content of silica dioxide in POFA was found to be 31.1%.

According to Tangchirapat et al. (2007) the Silicon dioxide found in POFA was 20.90%. It can be seen from figure 4.1 that presence of amorphous silica can be detected during XRD analysis. It can be observed that the content of 600°C incinerated SCB shows similar silica dioxide content to other agricultural waste such as POFA.

The silica powder was obtained from oven drying the gel for 4 hours. It can be observed from table 4.5 that all non-pre-treated silica and pre-treated 600°C was white in colour. Whereas the pre-treated 700°C and 800°C silica had a yellowish colour.

The compressive strength of concrete was tested at an early curing phase of 7 days. As shown in figure 4.7, there is not significant difference between the compressive strength of Pre-Treated and Controlled sample. The compressive strength of controlled sample recorded was 5.96 MPa.

Although the Pre-Treated samples for 600°C did show a slightly higher compressive strength at a 30.29% increase in difference between untreated and treated samples. Whereas for 700°C and 800°C, the percentage increase was low at 8.05% and 6.29% respectively.

Referring to table 4.12, the percentage increase between controlled and pre-treated samples of 600°C, 700°C and 800°C burning temperature were 5.36%, 8.05 % and 4.87% respectively. The highest difference in percentage increase is between 700°C and 800°C, where 700°C burned sample is 3.18% higher than 800°C burned sample.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study investigated the burning time and temperature of Pre-Treated Bagasse and the quality and quantity if silica gel needed as cement replacement material. XRD analysis confirmed the presence of amorphous silica in the samples. Whereas XRF analysis further verified the content of silica dioxide and silica in the Pre-Treated 600℃ sample at 28.8% and 18.7% respectively. Based on the results obtained, the compressive strength at an early curing stage of 7 days for Pre-Treated burning samples of 600°C, 700°C and 800°C are 6.28 MPa, 6.44 MPa and 6.25 MPa respectively. This indicates that a 5% silica gel replacement shows a slight difference in compressive strength between varying samples. The quality and quantity of silica gel was also obtained from the XRD and XRF analysis of various burning temperature samples.

5.2. Recommendation

5.2.1. University Recommendation

Throughout this study there has been several limitations due to the limited number of equipment available. This resulted on the unexpected delay of the burning process. It would be recommended that the university provide an incinerator for a more efficient incineration process. Besides that, due to insufficient FYP funding many laboratory analysis could not be performed. This resulted in not being able to draw a more comprehensive conclusion towards the study. It is recommended for the university to increase the FYP funding to further strengthen the findings of the study.

5.2.2. Study Recommendation

There are several recommendations towards this study that could be suggested. Firstly, to increase the scope of study towards increase the varying percentage of silica gel as cement replacement. Besides that, a more comprehensive conclusion can be made on the performance of concrete if the curing days of concrete are further added (14,21,28 days). It is also recommended for XRF testing to be done on all varying samples so that detailed comparison can be made on the content of silica dioxide present. Lastly, the usage of incinerator should be implemented as the muffle furnace that was used throughout this study could only be opened after reaching normal temperature for safety reasons. This would affect the quality of SCBA remaining in the furnace as the burning time exceeds 1 hour.

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