Effect of use of corn leaf ash on concrete compressive strength

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Abstract. Cement as one of concrete materials can cause the negative effect on environmental, starting from taking raw materials, production process to the resulting ash pollution. Therefore, it needs another alternative material that can be used as a substitute material of cement. Potentially, organic waste can be utilized, such as corn leaf, rice husks, palm oil waste, etc. The corn leaves are one organic waste on agricultural area which still very poorly in processing. Accordingly, this study will investigate utilizing the corn leaf ash on the concrete. The corn leaf ash was used as the cement replacement material (CRM). There are eight different percentages, namely 0%; 2.5%; 5%; 7.5%; 10%; 12.5%; 15% and 17.5%. The concretes-based corn leaf ash (ADJ) were tested at the curing ages of 7, 14, and 28 days. The test results showed that the compressive strength of ADJ of 2.5%, 5% and 7.5% increased. ADJ of 7.5% provided the maximum compressive strength. These results proved that corn leaf ash can be used as CRM.

1. Introduction

Concrete consists of several different ingredients, such as Portland cement (or hydraulic cement), water, fine aggregate, coarse aggregate, and additives [1]. Concrete plays a very important role in the construction sector. But, aside from its benefits, concrete also can cause problems. The negative impact of concrete due to the use of cement as concrete materials. Based on the Indonesian Cement Association (2018), the total cement consumption in 2017 was 66.3 million tons [2], where cement consumption increased 7% from the previous year. Negative impacts due to the use of cement include taking raw materials, the production process, to the impact of ash pollution caused. Some raw materials in producing cement such as lime is classified as non-renewable natural resources. Continual exploration will disrupt the environmental balance. The next impact that becomes the center of attention and most felt by everyone is the cement production process. In the process of cement production, carbon dioxide gas (CO₂) can accelerate global warming.

Every year, the average cement production worldwide is more than 4 billion tons, producing around 8% of carbon dioxide gas (CO₂) emissions [3]. The last impact is ash which is spread into the air which causes respiratory disease. Almost all regions in Indonesia producing corn. According to Ministry of Agriculture data, 2019 corn production in Indonesia in 2018 will reach 30 million tons [2]. Corn leaf waste is found on agricultural land, piled up and scattered on the land surface, which can reduce aesthetics of the environment. In the manufacture of concrete, there have been many developments and advances in modifying concrete compositions, in order to strive for and create concrete that has an environmentally friendly building material called green concrete. If the use of cement in all jobs is replaced with waste by 25-30% it will reduce emissions by 2% [4].

In supporting the concept of green concrete, many ideas have been proposed to utilize organic wastes as a substitute for cement such as rice husk ash, bagasse ash, oil palm shells, palm oil leaves, and others. The use of organic ash as a substitute for cement in the concrete mixture is because generally organic wastes have silica oxide [5]. Silica oxide will react with calcium hydroxide, which is the result of hydration reaction between cement and water, then produce calcium silicate hydrate (CSH) increasing concrete compressive strength [6]. Calcium hydroxide (CaOH₂) causes the concrete porous and easily penetrated by water, otherwise calcium silicate hydrate is solid [7]. Based on above descriptions, this study will investigate utilize of the corn leaf ash as the cement replacement material (CRM), so it can produce the green concrete which friendly environmental.
2. Method

2.1. Mix design

The normal concrete mix design in this study refers to the SNI 03-2834-2000. The mix proportion can be seen in Table 1.

| ADJ Content | Portland Cement (kg) | Corn Leaf Ash (kg) | Water (kg) | Fine Aggregate (kg) | Coarse Aggregate (kg) |
|-------------|-----------------------|--------------------|-----------|--------------------|----------------------|
| 0% ADJ      | 455                   | 0                  | 250.25    | 820                | 927                  |
| 2.5% ADJ    | 443.63                | 11.38              | 250.25    | 820                | 927                  |
| 5% ADJ      | 432.25                | 22.75              | 250.25    | 820                | 927                  |
| 7.5% ADJ    | 420.88                | 34.13              | 250.25    | 820                | 927                  |
| 10% ADJ     | 409.50                | 45.50              | 250.25    | 820                | 927                  |
| 12.5% ADJ   | 398.13                | 56.88              | 250.25    | 820                | 927                  |
| 15% ADJ     | 386.75                | 68.25              | 250.25    | 820                | 927                  |
| 17.5% ADJ   | 375.38                | 76.93              | 250.25    | 820                | 927                  |

2.2. Materials

a. Portland Cement

The cement used in this research is Cement with Type-I, known as Ordinary Portland Cement (OPC), that produced by PT. Semen Padang, Indonesia.

b. Corn Leaf Ash

In this study, corn leaf waste from corn fields around Padang Bulan Medan, North Sumatra and surrounding areas. Corn leaf ash before it is used and determined as a concrete mixture, is examined at the Palm Oil Research Center (PPKS) to determine the chemical composition [8]. Corn leaves must be ensured dry. Burning is done without using any fuel. Corn leaf ash is not inspected as a sieve analysis or specific gravity inspection etc. and no refinement is carried out.

c. Fine Aggregate

Fine aggregate from PT. KRATON. Fine aggregate (sand) that will be used as a concrete composition material must go through sand sieve analysis (SNI-03-1968-1990) and examination of sand specific gravity (SNI-03-1970-1990).

d. Coarse Aggregate

Coarse aggregate around 10 mm from PT. KRATON. The examination carried out on coarse aggregate is gravel sieve analysis (SNI-03-1968-1990) and gravel specific gravity inspection (SNI-03-1969-1990).

e. Water

Water used in concrete mixtures and for curing, was taken from the Concrete Laboratory, Department of Civil Engineering, Faculty of Engineering, University of North Sumatra.

2.3 Specimen preparation

In this study, the specimen used was a concrete cylinder with a diameter of 150 mm and a height of 300 mm. The number of samples from each variation of corn leaf ash amounted to 3 pieces for ages 7, 14 and 28 days. Variations in corn leaf ash as a partial replacement for cement include 0%, 2.5%, 5%, 7.5%, 10%, 12.5%, 15% and 17.5%. Thus, the total number of samples is 72.

2.4 Slump test

The Slump test conducted according SNI 1972:2008 to find out the workability of fresh concrete.
2.5 Unit weight test
Concrete unit weight testing is carried out on specimen in a dry air when the curing age of 28 days.

2.6 Compressive test
The compressive test conducted according to SNI 1974:2011 for 150 mm x 300 mm cylinder specimen. After slump test, the samples were molded and cured for 7, 14 and 28 days. Before test was carried out at the age of 7, 14 and 28 days, each concrete cylinder is "capped" at the top with sulfur. Compressive tests were carried out to determine the compressive strength of concrete cylinders in normal concrete and corn leaf ash concrete.

3. Results and discussion
3.1 Slump test
Table 2 and Figure 1 shows the slump test of fresh concrete.

| ADJ Content | Slump (cm) |
|-------------|------------|
| Normal      | 12         |
| 2.5% ADJ    | 11.1       |
| 5% ADJ      | 10.2       |
| 7.5% ADJ    | 10         |
| 10% ADJ     | 10         |
| 12.5% ADJ   | 10         |
| 15% ADJ     | 9.6        |
| 17.5% ADJ   | 9.5        |

Figure 1. Fresh Concrete Slump of Normal Concrete and ADJ

Based on the results of the slump test in Table 4 and Figure 2, it can be seen that the more the percentage of ADJ, the lower the value of the slump of fresh concrete mix. The percentage value of ADJ and the percentage of cement replaced has the same weight. But if measured by volume, the ADJ volume is more than the volume of cement. For the same weight, the number of ADJ grains is higher than cement grains. This condition can cause ADJ absorb more water than cement.
3.2 Unit weight test

The results of unit weight test in this study can be seen in Table 3 and Figure 2.

**Table 3. Unit Weight of Normal Concrete and ADJ**

| ADJ Content | Unit Weight (Kg/m³) |
|-------------|---------------------|
| 0% ADJ      | 2435.09             |
| 2.5% ADJ    | 2422.29             |
| 5% ADJ      | 2409.49             |
| 7.5% ADJ    | 2396.69             |
| 10% ADJ     | 2389.90             |
| 12.5% ADJ   | 2370.13             |
| 15% ADJ     | 2366.76             |
| 17.5% ADJ   | 2356.68             |

**Figure 2. Unit Weight of Normal Concrete and ADJ**

Based on the results shown in Table 3 and Figure 2, the more percentage of ADJ, the smaller the unit weight produced. The ADJ content is around 2.5-7.5% giving a concrete volume weight of around 2400 kg/m³. Reviewed of the cement hydration reaction, it is possible that many ADJ particles that do not react to produce CSH, and become loose material, and possibly also concrete becomes more porous.

3.3 Concrete compressive strength test

The compressive strength test results for all variations of ADJ can be seen in Table 4.

**Table 4. Average Compressive Strength of All Samples**

| No | ADJ Content | Days    |
|----|-------------|---------|
|    |             | 7       | 14     | 28     |
| 1  | Normal      | 18.350  | 21.746 | 28.066 |
| 2  | 2.5% ADJ    | 18.633  | 22.349 | 28.815 |
| 3  | 5% ADJ      | 18.929  | 23.175 | 28.929 |
In this study, partial substitution with a percentage of ADJ 2.5-7.5% gives compressive strength of concrete that is greater than the normal concrete. This shows that the SiO$_2$ ADJ is only effective in reacting to the cement hydration process in the formation of CSH, which is when the ADJ content reaches 7.5%. Silica oxide owned by ADJ will produce CSH that are better than the normal hydration results of the concrete cement hydration reaction, so that it has better aggregate binding ability. This causes the compressive strength of concrete to be potentially higher than the compressive strength of normal concrete.

| ADJ Percentage | Compressive Strength (MPa) |
|----------------|---------------------------|
| 7.5%           | 20.171                    |
| 10%            | 16.832                    |
| 12.5%          | 16.745                    |
| 15%            | 14.807                    |
| 17.5%          | 12.307                    |

![Figure 3. Relation Between ADJ Variations, Concrete Age and Compressive Strength](image)

If the ADJ content is greater than 7.5%, it is possible that the ADJ will become a filler and a free/loose material. As a result of this condition, if the ADJ content is greater, it will make the bonding phase of the cement become disrupted. More and more ADJ particles enter the pores between the aggregates. Cement paste is not able to work effectively to bind all aggregate grains. The possibility of concrete can become more porous. So that, if the ADJ content is greater than 7.5%, it can cause the compressive strength of concrete decreases.

4. Conclusion
Based on research that has been done and the test results, it can be drawn the conclusion, as follow:
1. Based on the results of tests on the chemical composition of Corn Leaf Ash (ADJ) at the Palm Oil Research Center, it is known that the most prominent content in corn leaf ash is silica oxide (SiO$_2$) in the amount of 62.32%.
2. The use of ADJ as a substitute material for cement as a percentage in a concrete mixture can reduce the value of the concrete "slump" because a greater percentage of the use of ADJ, the more water is absorbed by ADJ particles.
3. The use of ADJ as a cement replacement material has an influence on the volume weight of concrete. The greater percentage of ADJ content, the volume of ADJ concrete weight getting smaller.

4. Concrete compressive strength for variations in the percentage of ADJ 2.5%, 5% and 7.5% of the weight of the initial cement has increased compared to normal concrete (0% ADJ). On the contrary, for the compressive strength of concrete, the ADJ percentage of 10%, 12.5%, 15% and 17.5% of the weight of cement has decreased.

5. The most optimum percentage of ADJ used as a substitute material for cement in a concrete mixture is at a percentage of ADJ of 7.5% by weight of cement. The use of ADJ as a substitute for cement as much as 7.5% provides the greatest compressive strength compared to normal compressive strength (control). Compressive strength in concrete with ADJ of 7.5% at the age of 7; 14 and 28 days respectively was 20.171 MPa; 24.212 MPa and 30.923 MPa, or experienced an increase in compressive strength of 9.92%; 11.34% and 10.18% compared to the normal compressive strength of compressive strength at 7; 14 and 28 days respectively 18.350 MPa, 21.746 MPa and 28.066 MPa.

6. Corn Leaf Ash (ADJ) can be proposed as a partial cement replacement material (percentage) for increases the compressive strength of concrete.

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