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The Effect of Adding Corn Cob Ash to The Physical and Mechanical Properties of Mortar

Pulung Karo Karo[a], Rio Orlando Pratama[b], and Roniyus Marjunus

Department of Physics, Faculty of Mathematics and Natural Sciences, University of Lampung, Bandar Lampung, Indonesia, 35141

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Abstract

The research was carried out about the effect of adding corn cob ash on mortar's physical and mechanical properties. Mortar was molded with three compositions, i.e., portland cement, corn cob ash, and corn husk fiber. Corn cob ash was burned at a temperature of 700℃ for 2 hours. Corn husk fiber was mechanically sliced up to 0.8 mm in size. Then, mortar molding and maintenance were processed for 28 days. The mortars that had reached the age of 28 days were tested according to the Indonesian National Standard (SNI), including physical properties (density) and mechanical properties (compressive strength, flexural strength, splitting tensile strength). Characterization of microstructure, morphology, and composition of all elements on the mortar's surface was processed using Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDS). The research results show the influence of adding corn cob ash on mortar's physical and mechanical properties. The mortar with the most optimum physical and mechanical properties has a composition of 82:6:12. The characterization results using SEM-EDS show that the surface of this composition sample is better than other samples. The most dominant elements in the mortar are elements of Ca and Si, which function as mortar binders and hardeners.

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Abstrak

Penelitian yang dilakukan tentang pengaruh penambahan abu tongkol jagung terhadap sifat fisis dan mekanis mortar. Mortar dicetak dengan tiga perbandingan komposisi antara semen ordinary portland, abu tongkol jagung, dan serat kulit jagung. Abu tongkol jagung dibakar pada suhu 700 ℃ selama 2 jam, serat kulit jagung dirajang secara mekanis hingga berukuran 0,8 mm, kemudian dilakukan pencetakan mortar dan perawatan selama 28 hari. Mortar yang telah mencapai usia 28 hari di uji sesuai dengan Standar Nasional Indonesia (SNI), yang meliputi sifat fisis (kerapatan), dan sifat mekanis (kuat tekan, kuat lentur, kuat tarik belah). Karakterisasi struktur mikro, morfologi, dan komposisi semua unsur yang ada pada permukaan mortar dilakukan menggunakan Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDS). Hasil penelitian menunjukkan adanya pengaruh penambahan abu tongkol jagung terhadap sifat fisis dan mekanis mortar. Mortar dengan sifat fisis dan mekanis yang paling optimum adalah mortar dengan komposisi 82:6:12. Hasil karakterisasi menggunakan SEM-EDS memperlihatkan permukaan mortar tersebut adalah yang lebih baik. Unsur yang paling dominan pada mortar adalah unsur Ca dan Si yang berfungsi sebagai pengikat dan pengeras mortar.

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* Corresponding author.
E-mail address: (a) pulung.karokaro@fmipa.unila.ac.id (b) rio.orlando42@gmail.com

1. Introduction

After rice and wheat, corn is the world's third most crucial food commodity. In Indonesia, corn is the second staple food after rice because corn has almost the same carbohydrate, protein, and calorie content as rice. Corn is also the second most important food ingredient in Indonesia after rice in terms of exploitation and use of the product, namely as a raw material for food and feed. Most corn production is used to feed raw materials, especially poultry. Of the total raw materials needed to manufacture poultry feed, the portion of corn is around 50%. Corn production in Indonesia in 2020 was 24.95 million tons (central agency for statistics and ministry of agriculture, 2021). The more corn production, the more waste is produced in the form of corn cobs and husks. Corn cob waste has a relatively high silica content of 66.38% (Raheem, 2009). The content of silica compounds in corn cobs allows it to be used as an additional material in mortar. Based on this study, research was conducted on the addition of corncob ash which varied on the physical and mechanical properties of the mortar, with variations in the ash content of corn cobs to be added to the mortar by 4%, 6%, and 8% and corn husk fiber by 12%. The factors affecting mortar's physical quality are bulk density, compressive strength, flexural strength, and splitting tensile strength.

2. Research Methods

2.1 Equipment and Parts

The tools needed in this research are a furnace, ceramic dish, 20 mesh (0.8 mm) and 100 mesh (0.1 mm) sieves, disk mill, brush, spoon, analytical balance, measuring cup, cement mixer container, mold sample, pounder, hydraulic compressive strength machine, splitting tensile strength testing machine, and flexural strength testing machine. The materials used are Ordinary Portland Cement (OPC), corn cob ash, corn husk fiber, water, and $CaCl^2$.

2.2 Research Procedure

The procedure carried out in this research is as follows.

1. Corn cob ash preparation can be done with the following steps: Corn cobs are cleaned to remove impurities. The corncobs are dried in the sun until the corncobs are dry. Corn cobs are burned in a furnace at a temperature of 700℃ for 2 hours to get corn cob ash.

2. Corn husk fiber preparation can be done with the following steps: Corn husks are cleaned to remove impurities. The corn husks are dried in the sun until the corn husks are dry. Corn husks are mechanically chopped using a disc mill until smooth to become fibers. Corn husk fiber that has been finely sieved using a 20 mesh sieve. Corn husk fibers that pass through a 20-mesh sieve will be used for making mortar.

3. Mixing: Composite cement is made of 700 grams with a variation of the ratio, namely:

Table 1. Sample Composition

Sample	Composition (100%)		
	Cement	Corn Cob Ash	Corn Husk Fiber
A	84	4	12
B	82	6	12
C	80	8	12

4. Stirring: The tools are prepared, and then the mold is oiled on each side, wipe and clean the excess oil. Materials for the manufacture of mortar samples are prepared. A Mixer container is prepared. Portland cement, corn cob ash, and corn husk fiber were mixed into a container and stirred evenly for 5 minutes. CaCl2 with a content of 80gr was dissolved in 300 ml of water. CaCl2 solution water is slowly added to the mortar mixture container. The dough is stirred evenly for 5 minutes. The walls of the mixing container are cleaned so that the mixing is evenly distributed.

5. Printing: After the mixing, the mortar sample is immediately printed. The initial mold is half. Then the dough is pounded to be evenly distributed and added until it is complete and pounded again. The surface of the mold is cleaned using a ruler so that the print is even. The mold dough is immediately stored for one day in a humid room so that the hydraulic process (hardening) occurs.

6. Treatment: The mold was opened, then the mortar sample was stored for 28 days for testing the treatment at 28 days. After 28 days, the mortar samples were tested.

7. Bulk Density: The mortar sample measuring 5x5x5 cm3 was weighed using a digital scale, then the volume of the mortar sample was measured.

8. Compressive Strength: The compressive strength test of 5x5x5 cm3 mortar samples refer to ASTM C 109/109M–02, Standard Test Method for compressive strength of hydraulic cement. At the time of testing, the tested sample will be detected by the tool if it is cracked. Thus the tool will stop and display the compressive strength value.

9. Flexural Strength: After the mortar sample measuring 16x4x4 cm3 is printed, put the mortar sample on the compressor machine to test the flexibility of the sample.

10. Split Tensile Strength: Split tensile strength test is an indirect tensile strength value of a cylindrical mortar sample with a size of 5x10 cm2. We tested the split tensile strength of mortar samples using a compression testing machine with a capacity of 2000 kN.

11. Scanning Electron Microscope-Energy Dispersive X-ray Spectroscopy (SEM-EDS): SEM-EDS characterization is used to see the microstructure, topography, and morphology with the microanalysis method. This characterization was done by making a rectangular mortar sample measuring 1.5x1x0.5 cm3.

3. Results and Discussions

3.1 Bulk Density

Samples A, B, and C were made in the form of a cube with a size of 5x5x5 and then calculated by Equation (2.1) to obtain a density value, as shown in **Figure 1**.

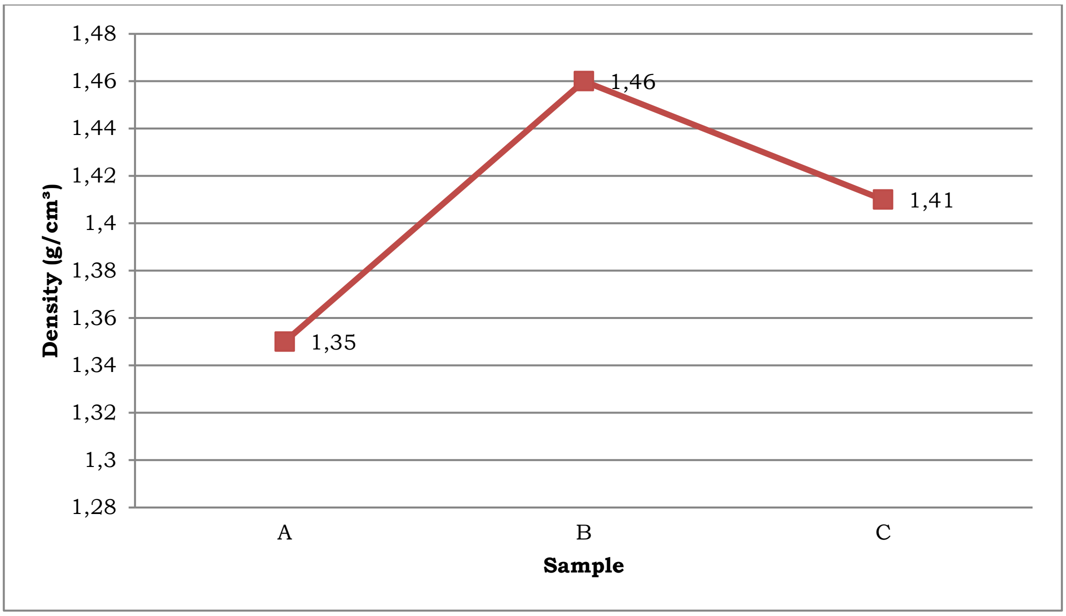


Figure 1. The effect of adding corn cob ash to mortar density with the ratio of cement: corn cob ash: corn husk fiber (A) 84%: 4%: 12%, (B) 82%: 6%: 12%, (C) 80%: 8%: 12%.

In **Figure 1**, the graph of the addition of corn cob ash to the density of the mortar, there is an anomaly in the density value. The cause of this density value anomaly is caused by the morphological structure and compound content of the elements that appear on the surface of the mortar, as well as the addition of silica corncob ash in the mortar (Fahmi & Abdul, 2016). The density value also affects the mechanical properties, including the mortar's compressive and split tensile strength. Thus, the most optimal addition of corncob ash to obtain a good density value in this study was found in sample B with 6% corncob ash with a density value of 1.46 g/cm³.

3.2 Compressive Strength

The mortar compressive strength test is the mortar's ability to maintain homogeneity when a constant force is applied before cracking occurs.

Figure 2. Compressive Strength Test

The test samples A, B, and C were formed into cubes with a size of 5x5x5 given constant pressure using a compressing testing machine to obtain data, as shown in **Figure 3**.

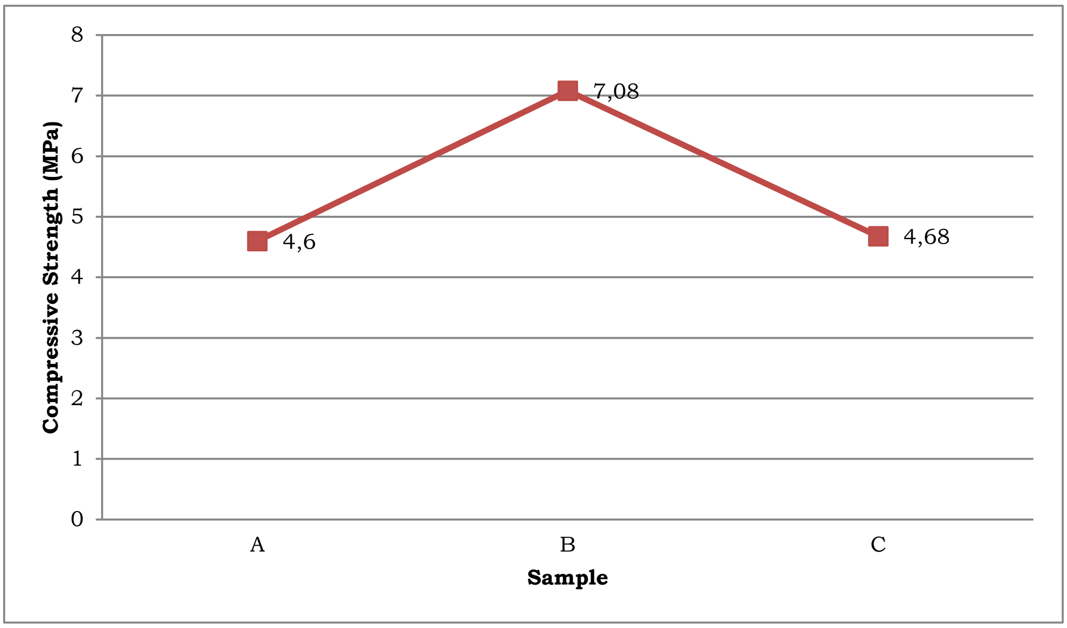


Figure 3. The results of the compressive strength test on each mortar with the ratio of cement: corn cob ash: corn husk fiber (A) 84%: 4%: 12%, (B) 82%: 6%: 12%, (C) 80%: 8%: 12%.

In **Figure 3**, it can be seen that sample B has the highest compressive strength value of 7.08 MPa, where this value is included in the category N mortar. Sample A has a compressive strength value of 4,60 MPa, which falls into the category O type mortar, and sample C has a compressive strength value of 4.68 MPa, which is included in the type O mortar category. The addition of excessive corncob ash can reduce the use of cement and decrease the quality of the mortar. This is because the lime compound in the cement during the setting and hardening process of the mortar is not optimum, so the most optimum addition of corncob ash is found in sample B with the addition of 6% corncob ash.

3.3 Flexural Strength

This flexural strength test was carried out to determine the maximum flexibility of the mortar. Samples A, B, and C have formed rectangles with a size of 16x4x4, as shown in **Figure 4**.

Figure 4. Flexural Strength Test

The sample is placed on a compression testing machine and then given a load in the middle with constant pressure, and then the data is obtained, as shown in **Figure 5.**

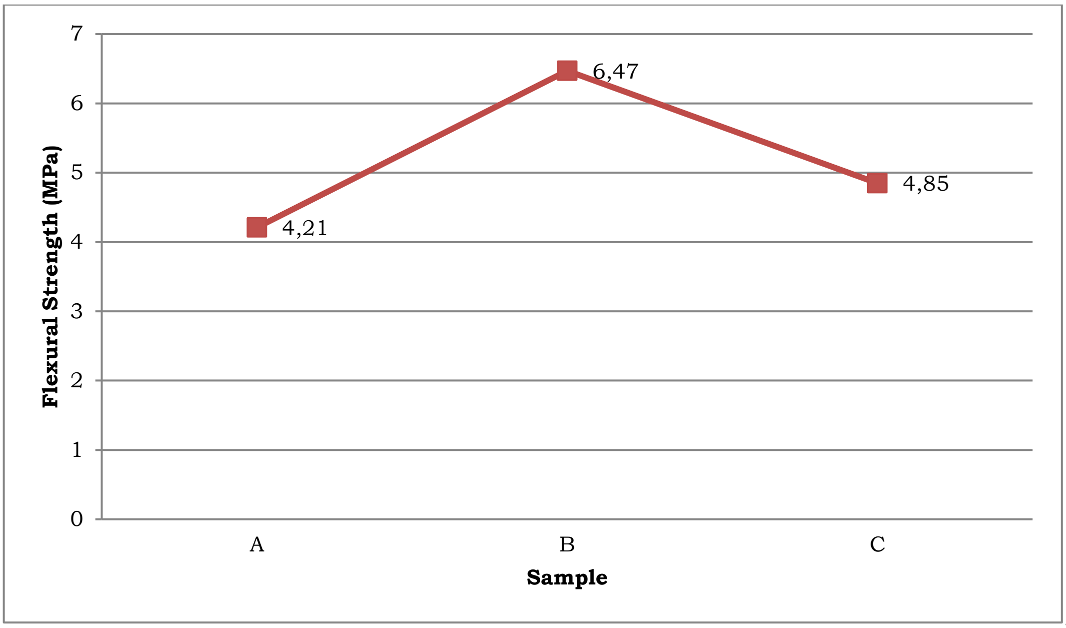


Figure 5. The results of the flexural strength test on each mortar with the ratio of cement: corn cob ash: corn husk fiber (A) 84%: 4%: 12%, (B) 82%: 6%: 12%, (C) 80%: 8%: 12%.

Figure 5 is the result of the flexural strength test on mortar. The best flexural strength value is found in sample B, with a value of 6.47 MPa. Then in sample A, the value is 4,21 MPa, and sample C obtained a value of 4.85 MPa. Ghofrani et al. (2015) reported that the maximum flexural strength value obtained was 3.6 MPa. Compared with the research results that had been carried out, the flexural strength results obtained from this study increased compared to previous research results.

3.4 Split Tensile Strength

A split tensile strength test was conducted to determine the maximum strength of laterally pressed mortar. Samples A, B, and C in the split tensile strength test were cylindrical with a diameter of 5 cm and a height of 10 cm.

Figure 6. Split Tensile Strength Test

The sample is placed in a compression testing machine in a horizontal position and then given constant pressure, and the data is obtained, as shown in **Figure 7.**

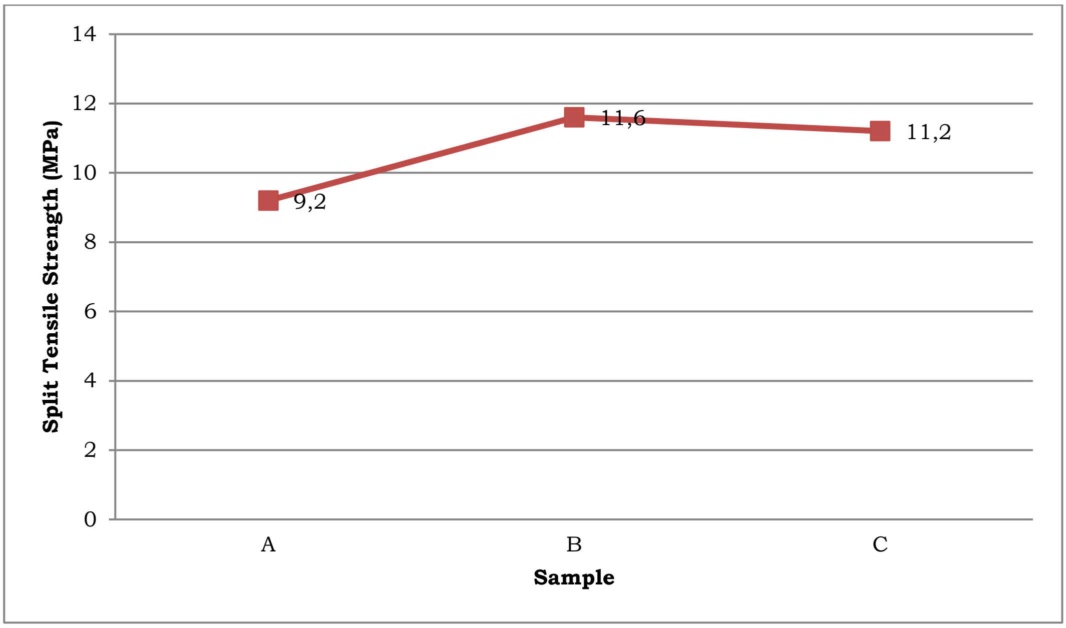
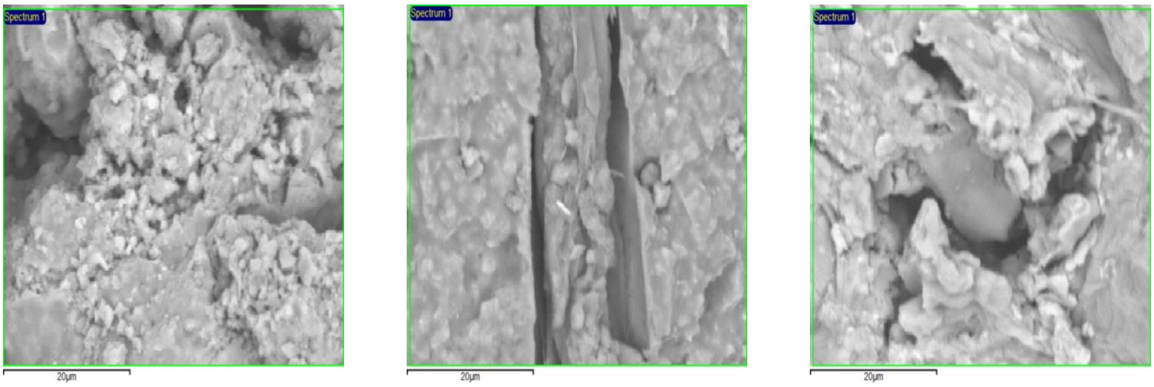


Figure 7. The results of the split tensile strength test on each mortar with the ratio of cement: corn cob ash: corn husk fiber (A) 84%: 4%: 12%, (B) 82%: 6%: 12%, (C) 80%: 8%: 12%.

Figure 7 is the result of the split tensile strength test on the mortar. The best split tensile strength test results were found in sample B with a value of 11.60 MPa, then sample A obtained a value of 9.2 MPa, and sample C obtained a value of 11.2 MPa. Ghofrani et al. (2015) reported that the maximum split tensile strength value obtained was 8.6 MPa. When compared with the results of the research that had been done, the split tensile strength results obtained from this study increased. Compared to the results of previous studies.

3.5 Scanning Electron Microscope-Energy Dispersive X-Ray Spectroscopy (SEM-EDS)

Characterization Results from mortar using a scanning electron microscope-energy dispersive x-ray spectroscopy (SEM-EDS) aim to observe the microstructure of the mortar and the elements formed in the mortar after 28 days of age. The results of the SEM-EDS analysis are shown in **Figure 8** and **Table 2**.



(a) (b) (c)

Figure 8. SEM results on the surface of samples A, B, and C with a magnification of 7000 times.

Table 2 shows the percentage of chemical elements detected in the mortar. The following are the results of identifying chemical elements obtained using EDS.

Table 2. Sample composition from the result of the EDS analysis.

Chemical Elements	Sample Element Mass A (%)	Sample Element Mass B (%)	Sample Element Mass C (%)
Carbon	20,334	16,730	13,594
Oxygen	41,199	50,057	43,958
Sodium	0,504	0,296	-
Magnesium	-	0,194	0,406
Aluminum	-	0,420	0,474
Silicon	0,491	2,906	3,744
Sulfur	0,363	0,381	0,406
Chlorine	13,709	5,454	4,981
Potassium	2,401	0,914	1,506
Calcium	21,001	21,707	30,791
Iron	-	0,941	0,591
Total	100	100	100

Figure 8 shows that in sample A, the microstructure of the mortar shows small granules that are unevenly distributed. On the sample's surface, there are empty cavities (pores) and diverse clumps (clusters). The elements contained in this sample can be identified by EDS analysis. The results in Table 4.1 show O, Ca, C, and Si elements. The elemental content of Ca in cement with compounds has a function as a binder. The Si element in corn cob ash with a compound that functions as a filler so that the sample will form calcium silicate hydrate compounds which are the main product of the hydration of Portland cement (Simanjuntak, 2007). In sample B, the microstructure of the mortar looks uniform, and there are no cavities (pores) on the sample's surface. The EDS results show that the elements O, Ca, and Si have increased so that the mortar sample is more homogeneous and the voids (pores) in the sample are covered. However, the element C has decreased, which resulted in decreased water absorption ability. Calcium silicate hydrate compounds ($3CaO.2SiO_2.3H_2O$) and portlandite are widely distributed on the surface of the mortar. The greater the Si content on the surface of the mortar, the more calcium silicate hydrate compounds formed on the surface of the mortar (Chopra et al., 2015). In sample C the microstructure of the mortar looks like different grains, and there is no cavity (pores) on the sample's surface. The EDS results show that the elements of Ca and Si have increased so that the mortar sample is more homogeneous and the voids (pores) in the sample are covered. However, the elements of O and C have decreased, resulting in decreased water absorption ability and decreased density in the mortar. Of the three samples analyzed, the elements of Si and Ca experienced a significant increase, resulting in a denser and more homogeneous mortar surface. In contrast, element C decreased, resulting in a decrease in the water absorption capacity of the mortar.

4. Conclusion

Based on the results of the research that has been done, the addition of corn cob ash can improve the quality of the mortar. This study's most optimum test results were sample B with a composition of 82%: 6%: and 12%, regarding physical, mechanical, and SEM-EDS characterization results. The elements of Si and Ca in the mortar sample affect the testing of physical (density) and mechanical properties (compressive strength, tensile strength, and flexural strength) in mortar.

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