RESEARCH ARTICLE | JULY 21 2023

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AIP Conference Proceedings 2689, 040006 (2023)
https://doi.org/10.1063/5.0114932

Compressive Strength Characteristic of Fly Ash Light Concrete Mixture using Artificial Light Weight Aggregate (ALWA)

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Abstract. Lightweight concrete consists of silica sand, lime, cement, water, plus other additives where the specific gravity is below 1800 kg/cm^3. Lightweight concrete is often found on the walls or roofs of houses and buildings without or with reinforcement because it is easy to mould and cut during installation and has fast ageing concrete. The specific gravity of lightweight concrete, in general, will be inversely proportional to its compressive strength. The lighter one is the concrete, and the lower one is the compressive strength. Artificial Light Weight Aggregate (ALWA) as a substitute for coarse aggregate will undoubtedly reduce the specific gravity of concrete. At the same time, the use of fly ash is expected to increase the compressive strength of lightweight concrete. The purpose of this study is to determine the optimum compressive strength of fly as a light concrete mixture using coarse aggregate ALWA with a percentage of 5%, 7.5%, 10%, 12.5%, 15%, compared to standard concrete with fly ash mixture of 12.5%. Three cube-shaped samples were prepared for each percentage of the ALWA mixture tested for compressive strength at 14 days, 21 days and 28 days, with a total of 63 samples. The test results show a decrease in compressive strength of up to 20.9% (from 19.85 MPa to 15.7 MPa) in 12.5% fly ash mixed concrete using ALWA coarse aggregate about 7.8% at 28 days of concrete age testing. Then, with the addition of ALWA coarse aggregate more significant than 7.8%, the compressive strength of the concrete will increase until it reaches 19.85 MPa in the range of 16% addition of ALWA. However, the specific gravity of fly ash mixed concrete will be reduced by 2.8% with 16% ALWA coarse aggregate. It can be seen that the addition of 16% of ALWA coarse aggregate in fly ash mixed concrete can optimally reduce the specific gravity of the concrete without reducing the compressive strength of standard concrete.

INTRODUCTION

Currently, the construction increasing growth as in the construction of a bridge, building, house, road, and the other buildings. The material concrete in the construction industry has been used for a long time because it has various advantages over other structural materials, such as compression strength. Therefore, concrete in modern construction significantly increased, which requires new technology developments of innovations concrete in the future. The lightweight concrete is a material of silica sand, lime, cement, water, plus other additives where the specific gravity is below 1800 kg/cm^3. Lightweight concrete is often found on the walls, blocks, or roofs of houses and buildings without or with reinforcement because it is easy to mould and cut during installation. The compressive strength of concrete was influenced by the type of coarse aggregate and fine aggregate as a filler bounded by a mixture of cement and water. In some areas in Indonesia, there are still problems to have good quality concrete in the field. Firstly, cement has limitations in its grain fineness, so that other alternative are needed to minimize the use of cement. Second, the cement production process also harms the environment, such as the air polluted by fine particles. Therefore, innovation and technological development are needed to comply with the use of good concrete. Mixing coarse aggregate with lightweight material is one alternative to produce good concrete innovation.

Toward Adaptive Research and Technology Development for Future Life
AIP Conf. Proc. 2689, 040006-1–040006-8; https://doi.org/10.1063/5.0114932
Published by AIP Publishing. 978-0-7354-4470-6/$30.00

Referring to [1], there are several innovations in increasing the compressive strength of concrete, namely fly ash as a partial replacement for cement composition in concrete. Fly ash can be used as a filler for cavities to increase the compressive strength of concrete and the concrete resistance to water, having an excellent particle shape. This substitute material can prevent fine cracks on the concrete surface. Nevertheless, using fly ash too excessively can make the quality of the concrete decrease. Artificial Light Weight Aggregate (ALWA) comes from burning clay in Cilacap and Central Java Indonesia for lightweight aggregate in concrete. Studies with this lightweight material as coarse aggregate in concrete mixtures show good results. Setiawati [2] examined 12.5% fly ash in concrete as an optimum substitute for cement, getting a concrete compressive strength of 39.6 MPa, an increase of 27.95% compared to standard concrete at the age of 28 days. Kasyanto & Susanto [3] have been researching 15% ALWA at the age of 56 days' influence of the compressive strength of standard concrete and obtain optimum results 39.7 MPa. It refers to the research on ALWA that has been carried out [3–10]. Therefore, this study combines fly ash as a partial replacement of cement with ALWA as a partial replacement of coarse aggregate to determine the compressive strength characteristics of lightweight concrete.

According to SNI 2847, concrete is defined as a mixture of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixture. In its manufacture, the composition of the concrete needs to be planned to achieve financial results by taking into account the specification limits and can guarantee the compressive strength of the concrete. In essence, concrete is classified into concrete based on quality and concrete based on specific gravity. Concrete based on quality divided: low quality with an average compressive strength of below 20 MPa, medium quality with an average compressive strength of 20-40 MPa, and high strength concrete with a compressive strength of more than 42 MPa. Concrete based on specific gravity can be grouped into four, namely very light concrete with a specific gravity <1000 kg/m^3, lightweight concrete with a maximum specific gravity of 1900 kg/m^3, concrete with a specific gravity of 2300 – 2500 kg/m^3, and heavy concrete with a specific gravity > 3200 kg/m^3. ALWA, commonly referred to as bekah clay, is made from shale-type clay burned in a rotary furnace, and then coal powder is added to help heating and development [10]. Based on data from the Research and Development Public Works Loka Settlement Technology in Cilacap [3], ALWA has a unit weight of 0.45 – 0.75 kg/cm^3, Absolute Dry Specific Gravity is 0.75 – 1.20 kg/cm^3, water absorption (24 h) is 16.50 – 20%, Fineness Modulus (FM) is 5 – 7% and crushing test 40 T is 40 – 53% (Figure 1). From the technical data, this ALWA has the potential of lightweight concrete that has high compressive strength. SNI 2460 (2014), fly ash has a relatively fine grain, which passes through the No sieve. 325 (45 mill microns). The pozzolanic processing properties of fly ash are similar to those of other pozzolanic materials. From the above theory, concrete with a light specific gravity and a high compressive strength by utilizing fly ash as a partial cement replacement can make high compressive strength and ALWA for a partial substitute for coarse aggregate, making the concrete light.

(a) (b)

FIGURE 1. (a) ALWA & (b) Fly Ash

METHOD OF RESEARCH

The method of aggregate testing refers to the SNI (Indonesian National Standard) testing standard. In general, the sequence of research stages includes preparation of concrete making materials, material testing, design of concrete mix (mix design), preparation of test specimens or concrete, examination of the slump, drying the specimen for 24 hours, soaking and Concrete Compressive Strength Testing. In this study, the concrete mix design calculation used is the internal method (SNI 7656-2012). According to (SNI 7656-2012), fine aggregate is natural sand resulting from the natural disintegration of rock or sand produced by the stone crusher industry and has a grain size of 5 mm. Referring to SK-SNI-T-15-1990-03, the sand roughness is divided into four groups according to the gradation: fine sand, slightly

fine, slightly coarse, and coarse. According to SNI 1970 (2008), coarse aggregate is a mixture of concrete in gravel resulting from the natural destruction of rocks or in the form of crushed stone obtained from breaking stones with grain sizes between 4.75 mm to 40 mm. Based on (SNI 7656-2012), water for the manufacture of concrete meets the minimum requirements, namely clean and free from damaging substances containing oil, oil, acid, alkali, salt, or other organic materials that can damage the concrete or its reinforcement. The methodology used for this experimental study can be seen in the Flowchart from Figure 2:

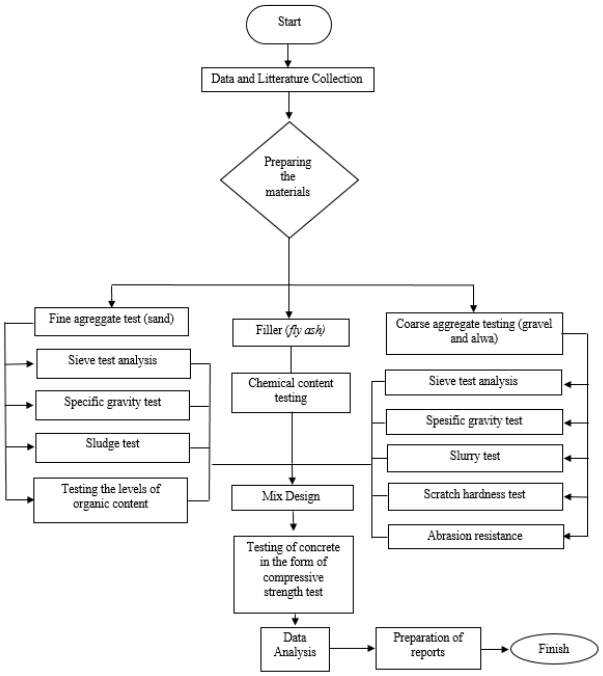

FIGURE 2. Flowchart of experimental test

This research use cube-shaped (150 mm x 150 mm x 150 mm) and samples of light concrete mixed with 12.5% fly ash along with ALWA aggregate as a substitute for coarse aggregate are testing. ALWA mixing variations in lightweight concrete are 5%, 7 ,5%, 10%, 12.5%, and 15% respectively. The compression test was carried out when the concrete reached the age of 14 days, 21 days, and 28 days. A comparison was also carried lightweight concrete compressive strength test with a mixture of 12.5% fly ash without ALWA.

RESULT AND DISCUSSION

The results of laboratory tests for coarse aggregate can be seen in Table 1:

TABLE 1. Coarse aggregate test

Test Type	Test Result	ASTM C-33 Standard	Conclusion
Bulk specific SSD	2,59 gr/cm^3	2,5-2,7	Qualify
Abrasion	29,52%	Maximum 50 %	Qualify
Mud Content	1,35%	-	-
Scratch Hardness	9,20%	-	-

The results of the fine aggregate test can be seen in Table 2:

TABLE 2. Fine aggregate test

Test Type	Test Result	ASTM C-33 Standard	Conclusion
Bulk specific SSD	2,62 gr/cm3	2,5-2,7	Qualify
Abrasion	4,3 %	5%	Qualify
Organic matter content	Light Yellow	Clear or Light Yellow	Qualify

Slump value is a measure of the degree of viscosity of a concrete mortar to ease the process in this study, as shown in Figure 3, which shows the addition of ALWA will increase the slump value in concrete:

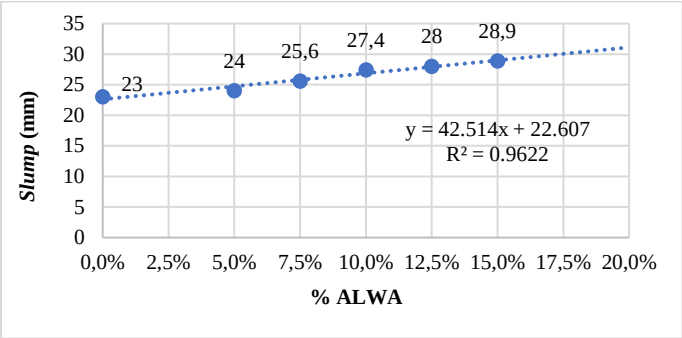

FIGURE 3. Slump value with variation of the addition of ALWA

The standard for testing the compressive strength of concrete used refers to SNI 1974-2011. The following are the results of the tests that have been carried out as shown in Table 3:

TABLE 3. Average compressive strength

	Average compressive strength (MPa)			
	14 Days	21 Days	28 Days	56 Days
Normal Concrete 0%	17,85	18,00	19,85	14,29
Normal Concrete Fly Ash 12,5%	17,92	18,51	20,73	-
Concrete Fly Ash 12,5%, ALWA 5%	12,67	16,00	16,97	30,71
Concrete Fly Ash 12,5%, 7,5%	13,03	14,30	15,70	19,07
Concrete Fly Ash 12,5%, 10%	13,78	15,33	16,89	22,21
Concrete Fly Ash 12,5%, 12,5%	12,00	17,70	17,85	41,79
Concrete Fly Ash 12,5%, 15%	15,70	17,70	19,11	24,36

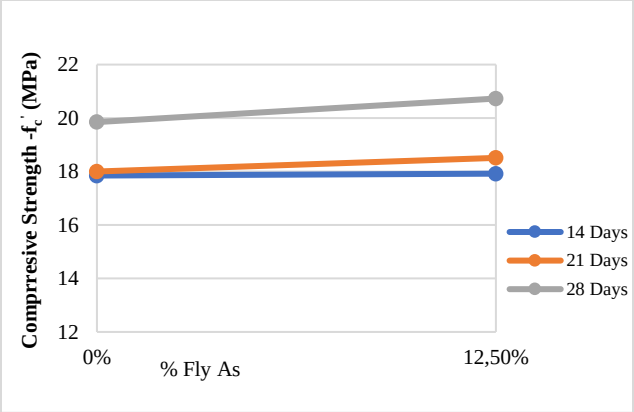

FIGURE 4. Compressive strength of fly ash mixture

The graph above shows that the addition of fly ash can increase the compressive strength of concrete at each age of concrete testing. This condition is possible because the fly ash particles are excellent to fill the voids of the concrete, which is becoming increasingly dense. Fly ash will also react to bind free lime created during the cement hydration process by the silica contained in fly ash. It can be seen that at the age of 28 days, the concrete has exceeded the planned compressive strength of lightweight concrete, which is 20.73 MPa. It can also be seen that with the increasing age of concrete, its compressive strength will also increase.

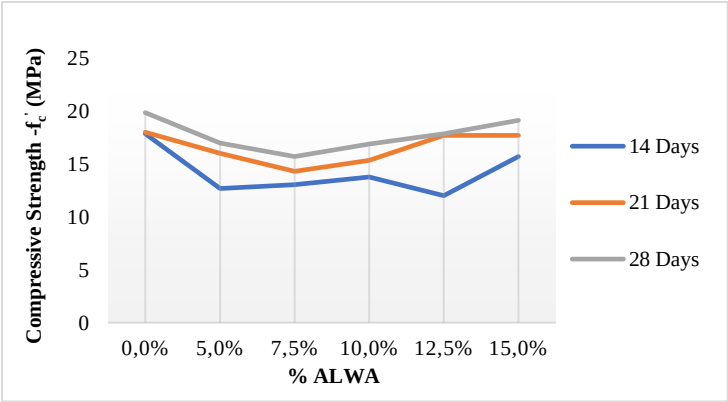

FIGURE 5. Compressive strength of 12.5% fly ash mixed concrete with a variation of ALWA addition

Figure 5 shows the comparison of the strength of concrete at the age of 14, 21 and 28 days. There is a downward trend in compressive strength with coarse aggregate ALWA instead of around 7%. The strength of concrete will increase again significantly until it reaches normal compressive strength with the addition of approximately 16% ALWA at the age of 28 days of testing. The test results data at 14 days more scattered than in the age of 21 days and 28 days because of preparation and moulding of test specimens manually affect the mixing and compaction of the concrete, whether it will accelerate or delay the process of hardening concrete.

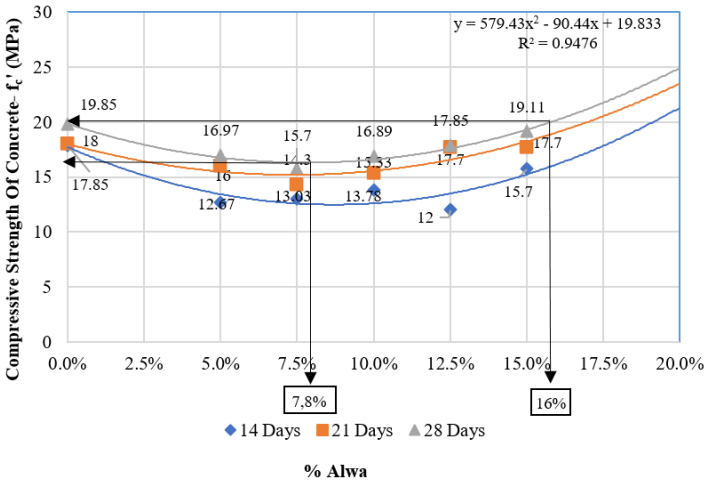

FIGURE 6. Combined compressive strength of fly ash concrete with ALWA

In Figure 6, visible characteristics are consistent for each of the ageing of concrete. There was a decrease to the point of minimum compressive strength of 16.30 MPa at the age of concrete 28 days with the addition ALWA 7.8%, which amounted to 18% compared to the compressive strength of standard concrete. After that, the compressive strength will increase by an average of 5.15% until it reaches the standard concrete compressive strength of 20 MPa with a percentage addition of 16% ALWA at the age of 28 days of testing.

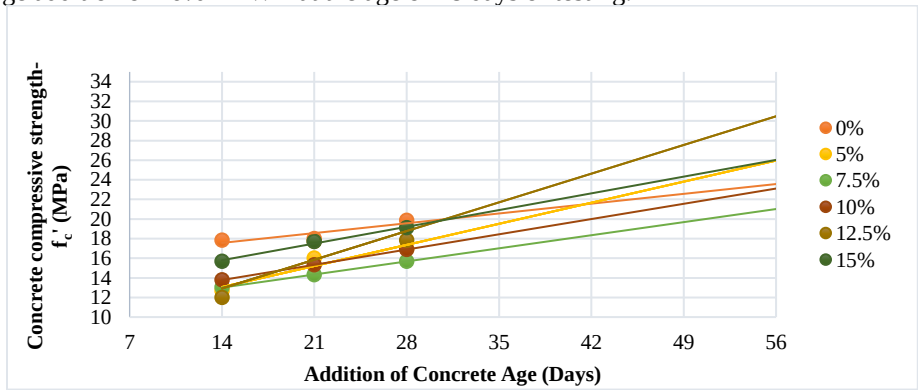

FIGURE 7. Compression strength prediction in 56-days concrete

Previous research showed that 15% ALWA concrete mixture obtained optimum results at a test age of 56 days [3]. In this experimental study, the compressive strength results can be estimated at 56 days of age from Figure 7. The optimum compressive strength occurs at the addition of 12.5% ALWA, which is 41.79 MPa. However, the compressive strength close to the compressive design strength is at 10% ALWA percentage, 22.21 MPa. Thus, an increase in the age of concrete is directly proportional to the increase in compressive strength of the concrete.

The test results at 28 days in standard concrete and concrete with fly ash mixture of 12.5% in a row is 2284 kg / m3 and 2281 kg/m^3. It can be seen that the specific gravity of the concrete only decreased by 0.1%, which means that fly ash had no significant effect on the decrease in the specific gravity of the concrete compared to the reduction in specific gravity with the addition of ALWA.

Figure 8 shows the test results lightweight density concrete with fly ash mixture of 12.5%, which varied as much as ALWA respectively 5%, 7.5% 10% 12.5%, 15%. At the age of 28-day compressive strength of concrete is achieved in a row is 1904 kg/m^3, 1881 kg/m^3, 1891 kg/m^3, 1874 kg/m^3, 1847 kg/m^3. Based on the data density with the addition of fly ash concrete, ALWA meets ISO standards 03-2847-2000. Concrete density reduction at ALWA mixture of 1%. The graph can also be estimated that density concrete with optimum ALWA addition of 16% is 1843 kg/m^3.

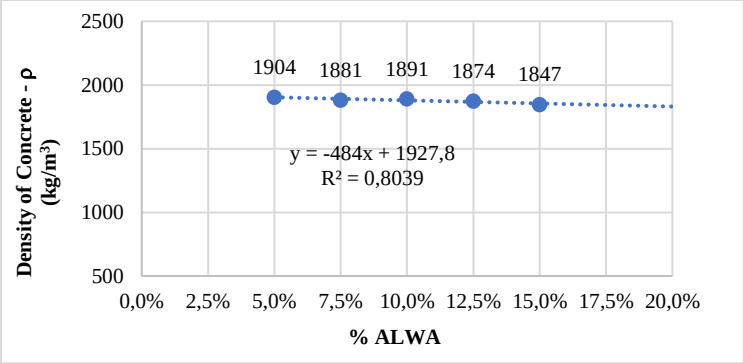

FIGURE 8. The density of concrete (ρ) with variation ALWA 28 days

Furthermore, the concrete with a 12,5% fly ash percentage decreased by 0.13% compared to standard concrete, but the compressive strength increased by 4.24% compared to regular concrete. This suggests that fly ash does not significantly influence concrete density because the concrete type weight loss is not significant. Instead, fly ash increased the compressive strength of concrete (Figure 9).

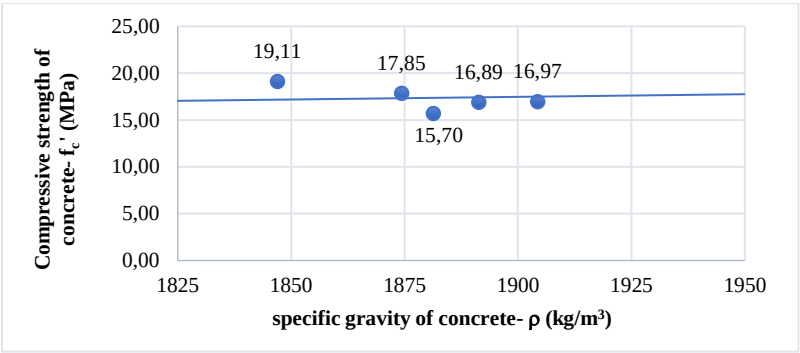

FIGURE 9. Specific gravity (ρ) vs compressive strength of mixture concrete at 28 days

TABLE 4. Percentage of decrease in specific gravity of concrete at 28 days

% ALWA	Specific Gravity (kg/m³)	F_c' (MPa)	% Reduction
0	2284	19,85	17%
5%	1904	16,97	1%
7,5%	1881	15,70	-1%
10%	1891	16,89	1%
12,5%	1874	17,85	1%
15%	1847	19,11	1%

The use of ALWA in concrete will reduce the specific gravity and the compressive strength of the concrete to a specific limit of around 7,5%. After that, even though the specific gravity of the concrete decreases with the addition of ALWA, the compressive strength will increase significantly until it reaches 20 MPa with the addition of 16% ALWA (Table 4). The addition of 5% ALWA will reduce the density of concrete significantly up to 17%, then with an average increase of 2.5%, ALWA only reduces the specific gravity of concrete equal to 1%.

CONCLUSION AND RECOMMENDATION

Based on the experimental test result, can be seen in the chart 12.5% fly ash replacement and ALWA affect the compressive strength of concrete. Concrete age of 28 days, decrease to the point of minimum compressive strength of 7.8%, i.e. 16.30 MPa. The decrease that occurs from the usual concrete compressive strength to the minimum point is

18%. Compressive strength increases an average of 5.15% until it reaches the compressive strength of the plan. It can be seen that the average standard concrete on day 28 is 19.85 MPa. While the optimum compressive strength of concrete with fly ash and ALWA is 19.11 MPa. Thus, the percentage reduction in compressive strength of standard concrete compressive strength to concrete Optimum ALWA fly ash is 3.72%. The substitute of 12.5% fly ash and ALWA of mixed concrete can affect the compressive strength of the concrete. It can be estimated that the increase in the compressive strength of the mixed concrete will meet the 20 MPa lightweight concrete can occur at an additional 16% of ALWA. The use of more ALWA will make the concrete lighter. Otherwise, the compressive strength of the concrete will decrease to a minimum of 7.8% ALWA and then slowly increase until it reaches the standard compressive strength of concrete at an ALWA percentage of 16%.

Moreover, fly ash has no significant effect on reducing the specific gravity of concrete but increases the compressive strength of concrete. The decrease in early compressive strength of concrete, ALWA expected to occur because of segregation between coarse and fine aggregate because the specific gravity of the ALWA aggregate is lighter than gravel. When it is inserted into the cube mould, the ALWA aggregate rises to the top. However, the specific gravity of fly ash mixed concrete will be reduced by 2.8% with 16% ALWA coarse aggregate. It can be seen that the addition of 16% of ALWA coarse aggregate in fly ash mixed concrete can optimally reduce the specific gravity of the concrete without reducing the compressive strength of standard concrete.

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