The Effect Of The Use of Aluminum Fiber As A Partial Substitution of Fine Aggregate on The Compressive Strength of Concrete

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Abstract
This study aims to utilize aluminum fiber waste as a substitute for non-structural concrete mixtures, as well as to determine the effect of adding aluminum fibers to the compressive strength of concrete. This study used a cylindrical test object with a size of 15x30 cm, with the addition of aluminum fiber waste varied from 0%, 0.2%, 0.4%, and 0.8% with a total of 12 specimens. The compressive strength test of concrete was carried out SNI 1974-2011 at the age of 7 days and 28 days. The results of the analysis of the addition of aluminum powder waste in the concrete mixture with several variations resulted in a decrease in the specific gravity of the concrete. The effect of using aluminum fiber waste in the concrete mixture effect increasing and decreases the compressive strength of concrete. For 28 days old concrete, all variants have reached the design concrete compressive strength (14.5 MPa). The results of the regression of the relationship between the increase in the average compressive strength of 7-day-old concrete with the percentage of LSA stated that it could be seen that the relationship formed between the addition of LSA variations and the compressive strength of concrete.

Keywords: Aluminum Fiber Waste (LSA), Fine Aggregate, Concrete, Compressive Strength

INTRODUCTION
Consumption of industrial products creates waste that can damage the environment. However, some of these waste materials can be mixed with cement to obtain sustainable concrete and improve its quality, mechanical strength, and durability [1]. Aluminum is one type of metal that is difficult to corrode, so aluminum is widely used in human life [2]. The research on the use of raw Aluminum extruded waste in the production of Normal concrete. The mixed design of this study used a 5% aluminum variant; 10%; 20%; and 30%. Good taste The concrete used in this study is a parallelepiped with a size of 150 mm x 300 mm. The beam dimensions are 100mm × 100mm × 600 mm. Tests were carried out when the concrete was 3 days, 7 days, 28 days, 60 days, and 90 days. Tests are carried out only on the compressive and flexural strength of concrete. The results of this test indicate that aluminum waste can be used as a partial replacement for cement, seen by increasing the compressive strength of concrete with the use of aluminum scrap between 5-10% [3].

The research through a mixture of aluminum powder and Paris plaster in the production of lightweight concrete blocks as a partial replacement for cement, Research mix design with 0% aluminum variant; 0.3%; 0.5%; and 0.7% by weight of Cement [4]. Concrete testing was carried out on cylindrical samples with a diameter of 150 mm and a height of 300 mm and was tested at the age of 28 days. The tests carried out include Density, water absorption, and strength of concrete. It was found from the results of this test that the smallest density was 1,946 kg/m² with a 0.7% Aluminum powder mixture, and the largest density was 2,069 kg/m² using 0% aluminum powder. The smallest water absorption value is 2.918% using a mixture of 0% aluminum powder. The smallest compression strength value is 13,599 MPa with 0.7% aluminum powder content. The essence of this research is that Aluminum can reduce the specific weight in the production of lightweight concrete, but has not yet reached the 1800 kg/m² lightweight concrete specification required [2]. The availability of aluminum fiber waste in the Kedungpring sub-district, Lamongan Regency is quite abundant because there are many craftsmen of display windows and frames and aluminum windows that produce a lot of aluminum fiber waste. This study aims to utilize aluminum fiber waste as a substitute for non-structural concrete mixtures. To determine the effect of adding aluminum fibers to the compressive strength of concrete. The addition of aluminum
fibers is expected to make the concrete denser so that it can increase the compressive strength of the concrete. Another hope is that the addition of aluminum fibers can also make the concrete lighter, compared to other concrete materials, the specific gravity of aluminum-zinc pieces is also lighter, if aluminum-zinc pieces are used instead of fine aggregate, the weight of the concrete will be lighter. This study aims to utilize aluminum fiber waste as a substitute for non-structural concrete mixtures and to determine the effect of adding aluminum fibers on the compressive strength of concrete.

RESEARCH METHODS

Concrete is an important component in modern infrastructure due to its high structural strength and durability. Concrete is widely used in the construction of bridges, dams, tunnels, and various infrastructures [5]. The form of substitute materials varies, including fibers, powders, powders, and even liquids with different results, indicated by examination of mechanical, chemical, and thermal characteristics. Not all substitute materials have increased the performance of concrete for various reasons such as their properties are not very good interaction with other concrete form components is not effective, so the composition of the components that substitute materials in some ways actually reduces the performance of concrete [6].

A. Normal Quality Concrete

Normal quality concrete is concrete that contains normal aggregate obtained from natural aggregate decomposed or without being dismantled to maintain density in the air or mass volume weight of concrete between 2100-2550 kg/m³ (ACI, 1999).

B. Concrete Test

a. Material Test

The components that make up concrete are coarse aggregate, fine aggregate, water, binder (Portland Cement), and additional materials if needed.

b. Concrete slump test

The slump test is one way to measure the workability of concrete. This test is used to estimate the level of ease in the process. Basically, the concrete is filled into a steel funnel in the form of a truncated cone, then the vessel is pulled up so that the concrete melts down.

c. Concrete Compressive Strength Test

The compressive strength of concrete is the maximum force per unit area acting on the concrete and mortar specimens. The compressive strength test of concrete is carried out based on SNI 03-1974-1990. At the time of rupture, the maximum working compressive force is recorded. The compressive strength of concrete and mortar is obtained by the formula:

\[ f_c' = \frac{F}{A} \]  

where:

- \( f_c' \) = Compressive strength (MPa)
- \( F \) = Maximum load force (N)
- \( A \) = Surface area (mm²)

C. Material Inspection

The characteristics of the fine and coarse aggregates used are tested first. The results of the examination of the characteristics of the fine aggregate are as follows:

Table 1. Characteristics of Coarse and Fine Aggregates

<table>
<thead>
<tr>
<th>Type of Agragat</th>
<th>Type of Test</th>
<th>Result</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Coarse</td>
<td>Density</td>
<td>2.51 gr/cm³</td>
<td>2.2 – 2.7</td>
</tr>
<tr>
<td></td>
<td>Water Absorption</td>
<td>2.92 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contents Weight</td>
<td>1.43 gr/cm</td>
<td>&gt;1.2 gr/cm</td>
</tr>
<tr>
<td></td>
<td>Sieve Analysis</td>
<td>5.4</td>
<td>3.0 – 8.0</td>
</tr>
<tr>
<td>Aggregate Fine</td>
<td>Density</td>
<td>2.48 gr/cm³</td>
<td>2.2 – 2.7</td>
</tr>
<tr>
<td></td>
<td>Water Absorption</td>
<td>3.34 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contents Weight</td>
<td>1.69 gr/cm</td>
<td>&gt;1.2 gr/cm</td>
</tr>
<tr>
<td></td>
<td>Sieve Analysis</td>
<td>3.07</td>
<td>1.5 – 3.8</td>
</tr>
</tbody>
</table>

Source: Research Results, 2021

From table 1, the requirements for the characteristics of coarse aggregate and fine aggregate have been met the requirements.
D. Aluminum Waste
The aluminum scrap used in this study is a waste when cutting aluminum materials such as aluminum frames. Cutting aluminum produces waste of various sizes, large pieces as well as a fine powder. In this study, the aluminum material used was fine flakes. Aluminum itself is one of the chemicals used in the manufacture of cement, in the form of aluminum oxide or aluminum oxide (Al2O3) with levels from 3 to 8%. Alumina is one of the materials that have thermal and electrical insulation properties. Aluminum is a material that is not easily exposed to rust and can be used as an ingredient in cement.

E. Mixed Design
Based on the material test results that have been obtained from table 1, it can be calculated the design of the concrete mix. This concrete mix design was made in accordance with the reference to SNI 03-2834-2000, concerning Procedures for Making Normal Concrete Mixture Plans. The required concrete compressive strength target (f’c) at the age of 28 days of concrete is 14.5 MPa.

In this study, there are 4 types of mixture composition to be made, namely LSA 0 for concrete mixtures without partial materials, LSA 0.2 for concrete with aluminum mixtures of 0.2%, LSA 0.6 for concrete with an aluminum mixture of 0.6%, and 0.8 LSA with an aluminum mixture of 0.8%. The design of the concrete mix in this study can be seen in table 2.

F. Test Object
- Manufacture of cylindrical specimens 150x300 mm
- Examination of compressive strength at the age of 7 and 28 days.
- The number of test objects used is 12 pieces for each age of the compressive strength test.
- Check the compressive strength of 0%, 0.2%, 0.4%, and 0.8% substitution of aluminum fibers in coarse aggregate for each age of the concrete to be tested.
- The number of test objects used is three for each test

G. Test Method
The compressive strength test of concrete was carried out in accordance with the reference to SNI 1974-2011 concerning Methods of Testing the Compressive Strength of Concrete with Cylindrical Test Objects, Concrete was tested with a universal testing machine (UTM) at the age of the specimens 7, and 28 days.

RESULTS AND DISCUSSIONS

A. Slump Test
Tests on fresh concrete carried out are slump tests to determine the consistency and workability of concrete mix. In this study, the targeted slump value is 20±2 cm. The results of the slump test of the concrete mixtures in this study can be seen in table 3.

Table 3. Slump Test Value

<table>
<thead>
<tr>
<th>Mixed Code</th>
<th>Variation Mixed</th>
<th>Slump Height (cm)</th>
<th>Average (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSA 0</td>
<td>0 %</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>LSA 0.2</td>
<td>0.2 %</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>LSA 0.4</td>
<td>0.4 %</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>LSA 0.8</td>
<td>0.8 %</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

In table 3, the Slump value is obtained. The slump test value varies between 11.5 cm to 12.5 cm. The slump value varies due to the non-uniform moisture content and absorption of aggregate, the greater the percentage of aluminum powder, the higher the slump value. To maintain the slump value according to the planned slump, a correction is made to the water consumption during mixing.

A. B. Specific Gravity Test
In addition to testing the compressive strength and tensile strength of concrete, research was also conducted on the specific gravity of concrete. The specific gravity of the concrete in this study can be seen in Table 4 below.

Table 4. Specific Gravity Test Value

<table>
<thead>
<tr>
<th>Mixed Code</th>
<th>Specific Gravity (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSA 0</td>
<td>2.6</td>
</tr>
<tr>
<td>LSA 0.2</td>
<td>2.65</td>
</tr>
<tr>
<td>LSA 0.4</td>
<td>2.68</td>
</tr>
<tr>
<td>LSA 0.8</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Source: Research Results, 2021

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Figure 1. Aluminum Fiber
Source: Research Results, 2021
The compressive strength test of concrete is carried out based on SNI 03-1974-1990. Variations in the increase were not linear.

From Table 4, the specific gravity of concrete can be calculated by dividing the weight of the concrete specimen by the volume of the concrete test object. Concrete with aluminum fiber waste has a lower specific gravity value than normal concrete. For concrete aged 7 days, the lowest specific gravity value was with LSA 0.8, as well as for concrete aged 28 days. The specific gravity of concrete with LSA is included in the Normal concrete category.

A. C. Compressive Strength of Concrete

The compressive strength of concrete can be seen. The relationship between the addition of variations in LSA and the percentage of LSA states that it can be seen that the optimum value. This percentage will be able to provide the optimum compressive strength value compared to other optimum values. This percentage will be able to provide the optimum compressive strength value compared to other optimum values.

In Figure 4, it can be seen that the use of LSA in the concrete mixture affects the compressive strength of the concrete. This effect can be seen from the decrease in compressive strength that occurs at LSA 0.2 and LSA 0.4 while the increase in compressive strength occurs at LSA 0.8. If viewed from the regression results, the relationship between the increase in the average compressive strength of concrete and the percentage of LSA states that it can be seen that the relationship between the addition of variations in LSA and the compressive strength of concrete can be seen. The optimum value obtained from the regression equation \( y = -53.229x^3 + 77.063x^2 - 25.033x + 10.65 \) with the optimum value. This percentage will be able to provide the optimum compressive strength value compared to other variations.

**CONCLUSION**

Based on the test results, several conclusions were obtained, namely:

1. The addition of aluminum powder waste (LSA) to the concrete mixture with several variations resulted in a decrease in the specific gravity of the concrete as the amount of LSA was increased. The density of normal concrete is around 2400 kg/m3, where in this study the
concrete sample as a whole met normal concrete.

2. The effect of using LSA on the concrete mixture also affects the increase and decrease in the compressive strength of concrete. In 7 days old concrete, the decrease in compressive strength of concrete occurred at LSA 0.2 (8.30 Mpa) and LSA 0.4 (9.56 Mpa), while for LSA 0.8 (12.69 Mpa) an increase of 19% from normal concrete LSA0 (10.65). For 28 days old concrete, all variants have reached the design concrete compressive strength (14.5 MPa). The highest compressive strength was at LSA 0 (17.86 MPa) without the addition of LSA. As for the compressive strength of concrete with the addition of LSA, the highest compressive strength is in the LSA variant 0.4 (15.82)

3. The results of the regression of the relationship between the increase in the average compressive strength of 7-day-old concrete with the percentage of LSA stated that it can be seen that the relationship formed between the addition of LSA variations and the compressive strength of concrete can be seen. The optimum value obtained from the regression equation y = -59.74x3 + 77.094x2 - 26.379x + 17.86 is 0.72% with the optimum value. This percentage will be able to provide the optimum compressive strength value compared to other variations.

REFERENCES


