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ANALYSIS OF CHEMICAL COMPOSITION OF SUGARCANE BAGASSE ASH WITH VARIATION OF FINAL CALCINATION TEMPERATURE

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Abstract

Cement production contributes in increasing CO2 emissions. Industrial and agricultural waste can cause serious problems for the environment. One of the wastes that can be utilized as supplementary cement materials from agricultural waste is sugarcane. This research was conducted as a form of implementation of Concrete Technology Course in Building Engineering Education Study Program to determine the content of chemical composition contained in the sugarcane bagasse ash which is suspected to have similarities with cement. The calcination temperature has a significant impact on the silica content in sugarcane bagasse ash, thus it's important to establish the ideal temperature that can also produce the best silica. This research used an experimental method, with the type of pre-experimental research which has a one-shot study case type research scheme. The results of this research indicated that sugarcane bagasse ash with a final calcination temperature of 600°C had the highest silica content compared to sugarcane bagasse ash with final calcination temperature of 500°C and 700°C. The analysis results indicate that with a relatively high percentage of silica, sugarcane bagasse ash with calcination temperature of 600°C can be used as supplementary cement materials.

Keywords: Sugarcane Bagasse Ash, Cement, SEM-EDS

Introduction

Infrastructure development also aids in the growth of the national economy. According to data on infrastructure from the Ministry of Public Works and Public Housing for 2022, the construction industry has contributed an average of 10.53% to the national economy during the last ten years. Contributions made to the construction industry are in the form of general construction, and building and civil construction. The production for materials, including cement, can be increased due to the construction activity. According to statistics from the Indonesian Cement Association's Directorate General for Construction Development for 2023, the average annual production of cement from 2018 to 2022 totaled 110.4 tons, and it climbed by 3 tons in 2022. The environment has been impacted severely as a result of the rise in cement production (Miller et al., 2018; Moumin et al., 2020).

Cement production is on of the environmental issues because its production consumes a large amount of energy and emits a lot of CO_2 (Bahurudeen & Santhanam, 2015; Mangi et al., 2017; Minnu et al., 2021). At least 7 – 8% of the world's CO_2 emissions are caused by cement production (Andrew, 2019). The decarboxylation process contributes 50% to CO_2 emissions in the cement production process, followed by the clinker furnace combustion process (40%, raw material transportation (5%), and electricity use (5%) (Berenguer et al., 2020). The predicted amount of CO_2 emissions from global cement production in 2050 is roughly 2.34 billion, assuming no subsequent declines in cement production (Berenguer et al., 2020). As the public's awareness of CO_2 emissions from cement production has grown, numerous research has been conducted on various topics, such as figuring out the composition of concrete for certain uses, using alternative raw materials, and utilizing supplementary materials (Miller et al., 2018). The use of supplementary cement material (SCM) is one of the efforts made to produce harder concrete and also cement with lower CO_2 emissions (Panesar & Zhang, 2020). By utilizing industrial or agricultural waste as SCM, waste and harmful effects from this waste can be reduced (Bahurudeen & Santhanam, 2015; Minnu et al., 2021).

Pozzolans are materials with high reactive silica and alumina content that typically have little to no binding property but have a propensity to react with water and $Ca(OH)_2$ to create cementitious compounds and harden like cement (Suliman & Almola, 2011; Yadav et al., 2020). Due to the abundance and ease of processing, industrial and agricultural wastes with high contents of silica and alumina are frequently employed as supplementary (Deepika et al., 2017; Yadav et al., 2020). Sugarcane bagasse ash (SCBA) is one kind of agricultural waste that can be utilized to make SCM.

One of the agricultural products from tropical nations, including Indonesia, is sugarcane. According to Directorate General of Estates in Statitical of National Leading Estate Corps Commodity 2020 - 2022, the average sugarcane production in Indonesia from 2016 – 2022 is 2.6 million tons. The large amount of sugarcane produced will also cause an enormous amount of waste. Sugarcane bagasse or known as bagasse is the remaining fiber from sugarcane stalks that have been crushed to extract the juice (Jahanzaib Khalil et al., 2021; Suliman & Almola, 2011). At least 26% bagasse with be produced from every ton of sugarcane produced (Mangi et al., 2017), meaning that the average bagasse produced in 2016 – 2021 is 676.000 bagasse. This bagasse is generally left in the disposal area or burned to make more space (Soares et al., 2014; Xu et al., 2018). The bagasse left alone in the disposal area can cause problems to the environment in form of methane emissions (Cordeiro et al., 2008; Mangi et al., 2017; Xu et al., 2018).

Sugarcane bagasse ash (SCBA) is known as a pozzolanic material (Frías et al., 2011; Kazmi et al., 2017; Mangi et al., 2017). Several research shown that SCBA has a high silica content and can be used as a pozzolanic material (Batool et al., 2020; Chusilp et al., 2009; Cordeiro et al., 2008; Gar et al., 2017;

Joshaghani & Moeini, 2017; Kazmi et al., 2017; Rossignolo et al., 2017; Soares et al., 2014; Xu et al., 2018). Suliman & Almola (2011) research revealed that the chemical composition of SCBA is nearly identical to other pozzolanic materials, such as fly ash. A suitable calcination procedure can yield silica content in SCBA (Cordeiro et al., 2009; Cordeiro & Kurtis, 2017; Soares et al., 2014). The calcination temperature has a significant impact on the silica content in SCBA. An inadequate amount of silica in the SBCA due to incomplete calcination by excessively low temperature. The amount of silica content can also be inadequate due to excessive heat. Calcination of bagasse fiber at temperature between 600 – 800°C results in the production of a significant amount of amorphous silica, which is well suited for usage as SCM due to its outstanding pozzolanic qualities (Bhargavi & Murali, 2018; Embong et al., 2016; Jahanzaib Khalil et al., 2021). Through several other research, it was discovered that the ideal calcination temperature for producing SCBA with amorphous silica was between 600 – 700°C (Bahurudeen & Santhanam, 2015; Cordeiro et al., 2009; Kolawole et al., 2021; Subedi et al., 2019).

The use of SCBA as SCM can also help in overcoming environmental issues such as reducing the problem of agricultural waste in landfills (Cordeiro et al., 2008) and obtaining cement that is more environmentally friendly with reduced CO2 emissions (Aprianti et al., 2015; Berenguer et al., 2020; Katare & Madurwar, 2017; Shafiq et al., 2016). Other research have found that adding SCBA to cement can lower emissions by 1.4 – 8.2% (Fairbairn et al., 2010; Jamora et al., 2019; Kolawole et al., 2021).

The research conducted in this article was carried out as a form of implementation of the Concrete Technology Course in the Building Engineering Education Study Program, Faculty of Engineering Universitas Negeri Jakarta. The goal from this research is to identify the suitable SCM from industrial and/or agricultural waste, both of which are major issues that need to be addressed further. Based on the description above, an analysis of SCBA will be carried out with variations of final calcination temperature and compared with the cement composition so that the optimum calcination temperature is obtained.

Research Methods

This research is quantitative research with experimental research methods. This research was conducted at the Laboratory of Materials Testing Department of Civil Engineering, FT UNJ to carry out sample preparation and at the Physics Laboratory, FMIPA UNJ for sample testing with the Scanning Electron Microscope – Energy Dispersive X-Ray (SEM-EDS). SCBA was treated with variations of calcination temperature, namely 500°C, 600°C, and 700°C. The following is a flowchart of the research conducted.

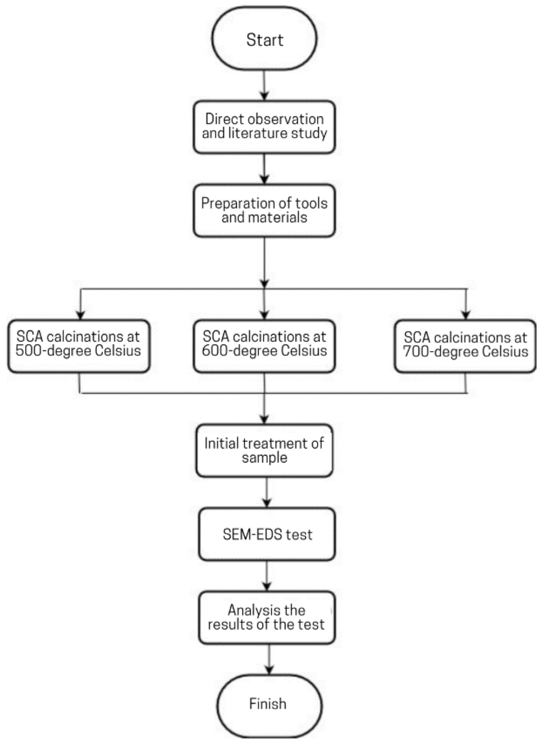


Figure 1. Research flowchart

Research Results and Discussion

SEM-EDS Testing Process

Before the SEM-EDS testing is carried out, the bagasse must be processed into SCBA first. The stages of the process include:

1. Preparation of equipment and workplace. The room and equipment to be used must be clean and free of dirt.
2. Cut the bagasse into pieces with a length of ±10 cm so that the bagasse fits the kiln.
3. Heat the kiln to room temperature. Place the bagasse into the kiln.
4. Burn the bagasse in the kiln until it reaches the specified temperature variation (500°C, 600°C, and 700°C).
5. Record the temperature rise until it reaches the specified temperature. Recording is done every 10 minutes.
6. When the specified temperature has been reached, turn off the kiln, and leave the SCBA in the kiln for 24 hours.
7. After letting it sit for 24 hours, take it out from the kiln.
8. Sieve the SCBA using sieve no. 200.
9. The SCBA that passes the sieve is ready to be taken to the Physics Lab for SEM-EDS testing.

Figure 2. Sample preparation process

Samples that can be analyzed using SEM-EDS must be conductive. For non-conductive test objects must be coated by a conductor, namely gold or platinum. The specimen is mounted on a metal slub using a sticky carbon disc which increases the conductivity. Furthermore, the test object that is ready to be tested is placed in the reactor under vacuum conditions.

Chemical Composition Based on Calcination Temperature Variations

The results of the SEM-EDS testing are in the form of micro photographs and the contents contained in SCBA. The following is the results of micro photographs on bagasse ash with 500x and 1000x magnification.

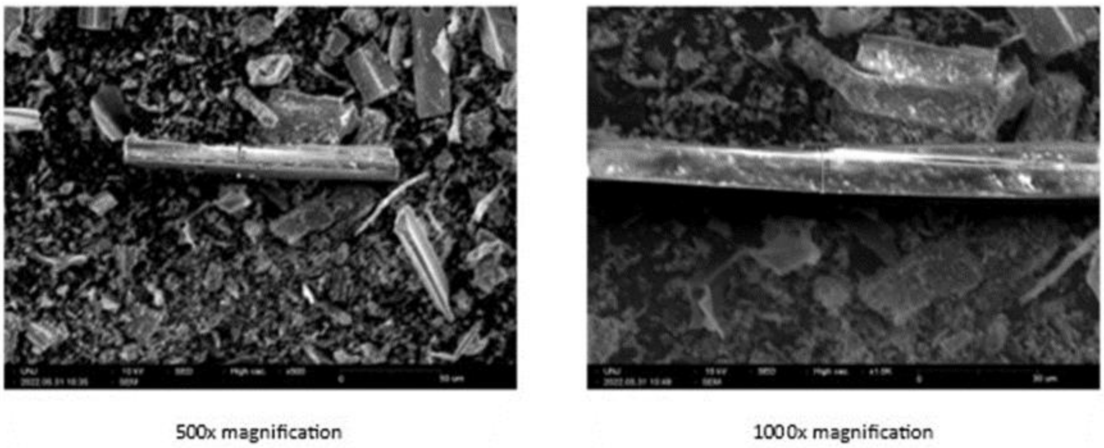
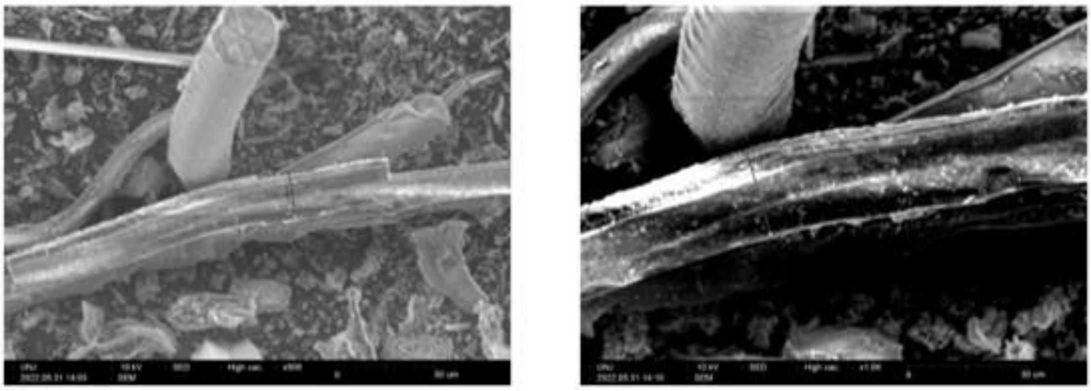
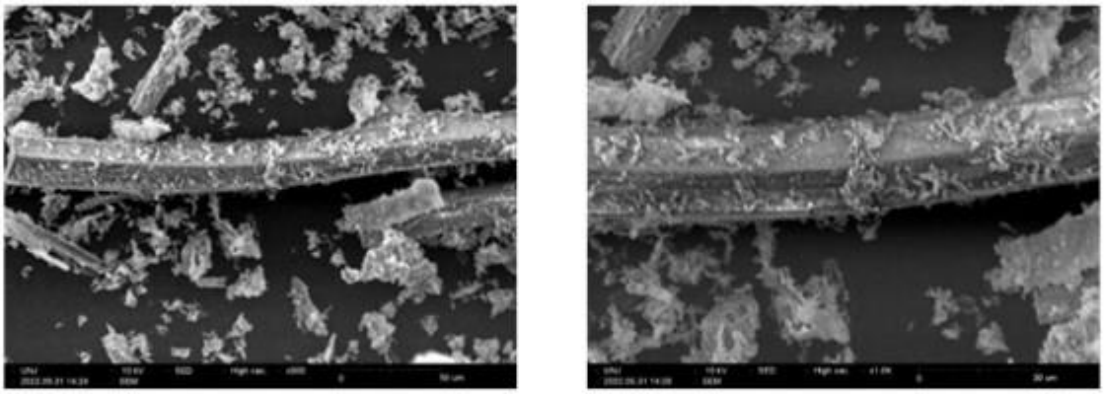


Figure 3. SCBA with final calcination temperature of 500°C



500x magnification   1000x magnification

Figure 4. SCBA with final calcination temperature of 600°C



500x magnification   1000x magnification

Figure 5. SCBA with final calcination temperature of 700°C

The electron microscope in the SEM-EDS test acts as a tool to analyze the chemical composition in SCBA. From the results of the SEM-EDS testing, it was found that the number of chemical compositions was different for each final calcination temperature. The chemical compositions contained in SCBA can be seen in the following table.

Table 1. Percentage of chemical compositions based on SEM-EDS testing

Elements	Mass (%)		
	500°C	600°C	700°C
Silicon (Si)	16.23	35.73	19.72
Calcium (Ca)	3.05	4.51	3.20
Carbon (C)	34.93	0	33.06
Oxygen (O)	37.51	52.81	39.17
Calium (K)	4.96	4.01	2.71
Magnesium (Mg)	2.51	1.66	1.90

The compositions needed as SCM is the content of silica or silicon dioxide, so that SCBA is needed with the highest silicon element content. From the table above, all of the SCBA contains a higher element of oxygen than the other elements. The highest silicon element is found in SCBA with a final calcination temperature of 600°C, which is 35.73%.

The table shows that the carbon content in SCBA with a calcination temperature of 500°C is 34.93% and decreases to 0% at a calcination temperature of 600°C. When the temperature is raised to 700°C, the carbon content again increases to 33.06%. The carbon content is inversely proportional to the silica content. So from this research, the optimum calcination temperature for SCBA which can be used as a SCM.

The amount of silica contained in Portland Cement composition based on SNI 15-2049-2004 is minimum of 20%. Meanwhile, based on BS EN 197-1:2011, the minimum standard for silica content in cement is 25%. This means that the silica content in SCBA with a final calcination temperature of 600°C can be used as a SCM because it contains more than 30% silica.

The silica content of SCBA in this research still met the minimum standards of SNI 15-2049-2004 or BS EN 197-1:2011, but the amount was not as high as SCBA from other countries such as Brazil. The content of silica can be influenced by several factors such as the calcination process, temperature, and time, also the type of soil in sugar cane plantations, and the conditions of the bagasse itself (Jahanzaib Khalil et al., 2021; Lyra et al., 2021; Zareei et al., 2018).

Conclusion

Based on the analysis that has been done, it can be concluded that the silicon content which is more than 30% indicates that SCBA can be used as a supplementary cement material. The optimum final calcination temperature to achieve a silicon content of more than 30% is 600°C compared with 500°C and 700°C. The content of other elements is also similar to the element contained in cement. As further research, it is possible to analyze the mechanical properties of SCBA and also its strength as concrete.

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