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Addition of Fly Ash And Aluminum Slag As Cement Substitute Materials To Cellular Lightweight Concrete

Yogie Risdianto[1]

[1]Department of Civil Engineering, State University of Surabaya, Surabaya 60231, Indonesia
E-Mail: yogierisdianto@unesa.ac.id

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Cellular Lightweight Concrete; Aluminum Slag ; Fly Ash; Compressive Strength; Density; Water Absorption

Abstract

The construction of non-structural elements of the building applies CLC lightweight concrete at a lower cost than standard concrete due to faster work, more temperature resistance, ease of handling, and lighter density. This study aims to find the optimum percentage and effect of using aluminum slag and fly ash as a partial replacement of cement in cellular lightweight concrete. The test object is printed in a molding size of 5x5x5 cm3. The use of aluminum slag is 0%, 1.5%, 3%, 4.5%, 6%, and 7.5%, while the use of fly ash is 15% of the cement weight. The tests carried out included volume weight, compressive strength, and water absorption at the age of 3, 7, 14, 21, and 28 days. The results of this study, it can be concluded that increasing the variation of aluminum slag with fly ash content remains at 15% in each variation as a cement substitution, the most significant variation is 1.5%. The optimum compressive strength test results at a variation of 1.5% of 4.1 MPa with the highest specific gravity of 752 gr/cm3, and water absorption of 66.67%, it all specimens at the age of 28 days.

1. Introduction

Construction buildings that are often encountered, such as buildings, offices, and others, almost all of these buildings use concrete as a building material. With the development of concrete technology, new modified concrete is created, such as lightweight concrete, shotcrete, fiber concrete, high-quality concrete, very high-strength concrete, self-compacted concrete, etc. most used in the world. Therefore, the variation of the concrete itself is being studied more and more so that it can develop higher quality concrete, one of which is lightweight concrete.

Lightweight concrete is a concrete mortar that has a lighter specific gravity than concrete mortar in general. According to (Nasional, 2009) SNI 03-3449-2002 lightweight concrete mortar should not exceed the maximum weight of lightweight concrete of 1850 kg/m3. One type of lightweight concrete mortar that is often encountered (Ramamurthy, Nambiar, & Ranjani, 2009), is lightweight concrete CLC (Cellular Lightweight Concrete), which is a lightweight concrete that contains many air pores caused by air bubbles added to the concrete mortar mixture and through natural curing process(Anwar & Hafidz, 2019).

Substitution of aluminum slag ash is a material composition that functions to overcome the weaknesses of cellular lightweight concrete, which can be the result of smelting unused aluminum as a pore filler in lightweight concrete, thereby increasing mechanical strength in the form of compressive strength. And also the use of fly ash in concrete can increase the compressive strength of concrete properly while reducing the use of cement (Zakariya, 2018).

Lightweight cellular concrete has a composition in the form of portland cement, silica cement, pozzolan cement, pozzolan-lime or silica lime paste or a mixture of pastes derived from these materials and also has trapped air cavities resembling the cell structure derived from air bubble formers or foam agents (Cement, 2013).

Aluminium Slag

Aluminum slag is a waste material resulting from the smelting of aluminum metal in the form of ash. The primary aluminum smelting process produces primary ash or dross which still contains 20-45% aluminum residue.

Aluminum slag waste is a type of hazardous waste and is included in the B3 waste category. Based on Government Regulation (PP) Number 101 of 2014 concerning Management of Toxic and Hazardous Waste, handling B3 waste requires special treatment and is not the same as waste other than B3(Reddy & Kumar, 2017).

Records from the Jombang Regency Environment Service (DLH) stated that the number of aluminum slag processing entrepreneurs in Kesamben and Sumobito Districts was 60 entrepreneurs. In 2014, DLH noted that there were 135 entrepreneurs running B3 waste processing businesses.

Figure 1.
Aluminum Slag

Fly Ash

According to ACI Committee 226, it is explained that fly ash has fine grains, which pass sieve No. 325 (45 milli micron) 5-27 %. Fly Ash is generally in the form of solid or hollow balls. Fly ash has a density of 2.23 gr/cm3, with a moisture content of around 4%. Fly ash has a specific gravity between 2.15-2.6 and is gray-black in color. The particle size of fly ash from burning bituminous coal is smaller than 0.075 mm. Fly ash has a specific area of 170-1000 m2/kg. The average particle size of sub-bituminous coal fly ash is 0.01 mm – 0.015 mm, the surface area is 1-2 m2/g, the particle shape is mostly spherical, that is, most of it is spherical, resulting in better workability (Bella, Pah, & Ratu, 2017).

Based on Government Regulation number 101 of 2014 concerning Hazardous and Toxic Waste Management, FABA is categorized as hazardous and toxic waste (B3) category 2. Then, there was a change to Non-Hazardous and Toxic Waste (B3) according to Government Regulation (PP) 22 Years 2021 concerning Implementation of Environmental Protection and Management. Thus, FABA can be used by the cement industry, or the cement industry, such as bricks, tiles, paving blocks, and so on, because it has pozzolanic properties.

Comparison of Chemical Properties

Aluminum slag, fly ash, and cement are chemically similar. A comparison of the physical properties of aluminum slag, fly ash, and portland cement can be seen in table 1.

Table 1
Comparison of the Chemical Properties of Aluminum Slag, Fly Ash, and Portland Cement

Comparison	Aluminium	Fly Ash (%)	Portland

Components	Slag (%)		Cement (%)
CaO	3.2	1.71	65.3
SiO2	4.9	60.48	18.3
Al2O3	69.39	28.15	5.7
SO3	-	-	4.3
TiO2	1.9	-	0.5
Cl^-	-	-	0.2
Fe2O3	1.96	4.25	-
MgO	8,33	0.47	-
K2O	-	1.41	-
Na2O	-	0.14	-
L.O.I	-	1.59	-

Source: Setiawati (2018)

2. Materials and Methods

The research method used in this study was quantitative research results, using experimental methods. The empirical design method in research is carried out by conducting experimental activities to obtain data through observations in each experiment. The research data is in the form of quantitative data which is then processed in order to get results.

The design of this study will be carried out experiments on the substitution of aluminum slag and fly ash for cement in cellular concrete mixtures which aim to determine the unit weight, compressive strength, water absorption and optimum percentage of cellular lightweight concrete. The percentage of aluminum slag that will be added in the study is 0%, 1.5%, 3%, 4.5%, 6% and 7.5% by weight of cellular lightweight concrete, with a fly ash percentage of 15%. Data collection was carried out by making test specimens for compressive strength tests (5x5x5 cm3 cubes) tested at the age of 3, 7, 14, 21 and 28 days. The sample as primary data is used to analyze the data. The use of the material requirements used as a mixture of test specimens is shown in table 2.

Table 2
Material requirements for a cube 5x5x5 cm3

Code	Sand (kg)	Cement (kg)	Water (liter)	Foam (liter)	AS (gr)	FA (gr)	SP (ml)
A	2.604	1.107	651	2.083	0	195	5
B	2.604	1.087	651	2.083	20	195	5
C	2.604	1.068	651	2.083	39	195	5
D	2.604	1.048	651	2.083	59	195	5
E	2.604	1.029	651	2.083	78	195	5
F	2.604	1.009	651	2.083	98	195	5
Total	15.63	6.348	3906	12.50	292	1171	30

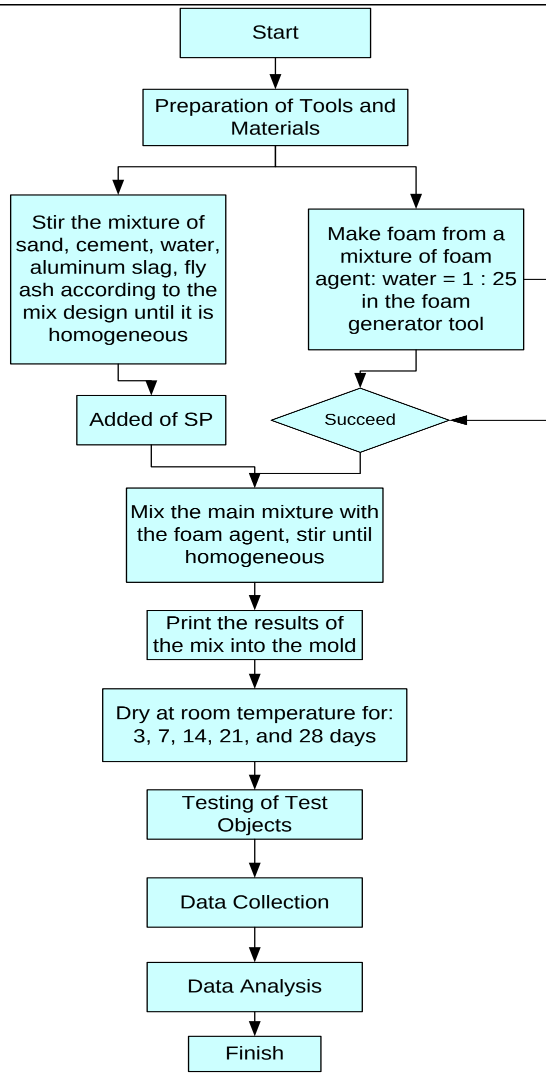

Figure 1
Flowchart for making test specimens

Volume Weight Testing

The concrete unit weight test is carried out before testing the compressive strength of the concrete. The volume weight test is carried out to determine the unit between the weight of the test object and the volume of the concrete test object. The formula for finding the volume weight is as follows:

volume weight (Bv) = $\frac{w}{v}$

Description:

Bv = Volume weight of the test object (Gram/cm3)

w = Weight of the test object (Grams)

v = Volume of the test object (cm3)

Compressive Strength

Testing The compressive strength test of concrete was obtained according to the standard according to (ASTM, 2012) test the compressive strength of mortar concrete with a 5x5x5 cm3 cube test object. The formula for finding the compressive strength is as follows:

$$fm = P/A$$

Description:

fm = Compressive strength (psi or MPa)
P = Maximum total load (lbf or N)
A = Compression area (in^2 or mm^2)

Water Absorption Test

Absorption test water in concrete is obtained according to (Nasional, 2009) SNI 03-0349-1989 explaining, the test object is suitable for use if the water absorption capacity has a maximum value of 25% with a 5x5x5 cm3 cube test object with a maturity of 28 days. The formula for finding the compressive strength is as follows:

$$K(water) = (AB)/B \; x \; 100\%$$

Description:
$K_{(water)}$ = Moisture content (%)
A = Wet mass of the specimen that has been soaked in water for 24 hours (grams)
B = Dry mass of the test object that has been in the oven for 24 hours (grams)

3. Results and Discussions

Material Test Results

Cement

The cement used has a specific gravity of 3.15 gr/cm3 which is the 40 kg Semen Gresik brand of PPC type (Pozzolan Portland Cement).

Fine Aggregate

The sand used is a type of Pasuruan sand. The results of the sand test obtained are shown in Table 3, as well as the sand gradation graph Figure 2.

Table 3
The Results of the Sand Test

No	Test Type	Test result
1	Specific gravity	2.231 gr/cm3
2	Weight Per volume	1,54 gram/cm3
3	Sludge levels	2,61 %
4	Sieve Analysis	Zona 2
5	Moisture Content	3,64 %

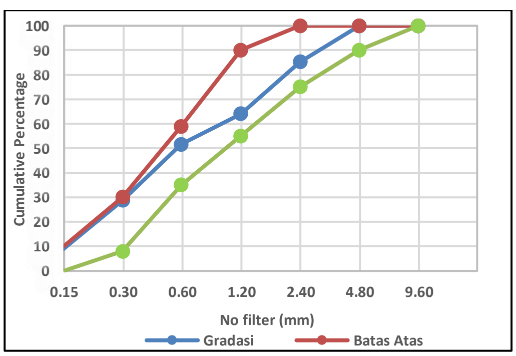

Figure 2.
The Graph of Sand Gradation Zone 2

Aluminum Slag

The aluminum slag used comes from the aluminum metal smelting home industry in Bakalan Village, District Sumobito, Jombang Regency The aluminum slag used to pass through the 200 sieve has a specific gravity of 2.941 gr/cm3. Aluminum slag is used as a substitute for using cement.

Fly Ash

The fly ash used passes through the 200 sieve and has a specific gravity of 2.941 gr/cm3. Fly ash is used as a substitute for using cement (Utomo, 2016).

Foam Agent

Foam agent has a specific gravity of 0.04 g/cm3 which is produced by the foam agent used by the brand Foam Agent GF 1420 for use in water with a ratio of 1:25 (1 liter of Foam Agent: 25 liters of water).

Compressive Strength Testing

The results of this compressive strength test were carried out at the age of 3, 7, 14, 21, and 28 days using the UTM (Universal Testing Machine) tool. The table presents data for the compressive strength of aluminum slag substitution variations of 0.0%, 1.5%, 3.0%, 4.5%, 6.0%, and 7.5% with 15% fly ash.

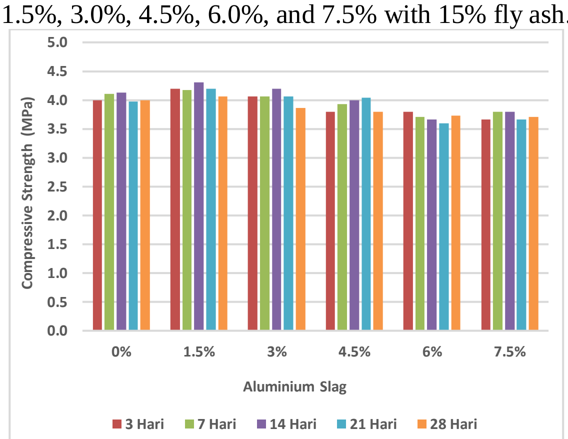

Figure 3.
Average Compressive Strength

Compressive strength decreases with increasing variations in aluminum slag. The decrease was due to the increase in the small bubbles in the dough formed from aluminum slag resulting in more air being trapped and causing cavities to appear in lightweight concrete. When aluminum slag is used within a certain range along with mixed minerals such as fly ash, there will be an increase in the workability and mechanical properties of lightweight concrete.

Figure 3 shows that the compressive strength test for each composition starting from 0% penis up to 1.5% is increasing then decreasing until the composition is 7.5%. So, it can be concluded that the optimum compressive strength of this lightweight concrete is a 1.5% composition of 4.1 MPa at 28 days of age.

Volume Weight Test

The results of this volume weight test were carried out at the age of 3, 7, 14, 21, and 28 days. The table presents data for the volume weight of variations of aluminum slag substitution 0.0%, 1.5%, 3.0%, 4.5%, 6.0%, and 7.5% with 15% fly ash.

Figure 4. It is shown that the results of the volumetric weight test for each composition starting from 0% control to 1.5% increased and then decreased to a composition of 7.5%. It can be concluded that the volume weight of the test object increases up to 1.5% composition and decreases if the aluminum slag composition increases with the fly ash material remaining 15%, but for the entire test object it still meets the requirements or is not too heavy.

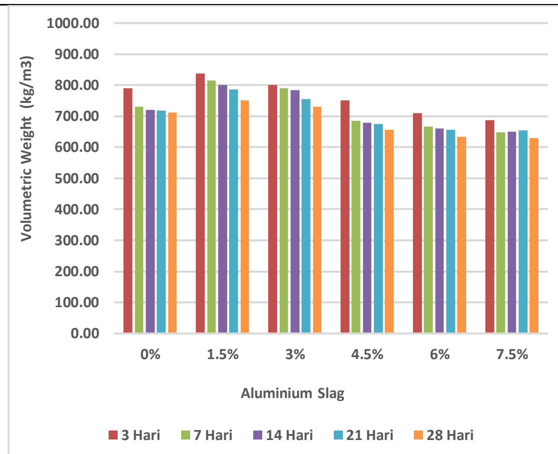

Figure 4.
Average Volumetric Weight

The results of this test use specimens that are 28 days old. Each specimen will be soaked in water for 24 hours then wiped dry or SSD and put in an oven with a temperature of 110˚C for 24 hours. Before soaking, after soaking, and after being in the oven, the test specimens are always weighed. The table presents data for water absorption of aluminum slag substitution variations of 0.0%, 1.5%, 3.0%, 4.5%, 6.0%, and 7.5% with 15% fly ash. Based on Figure 5. it shows that the water absorption test for each composition decreased at 1.5% composition by 66.67%, then continued to increase to 7.5% composition by 74.40%.

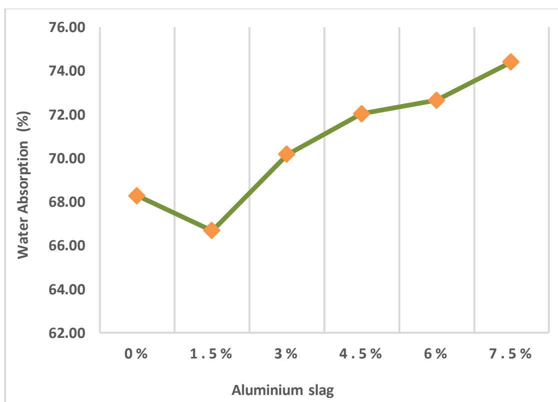

Figure 5.
Graph of Water Absorption Test

Relation of Concrete Compressive Strength to Water Absorption

This research was conducted to increase the quality of cellular lightweight concrete mixtures. Thus, this research can determine the optimum level of the substitute material used. The following is a graph of compressive strength with water absorption to the percentage of aluminum slag and fly ash when the test object is 28 days old.

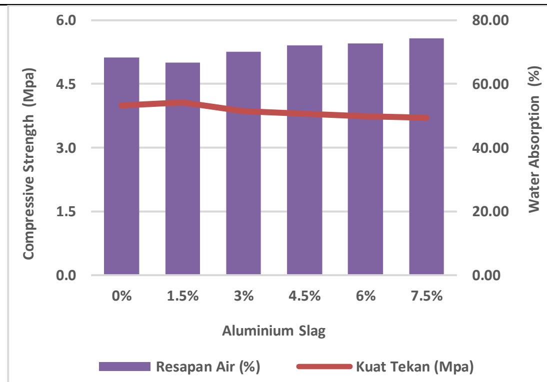

Figure 6.
The Relationship Between Compressive Strength and Water Absorption at 28 Days of Age

Figure 6. It can be seen that the peak compressive strength was at the percentage of 1.5% aluminum slag and at that time the water absorption was at a low position. So the optimum percentage of aluminum slag in terms of compressive strength and water absorption of the test object at a composition of 1.5% is with a compressive strength of 4.1 MPa and a water absorption of 66.67%.

Relationship of Concrete Compressive Strength to Volume Weight

Testing of compressive strength to unit weight of lightweight cellular concrete (CLC) bricks shows that they are interconnected, this can be seen from the weight of each specimen affecting the compressive strength test. However, there are several test objects that have volumetric weights that do not affect each other. This condition is caused by incomplete drying so that there is a lower unit weight but the resulting compressive strength is greater.

In this study also showed that there were several specimens that had a low volume weight but high compressive strength, so that the volume weight and compressive strength influenced each other. The cause of this condition is that the test object is still at an early age, the volume weight is still large because it still contains a lot of water, but the compressive strength shows a small value. This happens because the mixed reaction process is not perfect. Meanwhile, the test object that has been aged for a long time has reduced water content so that the volume weight has also decreased but the compressive strength shows a high value.

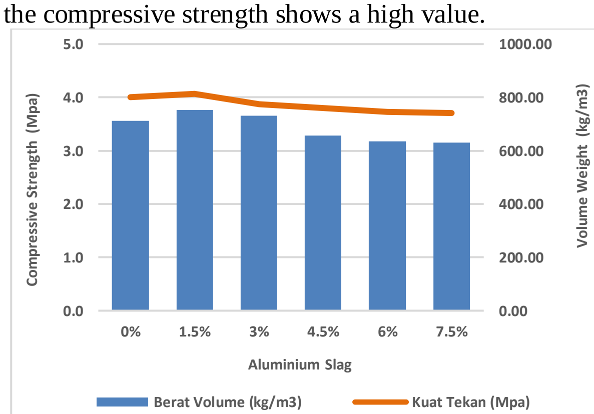

Figure 7.
Relationship Between Compressive Strength and Unit Weight at 28 Days Old

In Figure 7, it is explained that the 0% composition experienced an increase in volume weight and compressive strength up to 1.5% composition and then decreased to 7.5% composition. The optimum value at the age of 28 days is at a composition of 1.5% with a volume weight of 753 kg/m3 and a compressive strength of 4.1 MPa.

4. Conclusion

Based on the results of the research and discussion that has been done before, conclusions can be drawn as the optimum percentage of using aluminum slag and fly ash in CLC lightweight concrete mixtures as a cement substitution material is obtained in variations of 1.5% aluminum slag with 15% fly ash to the total weight of the test object in each variation. The addition of variations of more than 1.5% aluminum slag causes a lower unit weight, so the resulting compressive strength is also low. The effect of using aluminum slag and fly ash as a substitute for CLC lightweight concrete mixture on compressive strength according to variations of aluminum slag 0%, 1.5%, 3%, 4.5%, 6%, and 7.5% with 15% fly ash increased from the variation 0% by 4 MPa to an optimum value of 1.5% by 4.1 MPa and then decreased steadily by 3.9 MPa, 3.8 MPa, 3.7 MPa, and 3.7 MPa respectively at 28 days of age.

Suggestions

Based on the results of the research and discussion, there are several suggestions that can be taken as follows: Conduct another in-depth study of cement substitution using the optimum percentage of aluminum slag of 1.5% and fly ash of 15% with the addition of other ingredients to obtain better results. optimal. Treat the aluminum slag and fly ash specimens with the addition of other materials as cement substitutes by curing, so that the test specimens do not lose their water content. It is necessary to pay attention again to the implementation method at the stage of making and mixing mortar and foam dough, because if the mixing process is uneven it can affect the results of the test object. Furthermore, it is necessary to pay attention again when determining the comparison in the use of the water-cement factor (FAS), because it can affect the results of the test object.

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