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Utilization Of Aluminum Slag As A Substitutional Material For Cement In The Production Of Normal Concrete And Cellular Lightweight Concrete

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Abstract – The current development of construction development causes the need for cement as a binder in the concrete mixture to increase. It is necessary to have alternative materials that are economical and environmentally friendly as a substitute for cement, one of which is aluminum slag. The research was carried out by utilizing aluminum slag as a substitute for cement in a mixture of normal concrete and lightweight cellular concrete. The purpose of this study was to determine the effect of aluminum slag as a substitute for cement in a mixture of normal concrete and lightweight cellular concrete on the mechanical properties of concrete. This research is a quantitative research by conducting experiments on K-300 quality concrete. The concrete test specimens were varied using 0% aluminum slag; 1.5%; 3%; 4.5%, 6% and 7.5% with cube test objects measuring 15cm x 15cm. The compressive strength test was carried out at the age of 7, 14, 21 and 28 days with 3 specimens at each age, while for the water absorption test at the age of 28 days. The results of the study showed that the maximum compressive strength of aluminum slag was at a level of 1.5%, more than that the compressive strength and volume weight of the concrete would decrease because the air content in the concrete increased in direct proportion to the increase in the aluminum slag content. In the light cellular concrete research results, cement replaced with aluminum slag showed the highest compressive strength in lightweight concrete with a variation of 1.5% with a compressive strength value of 4.3 MPa and a volumetric weight of 669.3 kg/m^3 with a variation of 0% for compressive strength 4.2 MPa and a unit weight of 693.3 kg/m^3 were obtained for lightweight concrete samples aged 28 days. This can be explained by the large absorption of water in the concrete which is an indication of high porosity, besides that the impact of the increased air content due to aluminum slag causes expansion on the surface of the concrete.

Keywords – Normal Concrete, Cellular Lightweight Concrete, Aluminum Slag, Compressive Strength.

I. INTRODUCTION

The development of current construction has caused the need for cement as a binder in concrete mixes to increase. The increasing need for cement is the reason for looking for alternative materials to replace cement as a binder in concrete. Many alternative materials that are economical and environmentally friendly can be used as a substitute for cement such as waste, one of which is aluminum slag. Nursyafril (2014) tested the chemical composition of the aluminum slagtest slag consisted of 69.39% Aluminum Oxide; Magnesium Oxide of 8.31%; Silicate Oxide of 4.9%; Calcium Oxide of 3.2%; Iron Oxide of 1.96% and Titanium Oxide of 1.9%. Aluminum, Calcium, Silicate and Iron are some of the elements that are also present in portland, so that aluminum slag has the potential to be a cement substitute material.

Reddy & Neeraja (2016) conducted research with the title "Mechanical and durability aspects of concrete incorporating secondary aluminum slag". Study discusses aluminum slag which is used as a substitute for cement in concrete mixtures by testing the mechanical properties of concrete using a 15 cm x 15 cm cube sample. The results showed that aluminum slag able to replace the role of cement at a specified concentration of no more than 10% by weight of cement. Cellular lightweight concrete products are less attractive to the market in Indonesia due to various reasons, from unsecured quality, then unfavorable color, uneven shafts of bricks and others, it is necessary to add additives to make cellular lightweight concrete a product that can be compete with aerated lightweight concrete products. The development of processed lightweight cellular concrete is cheaper in terms of investment costs due to the need for simpler tools.

Lightweight concrete according to the Indonesian National Standard or SNI 2847-2013 is defined as concrete containing lightweight aggregates and a balanced volume weight between 1140 kg/m^3 and 1840 kg/m^3. Lightweight concrete has a lower specific gravity than normal concrete, and mass affects the weight of the building, so lightweight concrete can be used for earthquake resistant construction. ASTM explains that for cellular lightweight concrete the compressive strength value obtained must be greater than 1.4 MPa if it is less then it is declared as not meeting the criteria for lightweight concrete. The unit weight must comply with the range of 1100-1400 kg/m^3 or 1.1-1.4 g/cm^3, the tensile strength exceeds 0.17 MPa and the water absorption must not exceed 25%. Lightweight concrete has the purpose of using it to reduce the concrete's own load which is categorized as dead load in structural calculations, which will further reduce the dimensions of column elements, gravity load bearing elements and foundations, but in principle lightweight concrete is used to fulfill the same strength as normal concrete (Bayuaji and Biyanto, 2009).

This research used aluminum slag as a substitute for cement in a mixture of normal concrete and lightweight cellular concrete. The choice of aluminum slag in this study is an experimental effort to replace the role of cement by using environmentally friendly alternative materials such as waste from production waste in the form of aluminum slag. The purpose of this study was to determine the effect of aluminum slag as a substitute for cement in the manufacture of normal concrete on the mechanical properties of concrete.

II. Theoretical Framework

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. Dross aluminum is a gray solid or flakes, containing toxic chemicals that can pollute the environment, so caution is needed in the use of dross and its waste disposal. During the dross smelting process, aluminum will react in air to form aluminum oxide on the molten aluminum surface. Smelting of solid aluminum dross requires addition and flux to bind the remaining aluminum in primary ash, as well as sulfuric acid and ammonia acids, and produces secondary ash waste or slag which is blackish gray in color.

Aluminum slag is included in the hazardous waste material (B3) in PP 101 of 2014, namely with code B313-2 from aluminum smelting industry activities with hazard category 2, so it has the potential to pollute the environment. Aluminum is one of the constituent elements of cement, more precisely, namely aluminum oxide. Aluminum slag itself has aluminum content in it so that it has the potential to be a cement constituent.

Figure 1. Aluminum Slag

Compressive Strength of Concrete

Compressive strength criteria were obtained according to ASTM C109 M-07, using a 5x5x5 cm3 cube to test the compressive strength of concrete mortar. Cube test specimens measuring 5x5x5 cm3 were made by mixing the dough in the ASTM C305 mixer with a mixing time limit of 2 minutes 3 seconds. The purpose of testing the compressive strength of concrete is to determine the compressive strength value that can be accepted in concrete by applying a compressive force using a compression testing machine. The compressive strength of each specimen is determined by the highest compressive stress achieved during the experiment until the specimen is cracked/crushed (Mahendra, 2019). Good concrete is concrete that has a compressive strength value in accordance with the design compressive strength (Rusmansah, 2020). The compressive strength of concrete can be calculated using the formula according to SNI 03-1974-1990 as follows:

$$f'c = \frac{P}{A}$$

Description:

f'c = Concrete compressive strength (kg/cm^2)

P = Compressive load (kg)

A = Concrete cross-sectional area (cm^2)

(Source: SNI 03-1974-1990)

Water Absorption

Moisture is absorbed by the specimen. This water absorption occurs due to the presence of pores in cellular lightweight concrete. SNI 03-0349-1989 states that the specimen is suitable for use if the water absorption capacity has a maximum value of 25%. The water absorption test on concrete aims to determine the impermeability of concrete to water, good concrete generally has minimal water absorption. According to SNI 03-2914-1992 watertight concrete when tested by immersion in water must meet the maximum water absorption requirement of 6.5% by weight of oven dry concrete when soaked for 24 hours. Water absorption in concrete can be calculated using the formula according to SNI 03-2914-1992 as follows:

$$\text{Water Absorption} = \frac{bj-bk}{bk} \times 100\%$$

Description:

bj = Saturated weight (kg)

bk = Oven dry weight (kg)

(Source: SNI 03-2914-1992)

III. Research Methodology

The research method used in this study is the result of quantitative research using an empirical experimental design. Empirical design is a method that utilizes observation of the human senses so that other people can observe and know how to do it (Sugishirono, 2013). By conducting experiments in the laboratory using normal concrete made with aluminum slag as a cement substitution. The percentage of aluminum slag used is 0%; 1.5%; 3%; 4.5%; 6% and 7.5%. Data collection was carried out by making test objects in the form of cubes measuring 15 x 15 cm referring to SNI 03-1974-1990 regulations. Tests on the specimens included compressive strength tests at the ages of 7, 14, 21 and 28 days, as well as water absorption tests at the ages of 28 days with 3 specimens for each test.

Expansion on the concrete surface occurred during the trial using a cylindrical specimen, then it was decided to use a 15cm x 15cm cube specimen. The use of a 15cm x 15cm cube test object is because the cube has more sides so that when testing the compressive strength it can be placed on the side that does not expand. The trial results show that the compressive strength of a cube is much better than a cylinder with the same percentage of aluminum, slag this is also in accordance with the research by Reigita & Setiawan (2018) who conducted a concrete study with a mixture of aluminum slag with a content of 5%. using cylindrical test specimens experienced a drastic decrease in compressive strength with an average percentage of decrease reaching 77.2% of the design compressive strength. The empirical design in research is carried out by carrying out experimental activities and obtaining data through observation in each experiment. The survey data is in the form of quantitative data. Then it is processed to produce results. The stages of the research are presented in the form of a flowchart as follows:

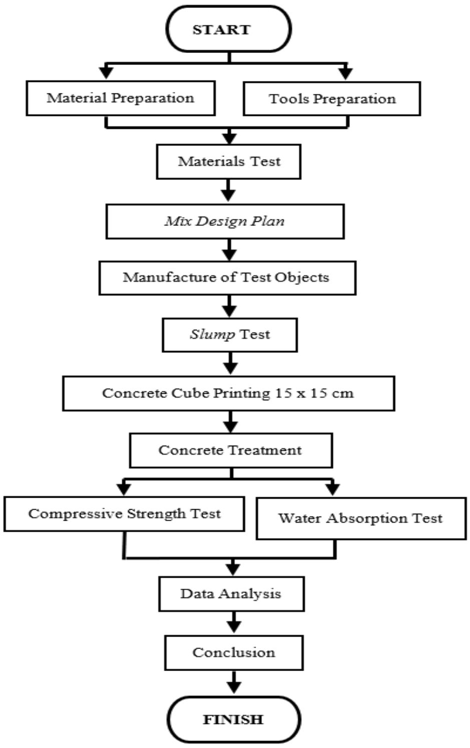

Figure 2. Research Flowchart

IV. RESULT AND DISCUSSION

Material Test

1. Cement.

Cement Gresik type used is PPC (Pozzolan Portland Cement) type cement with a specific gravity of 3.13 gr/cm^3.

2. Fine Aggregate.

The fine aggregate used is a type of Pasuruan sand that passes sieve no. 4. The results of the fine aggregate test can be seen in Table 1. The results of the fine aggregate material test are as follows:

Table 1. Fine aggregate material test results.

Test Type	Test result
Granular gradation analysis	Zone 2
Specific gravity	2,23 gram/cc
Weight per volume	1,54 gram/cm^3
Mud content in sand	2,61 %
Sand moisture content	3,64 %

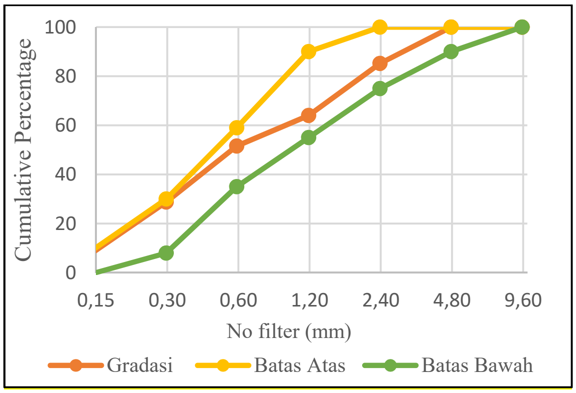

Figure 3. Graph of the Fine Aggregate Sieve Zone

3. Coarse Aggregate

The coarse aggregate used is a type of crushed stone.results of the coarse aggregate test can be seen in Table 2.

Table 2. The results of the coarse aggregate test

Test Type	Test result
Granular gradation analysis	Size < 20 mm
Fineness modulus	7,46
Specific gravity	2,78 gram/cc
Weight per volume	1,56 gram/cm^3
Free water (moisture) content of gravel	1,21 %

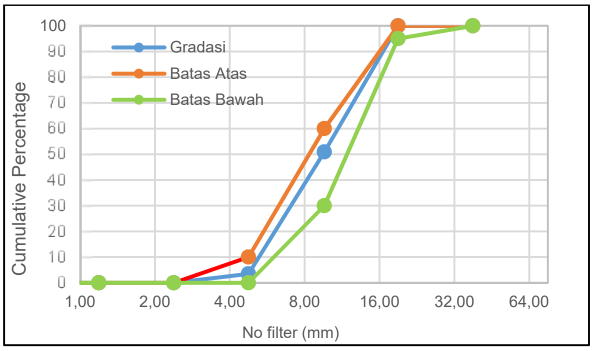

Figure 4. Gradation of coarse aggregate < 20 mm

4. Aluminium *Slag*

The aluminum slag used is waste resulting from aluminum smelting in Jombang district with a specific gravity of aluminum slag of 2.94 gr/cm^3.

Mix Desig

Calculation can be carried out mix design concrete The calculation of the composition of the concrete mix refers to the SNI 2834-2000 regulations. The quality of the planned concrete is the quality of K-300 concrete. In this study the percentage of aluminum slag used as a cement substitute was 0%; 1.5%; 3%; 4.5%; 6% and 7.5%. For the results of the composition of the concrete mixture on a cube test object measuring 15cm x 15 cm seen in table 3.

Table 3. The results of the composition of the concrete mix on a cube test object measuring 15cm x 15cm.

Variation	Gravel (kg)	Sand (kg)	Cement (kg)	Al *Slag* (kg)	Water (kg)	SP (kg)
0%	4,594	3,063	1,688	0	0,675	0,008
1,5%	4,594	3,063	1,663	0,025	0,675	0,008
3%	4,594	3,063	1,637	0,051	0,675	0,008
4,5%	4,594	3,063	1,612	0,076	0,675	0,008
6%	4,594	3,063	1,587	0,101	0,675	0,008
7,5%	4,594	3,063	1,561	0,127	0,675	0,008

Until now, there are no standard mix design. For mixed references, SNI 03-6825-2002 and relevant journals and studies are used. The mix design is based on a volume of 1 m3of lightweight cellular concrete mix, with a ratio of cement and sand of 1:2 with a water-cement factor (FAS) of 0.55. Making foam agent must be mixed with water according to the provisions in the circular letter of the minister of public works and public housing Number: 44/se/m/2015, namely the ratio of foam agent and water is 1:25 and the addition Superplasticizer is 0.5% of the total cement weight. . The compressive strength standard for lightweight bricks must be greater than 1.4 MPa with a maximum water absorption of 25%. The following is the composition of the mixed design mix in the form of a 5x5x5cm3 with the need for 18 test objects. Table 2 Results of the composition of the concrete mixture on the 5x5x5 cm^3 cube test object.

Table 4. Mix Design 5x5x5 cm^3 Cube Test Object cm^3

Code	Agregat halus (g)	Cement (g)	Al *Slag* (g)	Foam (g)	SP (ml)	Water (ml)
0%	2604	1302	0	3906	5	651
1,5%	2604	1283	20	3906	5	651
3%	2604	1263	39	3906	5	651
4,5%	2604	1243	59	3906	5	651
6%	2604	1224	78	3906	5	651
7,5%	2604	1204	98	3906	5	651

(Sumber: Hasil perhitungan).

Uji Slump

According to SNI 1972-2008, the purpose of the slump of concreteworkabilitylevel expressed in a certain value.test slump can be seen in Figure 5.

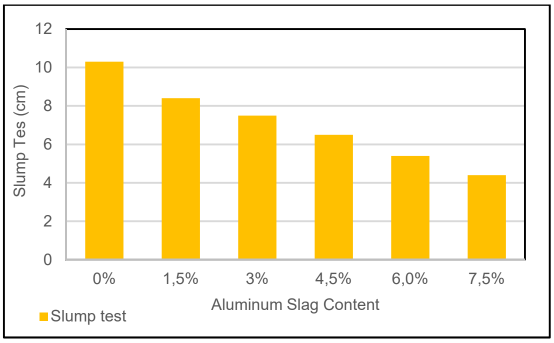

Figure 5. Test slump

Test slump in Figure 5 show that the more aluminum slag in the concrete mix, the slump decreases. The decrease that occurs in the slump is caused by aluminum slag which has a large enough water absorption. The large water absorption is due to the uniform grain size so that the cavities between the grains can still be entered by water. This shows that the use of aluminum slag as a substitute for cement in the concrete mixture can reduce the workability of fresh concrete.

Normal Concrete Volume Weight

The unit 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 concrete unit weight test refers to the 1973-2008 SNI regulations, testing was carried out at the ages of 7, 14, 21 and 28 days. For each volume weight test at each age per variation, there are 3 test objects used with 15 cm x 15 cm cube-shaped test objects.

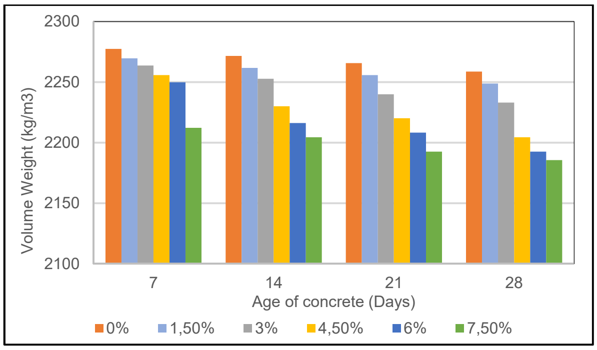

Figure 6. Graph of recapitulation of concrete unit weight results

The volume weight decreases in accordance with the proportion of aluminum slag used as a cement substitute, this can be seen in Figure 6. The effect of the presence of aluminum slag results in the swelling of the concrete surface. This expanding concrete was also found in research (Reddy and Neeraja 2016) in this study said that concrete experienced expansion due to the emergence of quite a lot of air bubbles due to chemical reactions caused by aluminum slag. Expansion in concrete due to air bubbles will become cavities in the concrete, these cavities make the concrete decrease in density so that the weight of the concrete is lighter.

Figure 7. The surface of the concrete specimen experiences expansion as a result of the influence of aluminum slag.

SNI 2834-2000 states that the unit weight of normal concrete ranges from 2200 kg/m^3 to 2500 kg/m^3, the unit weight test for concrete aged 28 days shows that the unit weight does not meet the requirements, namely the variation of 6% and 7.5 % by volume weight respectively only 2192,59 kg/m^3 and 2185,68 kg/m^3.

Volumetric Weight of Light Concrete

The process of testing the unit weight of lightweight cellular concrete is carried out before testing the compressive strength of lightweight cellular concrete. The volume weight test is carried out to determine the unity between the weight of the test object and the volume of the cellular lightweight concrete test object. This test is carried out by weighing the test object to find the weight of the test object, then from the data on the weight of the test object obtained, a calculation will be carried out to obtain the average value of the volume weight of the cellule lightweight concrete test object. This volume weight test uses a cube test object with a size of 5 x 5 x 5 cm^3. Figure 8 presents a summary of the weight-volume testing at 3, 7, 14, 21 and 28 days.

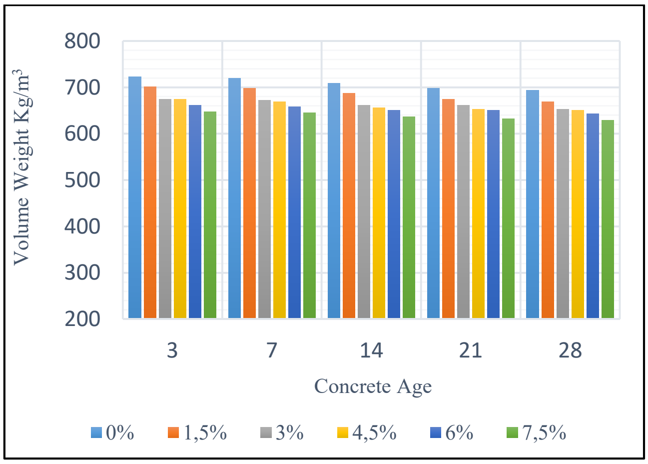

Figure 8. Volume Weight Recapitulation Graph

The highest volume weight values are found in the 0% variation with an average volume weight of 693kg/m3 and a 1.5% variation with an average volume weight of 669kg/m^3 at 28 days of age on cube test objects 5 x 5 x 5 cm^3. The resulting volume weight does not meet the requirements of the research volume weight provisions, namely between 1100-1400 kg/m^3 or 1.1-1.4 g/cm^3, however, this volume weight already meets very light concrete as insulation with a range of >800 kg/m^3 or 0.8 g/cm^3 (SNI-03-3449-2002).

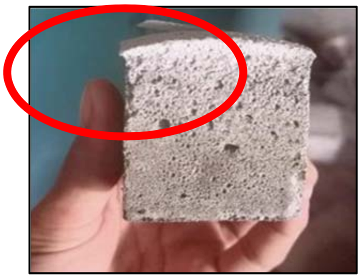

Figure 9. Expansion of Concrete Volume

The increase in the volume of light concrete due to the chemical reaction of aluminum *slag*, the increase in volume occurs at a variation of 7.5% as can be seen in Figure 5. Even though there is an increase in volume on the surface of the concrete, the volume weight is very low compared to the 0% variation.

Normal Concrete Compressive Strength

The compressive strength test of concrete was carried out in accordance with SNI 1974-1990 using cube-shaped specimens with a compressive strength unit of kg/cm2. The quality of the planned concrete is K-300. Compressive strength testing using a hydraulic concrete compressive strength tester at the Materials and Concrete Laboratory of Civil Engineering, Surabaya State University. The results of the compressive strength test can be seen in Figure 10.

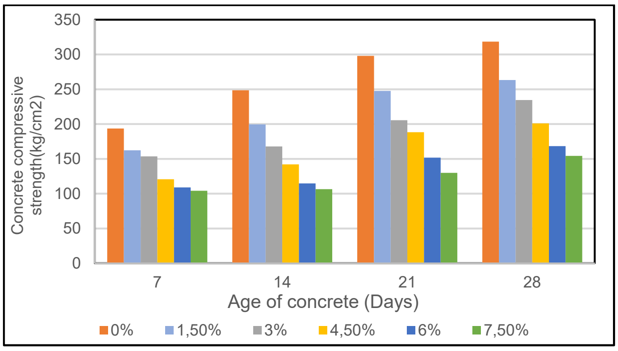

Figure 10. Graph of the compressive strength results of concrete

The results of the concrete compressive strength test in Figure 10 show that the presence of aluminum *slag* as a substitute for cement causes a decrease in the compressive strength of concrete. The compressive strength decreases as the density in the concrete decreases due to the large number of cavities that appear in the concrete due to the influence of aluminum *slag*. Optimum compressive strength was obtained with a mixture of aluminum *slag* varying 1.5% with a compressive strength of 263.3 kg/cm^2.

Compressive Strength Test of Light Concrete

Compressive strength test is carried out at the age of 3, 7, 14, 21, and 28 days using a *hydraulic tool.* This test refers to ASTM C869 (*Standard Specification for Foaming Agent Used in Making Prefoam Foam for Cellular Concrete*), explaining that for lightweight cellular concrete the compressive strength value obtained must be greater than 1.4 MPa. Each test uses 3 samples in all variations, with a cube size of 5x5x5 cm^3. Compressive strength at 28 days of lightweight concrete, with the highest compressive strength value found in a variation of 0% with an average compressive strength of 4.20 MPa, followed by a variation of 1.5% with a value of 4.13 MPa. Shows that the greater the aluminum *slag* given, the smaller the compressive strength that can be accepted, this shows that the decrease in the compressive strength value is inversely proportional to the percentage of aluminum *slag*. The compressive strength of CLC concrete cannot be as stable as it was before because the longer it lasts, the water content will decrease, because the reduced water content makes the compressive strength of CLC concrete decrease. Compressive strength recapitulation is presented in Figure 6. Compressive strength recapitulation shows the result of a decrease in compressive strength due to the addition of aluminum *slag*, the greater the addition of aluminum *slag*, the lower the compressive strength. The most optimal addition is found in the 1.5% variation and the compressive strength is almost the same as the 0% variation.

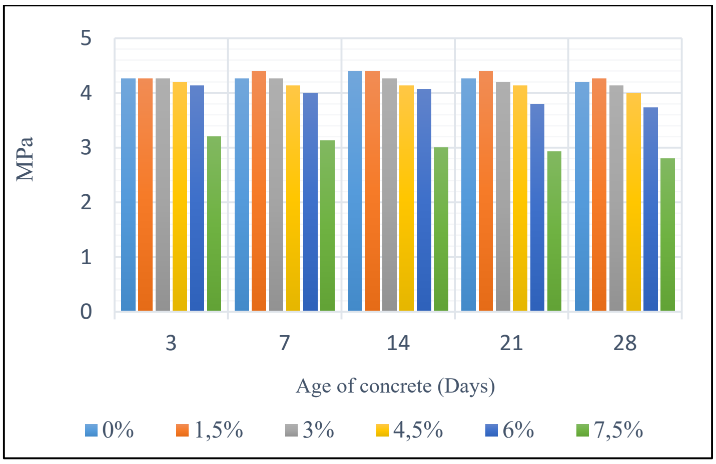

Figure 11. Compressive Strength Recapitulation Graph

Water Absorption Test on Normal Concrete

Water absorption test on concrete refers to SNI 2914-1992 regulations. Results of the water absorption test can be seen in Figure 12.

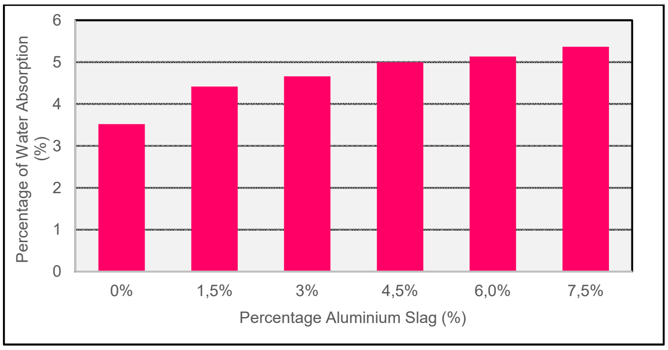

Figure 12. Graph of the results of water absorption in concrete

Recapitulation of the results of concrete water absorption in Figure 9 shows an increase in concrete water absorption due to the addition of aluminum *slag,* this shows that the increase in water absorption is directly proportional to the percentage of aluminum *slag*. The increase in water absorption occurs because of the voids created because the concrete expands due to the influence of aluminum *slag.* The cavity will provide empty space in the concrete, this is what increases the absorption of water in the concrete. The SNI 2914-1992 regulations state the requirement for watertight concrete with a maximum percentage of 6.5%, from this every variation from 0% to 7.5% meets the requirements in the regulations.

Water Absorption Test in Lightweight Concrete

The water absorption test was carried out aiming to determine the percentage of pore cavities in the specimen so as to determine the percentage of absorption that occurs in the specimen under study. This test refers to SNI-2914-1992. Tests were carried out on each variation, with the number of each variation being 3 test objects. Tests were carried out on CLC concrete specimens aged 28 days. Tests were carried out at the Laboratory of Materials and Concrete, State University of Surabaya. The results of the water absorption test refer to ASTM C869 with conditions of 25%.

There was an increase in the CLC concrete absorption test, due to the addition of aluminum *slag* causing many cavities in the CLC concrete. The results obtained exceeded the requirements, namely 25% water absorption from ASTM C869, so that it was declared as not meeting the requirements from ASTM C869. The most optimal addition of aluminum *slag* was in the 1.5% variation, because it has a small percentage of water absorption. The following figure 13:

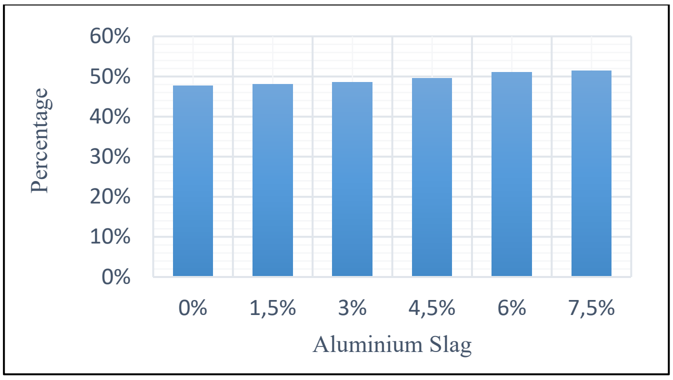

Figure 13. 28 Days Water Absorption Test

1. Results of Normal Concrete Relationship Analysis

a. The relationship between the compressive strength of concrete and the unit weight of concrete

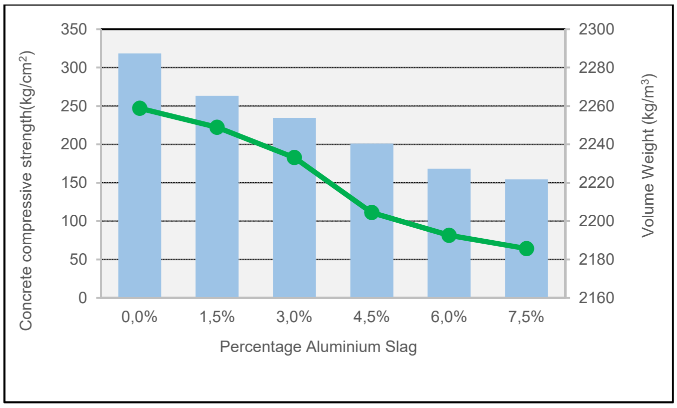

Figure 14. Graph of the relationship between compressive strength and concrete unit weight

Based on Figure 14, it shows that there was a decrease in the compressive strength of concrete on the 28th day, which is directly proportional to the concrete unit weight on the 28th day. The smaller the volume weight, the smaller the compressive strength concrete test object. The effect of aluminum *slag* causes the concrete to expand so that the volume in the concrete increases resulting in the creation of cavities which can reduce the density of the concrete, this is what affects the decrease in the compressive strength and unit weight of the concrete.

b. Relationship between compressive strength of concrete and water absorption

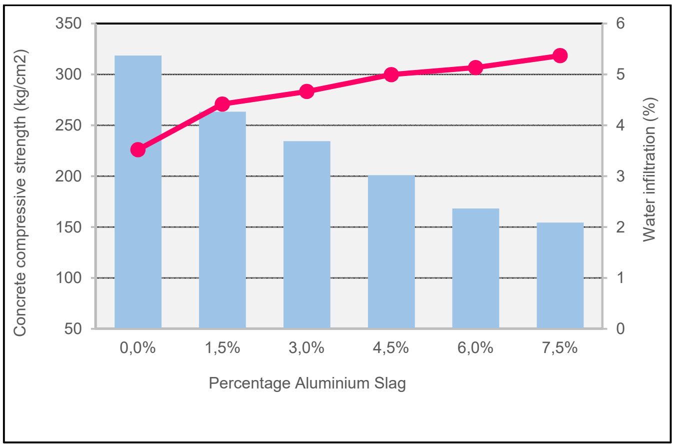

Figure 15. Graph of the relationship between compressive strength and water absorption in concrete

The graph of the relationship between compressive strength and water absorption in Figure 15 shows a decrease in the compressive strength of concrete on the 28th day which is inversely proportional to the increase in water absorption on the 28th day for each variation. The smaller the compressive strength of the concrete, the greater the absorption of water. The increase in water absorption is due to the creation of cavities in the concrete due to the concrete expanding due to the influence of aluminum *slag.* The cavity created will cause greater absorption of water in the concrete, but can also reduce the density of the concrete so that it will affect the decrease in the compressive strength of the concrete.

c. The relationship between the volume weight of concrete and water absorption

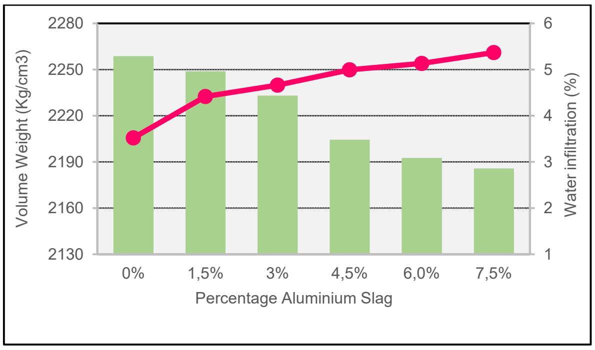

Figure 16. Graph of the relationship between volume weight and water absorption in concrete

The decrease occurred in the concrete volume weight on the 28th day which was inversely proportional to the increase in water absorption on the 28th day for each variation, this can be shown in Figure 12. The smaller the concrete's unit weight, the greater the water absorption. The cavity in the concrete that is created because the concrete expands due to the influence of aluminum slag makes the volume of the concrete increase thereby creating empty space in the concrete which reduces the density of the concrete so that it will affect the decrease in the weight of the concrete, but the number of cavities will result in increased water absorption in the concrete.

2. Results of Relationship Analysis of Lightweight Concrete

a. This relationship analysis was obtained after completing the compressive strength test and volume weight test on the test object in each variation. Relationship analysis will be carried out to find out comparisons in order to find out the results and comparisons for each variation used. The following are some results of the comparison of the compressive strength and volume weight tests carried out:

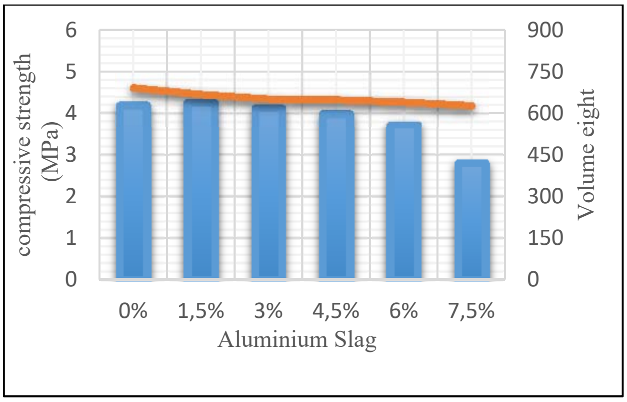

Figure 17. Analysis of compressive strength and volume weight at 28 days of age

Generate different values. At 0% variation without the addition of aluminum *slag* the compressive strength values were 4.2 MPa and 693.3 kg/m^3 on the volume weight test and on the addition of aluminum *slag* the compressive strength and unit weight values were the most optimum on the test object variation 1 .5% of 4.3 MPa and 669.3 kg/m^3 in the volume weight test. So it can be concluded that the compressive strength test and volume weight test at 1.5% variation have more optimum results, compared to other variations. The ASTM explains that for cellular lightweight concrete the compressive strength value obtained must be greater than 1.4 MPa. The volume weight must comply with the range of 1100-1400 kg/m^3 or 1.1-1.4 g/cm^3. So that it can be stated that it meets the requirements for compressive strength at 1.5% variation with a value of 4.3 MPa, while the volume weight at this 1.5% variation does not meet the target volume weight, but the volume weight meets very light concrete as insulation with a range >800 kg/m^3 or 0.8 g/cm^3 (SNI-03-3449-2002).

b. Analysis of the relationship between compressive strength and water absorption

Analysis of the relationship between compressive strength and water absorption. This analysis was obtained after completing the compressive strength test and water absorption test on the test object in each variation. Relationship analysis will be carried out to find out the ratio of compressive strength and water absorption to find out the comparison between every variation. The following are some of the comparative results of the compressive strength and water absorption tests carried out:

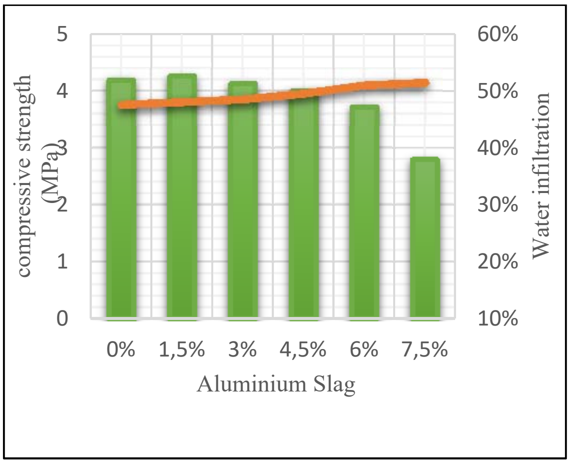

Figure 18. Analysis of Compressive Strength and Water Absorption at 28 Days Age

It is known that the analysis of the relationship between compressive strength and water absorption at 28 days CLC concrete ages, it is known that each variation produces a different value. In the 0% variation without the addition of aluminum *slag* , the compressive strength was 4.2 MPa and 47.6% in the absorption test. From the addition of aluminum *slag* which obtained the optimum compressive strength and water absorption values on the 1.5% variation test object of 4.3 MPa and 48.1% water absorption was tested. So it can be concluded that the compressive strength test meets the requirements because it is greater than 1.4 MPa (ASTM C869), while the water absorption has exceeded the maximum 25% provision in the regulations (ASTM C869).

c. Analysis of the relationship between weight-volume and water absorption

Analysis of the relationship between weight-volume and water absorption. Analysis of this relationship was obtained after completing the volume-weight test and water absorption test on the test object in each variation. variation. The following are some results of the ratio of volume weight and water absorption tests carried out:

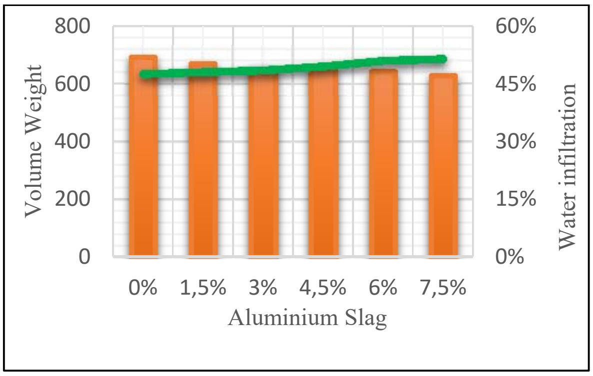

Figure 19. Analysis of volume weight and water absorption at 28 days of age

Figure 19 can be seen from the analysis of the relationship between volume weight and water absorption at the age of 28 days CLC concrete, it is known that each variation produces a different value. In the 0% variation without the addition of aluminum *slag* , the unit weight strength value was 693.3 kg/cm^3 and 47.6% in the absorption test. From the addition of *aluminum slag* , the optimum unit weight and water absorption values for the 1.5% variation test specimen were 693.3 kg/cm^3 and 48.1% were tested for water absorption. So it can be concluded that the highest unit weight test for this variation does not meet the target unit weight, but the unit weight meets very light concrete as insulation with a range of > 800 kg/m^3 or 0.8 g/cm^3 (SNI-03-3449- 2002), while the water absorption has exceeded the maximum requirement of 25% in the regulations (ASTM C869). testing was carried out at the age of 28 days.

V. Conclusion

Based on the results of the research that has been done, it can be concluded that the use of aluminum *slag* as a substitute for cement in normal concrete production requiresan increase in the volume of the concrete or expansion of the surface of the concrete which increases with the increase in the percentage of aluminum *slag*. The compressive strength and unit weight decreased as the percentage of aluminum *slag increased.* The decrease occurs because the large amount of air trapped in the concrete causes the density of the concrete to decrease. The optimal percentage recommended by using aluminum *slag* as a cement substitute is 1.5%, the use of too much aluminum *slag* in the concrete mixture can reduce the mechanical properties of the concrete.use of aluminum *slag* as a substitute for cement can reduce *workability* of concrete. The water absorption of concrete increases with increasing percentage of aluminum *slag*. The use of aluminum *slag* causes the concrete to expand thereby creating cavities, with the many cavities created causing greater water absorption in the concrete. While the use of aluminum *slag* as a substitute for cement in the manufacture of lightweight cellular concrete The optimal percentage of using aluminum slag in CLC lightweight concrete mixtures is obtained by substituting 1.5% aluminum slag to the total weight of cement for each variation, when it is greater than 1.5%, there will be the decrease in compressive strength and specific gravity is due to the fact that when the substitution is more than 1.5%, segregation of lightweight concrete material occurs so that the composition contained in lightweight concrete is unbalanced causing long drying time and swelling of the concrete. The addition of more than 1.5% aluminum slag causes a lower unit weight, when the specific gravity is low, the resulting compressive strength is low. The effect of substitution of added material in the form of aluminum slag in the CLC lightweight concrete mixture, affects its mechanical properties in the form of decreased compressive strength for 6% and 7.5% aluminum slag substitution compared to 1.5% substitution, the following is the value for 1.5% aluminum substitution slag obtained 4.3 MPa at the age of 28 days. The effect of volume weight on the substitution of added material in the form of aluminum slag in the CLC lightweight concrete mixture, the effect on the surface of the CLC concrete occurs in the form of an increase in the volume of CLC concrete in the substitution of the 7.5% aluminum slag variation compared to the 1.5% aluminum slag variation which gets a higher weight value. the optimum on the test object is 693.3 kg/cm^3. The relationship between compressive strength and curing time of CLC lightweight concrete is related especially to 1.5% aluminum slag substitution, when the age of CLC lightweight concrete increases, less water is in the concrete and at 28 days the greatest compressive strength occurs at 1.5% substitution. aluminum slag is 4.3 MPa and water absorption is 48.1%.

Recommendation

Suggestions from the testers for further research on normal concrete should check the condition of the material must be carried out so that the concrete can meet maximum results; it is necessary to test the material against aluminum slag, to find out its properties in detail; the addition of aluminum slag in the process of making normal concrete produces a small compressive strength, it is also necessary to add other materials so that the resulting compressive strength can meet the requirements of the compressive strength quality standard. Whereas for lightweight cellular concrete, to obtain more optimal results, the substitution rate for cement and aluminum slag is 1.5%, for CLC lightweight concrete mixtures, more in-depth research should be carried out on the substitution of cement and aluminum slag with the addition of other ingredients. It is necessary to reconsider the addition of aluminum slag or aluminum slag in CLC concrete support additives due to a decrease in compressive strength and water absorption. It is necessary to pay attention again to the comparison in the use of foam agents and water, then pay attention also to the process of making foam so as to obtain optimal results. It is necessary to pay attention again in mixing mortar and foam dough because when the mixing process is uneven it can affect the results of the test object.

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