Utilization of wood processing dust as a substitute for a part of cement in concrete

B Bunyamin\textsuperscript{1,*}, R P Munirwan\textsuperscript{2}, M Ridha\textsuperscript{3}, N Hendrifa\textsuperscript{2}
\begin{itemize}
  \item \textsuperscript{1}Department of Civil Engineering, Faculty of Engineering, Universitas Iskandar Muda, Banda Aceh, Indonesia, 23234
  \item \textsuperscript{2}Department of Civil Engineering, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia, 23111
  \item \textsuperscript{3}Department of Civil Engineering, Faculty of Engineering, Universitas Abulyatama, Banda Aceh, Indonesia, 24415
\end{itemize}

*E-mail: bunyamin@unida-aceh.ac.id

Abstract. The types of wood in Banda Aceh used was seumantok, meranti, and sembarang wood. The process of wood leaves sawdust. The sawdust becomes rubbish and could pollute the environment. There was five quality of woods, namely quality I - quality V. The purpose of this study is to optimize the sawdust of seumantok (quality I), meranti (quality II), and sembarang wood (quality III) to be processed into wood ash as a substitute for a part of cement in concrete with its percentage were 5% and 10%. The research method was experimentally in a laboratory-based on ASTM (American Society for Testing and Materials) and ACI (American Concrete Institute). The maximum diameter of the aggregate was 25.4 mm, and the compressive strength of concrete was 14.5 MPa with 21 specimens of cylindrical concrete. Concrete compressive strength results at 28 days with 5% wood ash variation and 10% respectively for quality I were 15.83 MPa and 14.20 MPa, quality II was 13.56 MPa and 12.75 MPa, and quality III were 13.79 MPa and 10.75 MPa. While the normal compressive strength of concrete was 15.86 MPa.

1. Introduction
Since the aftermath of the 2004 earthquake and tsunami, housing construction in Banda Aceh has increased rapidly. The use of wood as a building material has also increased. Many substitute building materials to replace wood which is cheap and environmentally friendly, such as aluminium and light steel. However, the people of Aceh continue to use wood as building material for housing construction.

The wood that is used as a frame, stances or other needs is ordered in wood processing. The woods which commonly available are seumantok, meranti, and sembarang wood. The result of the sawing of this type of wood is called sawdust waste, which if burned, can cause air pollution to the surrounding environment. This type of sawdust is very abundant and it will produce pozzolan that can be used as a substitute for cement in concrete if it is burned. Adding 5% of wood ash into cement will improve the quality of concrete [1]. However, the clear information of the difference in the quality of wood ash for each quality of wood and on how it affects the quality of concrete compressive strength has not been obtained yet. Therefore, this study utilizes wood species that are often used in Banda Aceh, namely, seumantok, meranti and sembarang wood. In this research, the wood ash of seumantok, meranti and
Sembarang are used as a substitute for a part of cement. Seumantok wood belongs to Quality I, meranti wood belongs to Quality II, and sembarang wood belongs to Quality III [2].

Pozzolan is an additional material derived from nature and rocks, which mostly contain silica (Si) and alumina (Al) compounds, which pozzolan react to Ca(OH)2 compounds resulting from the hydration reaction between cement and water [3]. Pozzolan can be divided into two parts, namely:

a. Natural pozzolan
   Natural material is sedimentation from ash or mountain larvae containing active silica (volcanic ash).

b. Artificial Pozzolan
   This artificial pozzolan is the combustion residue from the furnace, as well as the utilization of waste which is processed into ash consisting of reactive silica by combustion processes, such as fly ash, silica fume, and others.

Wood is a building material that is often used and is a natural resource that can be renewed if replanting is always carried out on trees that are cut down. To use wood as a building material, the shrinkage factor is important to note because it is related to the water content which is contained in it. Naturally, wood has its durability for each different type of wood [4]. The quality of wood is divided into 5 quality as shown in the following Table 1.

Table 1. Quality of wood [4].

| No. | Quality of wood       | Specific weight |
|-----|-----------------------|-----------------|
| 1   | I (Very good)         | ≥ 0.90          |
| 2   | II (good)             | 0.60 – 0.90     |
| 3   | III (Good enough)     | 0.40 – 0.60     |
| 4   | IV (Not good)         | 0.30 – 0.40     |
| 5   | V (bad)               | ≤ 0.30          |

The waste of wood ash can be used as a substitute for cement in high-quality concrete if the addition is 10% [5]. The research of compressive sand tensile strength of concrete against the addition of wood ash by 10%, 15%, and 20% into the cement was carried out at the age of 7, 14, and 28 days. The results show that concrete with wood ash has lower workability than concrete without wood ash. In terms of strength, concrete with wood ash has a compressive and tensile strength which is still below the strength of normal concrete but has a better strength improvement than normal concrete [3].

The sawdust obtained from the sawing is collected and burned with a certain temperature to the size of the grain like the size of a powder of cement and used in concrete as a substitute for a portion of cement. From the researcher, the parameters measured are compressive strength, tensile strength, and flexural strength of beams with the composition of wood ash into cement are 5%, 10%, 15%, 18%, and 20% with W/C (Cement Water Ratio) are 0.4 and 0.45, where the ratio of cement and water is still controlled as planned. The results show that there was a slight decrease in the compressive strength of the concrete against the addition of wood ash to the cement, but the strength increased with a longer maintenance period. Wood ash contains Silica which can be used as a substitute for cement and does not affect the strength of concrete [1].

The addition of 5 grams of sawdust into a 15 cm x 15 cm x 15 cm concrete cube causes the concrete compressive strength to increase by 1.08% when compared to normal concrete. The properties of fresh concrete such as workability were decreased by 50% than normal concrete [6].

The physical properties of wood ash vary, where the specific gravity (density) of wood ash is 2.26 - 2.60, and the bulk density (volume weight) is 162 kg / m3 - 1376 kg / m³ [7]. The physical and chemical properties are shown in Table 2 and Table 3.
### Table 2. The content of chemical in 100 grams of wood [7].

| No. | Chemical Properties | Volume (%) |
|-----|---------------------|------------|
| 1   | SiO₂               | 65,3       |
| 2   | Al₂O₃              | 4,25       |
| 3   | Fe₂O₃              | 2,24       |
| 4   | CaO                | 9,98       |
| 5   | MgO                | 5,32       |
| 6   | Na₂O               | 2,60       |
| 7   | K₂O                | 1,90       |
| 8   | Loss on Ignition   | 4,67       |

### Table 3. Physical properties of wood ash [7].

| No. | Physical Properties | Volume  |
|-----|---------------------|---------|
| 1   | Specific gravity    | 2,16    |
| 2   | Grain size          | 170 µm  |
| 3   | Volume weight       | 720 Kg/m³ |

The chemical composition contained in wood ash is different from wood. Wood ash particles are coarser when compared to cement because they are porous and irregular. The reaction occurs when wood ash is added to cement [8], as follows:

a. Adding wood ash to concrete will reduce the value of the slump plan.
b. An increase in water absorption by adding wood ash to the concrete.
c. There is a decrease in compressive strength and tensile strength against the addition of wood ash, but it increases with age due to increased pozzolanic reactions.
d. The addition of wood ash up to 10% can be used as a good additive for cement.

The research was carried out experimentally in the laboratory and by collecting the wood processing dust of quality I, II, and III in Banda Aceh. The objectives of this research are:

1. To reduce sawdust waste in Banda Aceh’s wood processing;
2. To determine the difference in the quality of sawdust quality I (seumantok), quality II (meranti), and quality III (sembabarang) added to the cement; and
3. To find out the concrete workability of adding wood ash of quality I, II, and III to cement by 0%, 5%, and 10%.

This research was conducted using 21 specimen of cylindrical concrete with the percentage of quality I, II, and III wood ash added to cement by 5% and 10%. The scope of the study is: an examination of physical properties of fine and coarse aggregates, slump test examination, and concrete compressive strength test.

Concrete compressive strength testing is carried out if the concrete treatment has reached 28 days using a compressive test machine. Dimensions and weight of the test specimen are measured before testing. Loading on the test specimen will produce fine cracks and if the load is increased continuously, the test specimen will experience destruction [9]. Concrete compressive strength (f'c) is calculated using equation (1) as follows:

\[
 f'c = \frac{P}{A}
\]

Where:
- \( f'c \) = Concrete compressive strength (Mpa)
- \( P \) = vertical load (N)
- \( A \) = Cross-sectional area (mm²)
2. Experimental method
The study was conducted experimentally in the Laboratory of Department Civil Engineering of Universitas Iskandar Muda based on the ASTM (American Society for Testing of Materials) and ACI (American Concrete Institute) regulations.

2.1 Wood ash and aggregate preparation
Preparation of wood ash begins with the collection of sawdust from the sawing in a wood processing. The sawdust was divided into 3 parts, where the sawdust of *seumnantok* was put into a quality I bag, *meranti* into a quality II bag, and *sembarang* wood into a quality III bag. The sawdust collected was brought to the Laboratory and weighed until it reaches about 40 kg each. The sawdust was burned to ashes and ground using a blender. Then it was sieved that passes the number of 200 sieve using an ASTM sieve. Fine and coarse aggregates were prepared and physical aggregate was examined [10]. The result of the physical properties of the aggregate by the regulations required, then it can be used as a concrete mixing material.

2.2 Concrete mix design
A concrete mix design was carried out based on the ASTM methods [10] and the ACI 211.1-91 [11]. The cement used was type I with a slump of 75-100 mm, fine aggregate used was that passed the sieve size of 4.76 mm and 9.52 mm and the maximum diameter of the coarse aggregate was 25.4 mm [12]. The addition of wood ash to cement were 0%, 5%, and 10% for each with the number of test specimen per wood quality as many as 3 (three) specimens. The total test specimen in this study was 21 (twenty-one) pieces. A slump test examination was done by looking at the workability of adding wood ash by 5% and 10%.

2.3 Equipment used
The equipments used were compressive test machine, concrete mixer, cylindrical concrete specimen, oven, iron diameter 16 mm with length 60 cm, ruler, aggregate filler spoon, cylindrical steel container, soaking bucket, sand cone mold with 15 mm diameter iron pounder with 25 cm long, glass (jar) with a glass plate lid, basin, brass brush, digital scales of 5 kg, a set of ASTM standard filters, and Abram's cone and a 45 cm x 45 cm x 45 cm steel plate.

2.4 Testing of concrete compressive strength
Concrete consists of cement, fine aggregate, coarse aggregate, water and with or added material. The physical properties of aggregates are very influential in determining the strength of concrete [13]. Concrete compressive strength is the maximum load arising divided by the cross-sectional area of cylindrical concrete specimen.

3. Result and discussion
The study was carried out experimentally in a laboratory by collecting the sawdust from the sawing in Wood Processing in the city of Banda Aceh. The results of the concrete mix design $f'_c$ 14.5 MPa with a Cement Water Ratio ($W/C$) of 0.66 were shown in the following Table 4.

| No. | Mix Design for 1 m$^3$ of concrete | Material Weight (kg) |
|-----|----------------------------------|---------------------|
| 1   | Water                            | 193.00              |
| 2   | Cement                           | 292.64              |
| 3   | Coarse Aggregate                 | 1138.57             |
| 4   | Coarse sand                      | 517.82              |
| 5   | Fine sand                        | 237.97              |
|     | Total                            | 2380.00             |
Test specimen were cylindrical with 21 test specimens. Addition of variations in wood ash quality by 5% and 10% combined with cement weight in kg/m³. The results of the concrete mix design for variations in wood ash quality were shown in Table 5.

Table 5. Concrete mix design (Kg/volume of 3 cylinders).

| No | Wood Ash (%) | Concrete Type       | Water (kg) | Portland Cement (kg) | Wood Ash (kg) | Coarse Aggregate (kg) | Fine Sand (kg) | Coarse Sand (kg) |
|----|--------------|---------------------|------------|-----------------------|---------------|------------------------|----------------|------------------|
| 1  | 0            | NC-01 to NC-03      | 3,529      | 5,347                 | 0             | 20,831                 | 4,426          | 9,404            |
| 2  | WAC.1-01 to WAC.1-03 | 3,529      | 5,080     | 0,267                 | 20,831        | 4,426                  | 9,404          |                  |
| 3  | 5            | WAC.2-01 to WAC.2-03 | 3,529 | 5,080                    | 0,267             | 20,831                 | 4,426          | 9,404            |
| 4  | WAC.3-01 to WAC.3-03 | 3,529 | 5,080 | 0,267                     | 20,831             | 4,426                  | 9,404          |                  |
| 5  | WAC.1-04 to WAC.1-06 | 3,529 | 4,812 | 0,534                    | 20,831             | 4,426                  | 9,404          |                  |
| 6  | 10           | WAC.2-04 to WAC.2-06 | 3,529 | 4,812                       | 0,534             | 20,831                 | 4,426          | 9,404            |
| 7  | WAC.3-04 to WAC.3-06 | 3,529 | 4,812 | 0,534                    | 20,831             | 4,426                  | 9,404          |                  |

Where:
NC-01 to NC-03 = Normal concrete of specimen 1 to 3
WAC.1-01 to WAC.1-03 = Seumantok wood ash concrete 5% of specimen 1 to 3
WAC.2-01 to WAC.2-03 = Meranti wood ash concrete 5% of specimen 1 to 3
WAC.3-01 to WAC.3-03 = Sembarang wood ash concrete 5% of specimen 1 to 3
WAC.1-04 to WAC.1-06 = Seumantok wood ash concrete 10% of specimen 1 to 3
WAC.2-04 to WAC.2-06 = Meranti wood ash concrete 10% of specimen 1 to 3
WAC.3-04 to WAC.3-06 = Sembarang wood ash concrete 10% of specimen 1 to 3

The results of the slump test as planned were 75-100 mm with a workability of 5% for the variation of wood ash 10%. It happened because of high levels of water absorption for the quality of wood types I and II. For more details, see Table 6.

Table 6. Slump value for variation in wood ash.

| No. | Type of test object | Wood Ash Content (%) | Slump Value (mm) | Workability (± Water Quantity) | High Slump Value Planned |
|-----|---------------------|----------------------|------------------|-------------------------------|--------------------------|
| 1   | NC-01 to NC-03      | 0                    | 82               | -                             |                          |
| 2   | WAC.1-01 to WAC.1-03| 5                    | 75               | -                             |                          |
| 3   | WAC.1-04 to WAC.1-06| 10                   | 97               | +5%                           |                          |
| 4   | WAC.2-01 to WAC.2-03| 5                    | 92               | -                             | 75 - 100 mm              |
| 5   | WAC.2-04 to WAC.2-06| 10                   | 80               | +5%                           |                          |
| 6   | WAC.3-01 to WAC.3-03| 5                    | 75               | -                             |                          |
| 7   | WAC.3-04 to WAC.3-06| 10                   | 75               | -                             |                          |

The results of compressive strength tests using cylindrical test specimens measuring 15 cm x 30 cm when the test specimen at 28 days old were shown in Figure 1.
Figure 1. The result of concrete compressive strength.

Where:
NC = Average of normal concrete of specimen 1 to 3
WAC.1-05 = Average of seumantok wood ash concrete 5% of specimen 1 to 3
WAC.1-10 = Average of seumantok wood ash concrete 10% of specimen 1 to 3
WAC.2-05 = Average of meranti wood ash concrete 5% of specimen 1 to 3
WAC.2-10 = Average of meranti wood ash concrete 10% of specimen 1 to 3
WAC.3-05 = Average of sembarang wood ash concrete 5% of specimen 1 to 3
WAC.3-10 = Average of sembarang wood ash concrete 10% of specimen 1 to 3

Figure 1 describes that the higher quality of wood, the higher the quality of concrete produced. Burning sawdust into wood ash greatly affects the quality of concrete. The greatest average compressive strength of concrete was found in normal concrete, which was 15.86 MPa. The compressive strength of seumantok wood ash concrete with a 5% mixed percentage that was equal to 15.83 MPa. The compressive strength of concrete obtained for the addition of 5% wood ash to cement was still as planned, which was above 14.5 MPa. The compressive strength value of concrete is almost the same as normal concrete compressive strength, so the percentage of the addition of seumantok wood ash concrete of 5% into the cement is still effective.

4. Conclusion
The conclusions from the results of the study by utilizing the remaining sawdust in Banda Aceh wood processing as follows:
1. The replacement of cement with wood ash quality I, II and III of 5%, and 10% are very influential in increasing the compressive strength of concrete.
2. Concrete compressive strength results at the age of 28 days with 5% and 10% variation of quality I wood ash were 15.83 MPa and 14.20 MPa, quality II wood ash were 13.56 MPa and 12.75 MPa, and quality III wood ash were 13.79 MPa and 10.75 MPa, respectively. While the normal compressive strength of concrete at 28 days was 15.86 MPa.
3. The most effective addition of wood ash into cement is 5% seumantok wood ash and the quality of concrete produced by mix design concrete which is above 14.5 MPa.
4. The properties of fresh concrete for wood ash quality I, II, and III are very different when viewed from workability. At the time of the slump test, there was an additional 5% water for wood ash of quality I and quality II.
As for some suggestions to improve the results of research on variations in the quality of wood ash to concrete as follows:
1. It is necessary to check the physical properties of each wood ash to determine what percentage of water absorption.
2. It is necessary to check the sawdust combustion temperature to get an accurate quality.
3. It is necessary to examine the properties of other fresh concrete, namely the volume weight of the concrete to see the difference in weight of the concrete if added variations in the quality of wood ash.

References
[1] Chowdhury S, Maniar A, Suganya O M 2015 Journal of advance research, 6(6) 907–913.
[2] Departemen Pekerjaan Umum 1961 Peraturan Konstruksi Kayu NI-5 PPKI 1961 Bandung: Yayasan Dana Norm Indones.
[3] Indra M J, Tjondro C, Sugiharto H 2013 Jurnal Dimensi Pratama Teknik Sipil, 2(2).
[4] Kawet R S S I 2018 Konstruksi Bangunan Yogyakarta: Deepublish.
[5] Ghorpade V G 2012 Environment Pollution Technology, 11(1) 121–124.
[6] Saifuddin M I, Edison B, Fahmi K 2014 Jurnal Mahasiswa Teknik, 1(1).
[7] Naik T R, Kraus R N, Siddique R 2003 Material Jornal, 100(3) 208–215.
[8] Chowdhury S, Mishra M, Suganya O M 2015 Ain Shams Engineering Journal, 6(2) 429–437.
[9] Bunyamin B 2020 Jurnal Serambi Engineering, 5(2).
[10] ASTM 2004 Annual Book of ASTM Standard 2004 Section 4, 04(2), Concrete and Aggregates. International Standard.
[11] ACI 2005 ACI Manual of Concrete Practice 2005, Part I, Report: ACI 104-71 (97) to ACI 223-98, Selecting Proportions For Mass Concrete (ACI 211.1-91). Detroit: Am Concr Institute.
[12] Bunyamin 2019 AIP Conference Proceedings, 20039.
[13] Mulyono T 2004 Teknologi Beton Yogyakarta: Andi Offset.