The Comparison of Compressive Strength of Normal Concrete with Artificial Lightweight Aggregate Concrete

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Abstract: This study was conducted to investigate the effect of using Artificial Lightweight aggregates (ALWA) from clay soil as partial substitution for coarse aggregates in normal concrete by determine the mass of concrete and its effect on the compressive strength. The proportion of ALWA in design mix was 0%, 10%, 20%, and 30% with w/c ratio 0.3 and 25 Mpa in concrete strength. The method used was ACI with cylinder sample at test age 28 and 56 days. The weight of ALWA concrete was 12.97 kg and 13.05 kg (0%), 12.07 kg and 12.12 kg (10%), 11.45kg and 11.58kg (20%) and 10.95 kg and 11.17 kg (30%). The test result in 0 % ALWA concrete was 25.67 MPa and 25.95 MPa, 23.40 MPa and 23.87 MPa (10%), 18.02 MPa and 18.49 MPa (20%) and 15.29 MPa and 15.85 MPa (30%). The results indicated that the higher the percentage in ALWA, the less the weight of concrete. Variation in ALWA percentages affected the compressive strength, but in concrete ages, it did not have effect. However, the strength of the concrete may decrease, but still can be used as a structural concrete with a lighter weight.

1 INTRODUCTION

Aceh Province is one of the areas that have a high level of earthquake intensity. The magnitude of the intensity of the earthquake caused many casualties and destroyed many residentsial building. Generally, construction planning and implementation in residential buildings, educational institutions, commercial, industrial and other public facilities are dominated by concrete structures that use aggregate materials as one of the main components.

These Aggregates make the mass of concrete increased and heavier. Another way to get lighter concrete is to replace some of the coarse aggregates with lightweight aggregates using alternative materials that are easily found in the environment. The lightweight aggregates can reduce the unit weight of concrete, but has compressive strength that is almost the same as normal concrete.

One way to get lighter concrete is to replace some of the coarse aggregates on the concrete. This coarse aggregate will be partially substituted with artificial Lightweight aggregates (ALWA) made from clay soils. The number of small industries engaged in the manufacture of bricks in Aceh Barat, especially Meulaboh has a type of clay soil that can be utilized as a material of lightweight aggregates.

This coarse aggregate of ALWA is made from clay soil by adding rice husk ash in it. The addition of rice husk ash is to increase the strength because the silica content in it is high. The use of rice husk ash is to reduce the rice husk waste that accumulates at the location of rice mill. Also rice husk ash and clay soil easily found in the surrounding Regency of West Aceh.

2 MATERIAL AND METHODS

2.1 Preparation of Samples

Production of ALWA is completed in brick factory in Gampong Ujong Patihah, Nagan Raya District. Concrete work started from examination of aggregate physical properties, making of specimens, curing and testing of specimens were conducted at the Public Works Laboratory of West Aceh.

The material used to produce artificial lightweight aggregate (ALWA) is Portland cement, clay soil, rice husk ash, fine aggregate (sand) and water. Then, as comparison, normal concrete was made at 25 MPa concrete strength with Portland cement material, fine aggregate (sand), coarse aggregate (gravel) and water. Portland cement type I used as ingredients in

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producing concrete. There is no Laboratory examination for cement because it meets Indonesian National Standard (SNI) l5-20490-1994. The examination is only done visually against the torn bag and there are no hard clumps on the cement.

Examination of coarse aggregates (gravel) and fine aggregates (sand) as concrete-forming materials is necessary to obtain good material quality (anonymous 1982). This examination is performed on aggregate properties that include specific gravity, absorption, bulk density, sieve analysis, and fineness modulus. Then continue with ALWA aggregate production process which is done in brick making factory in gampong Ujong Patihah of Nagan Raya Regency.

The water used in the mixture of concrete and its curing comes from clean water obtained from the West Aceh Public Works Laboratory. The water in this laboratory meets the standard of clean water suitable for concrete mix.

2.2 Stage of Works

2.2.1 Process and Producing Artificial Lightweight Aggregates (ALWA)

According to SNI 03-2461-2002, Artificial Lightweight Aggregates (ALWA) made by heating materials, such as furnace slag, smelting iron diatomaceous clay, fly ash, ground flakes, slate and clay. One of the artificial light aggregates is made of sedimenter clay that through burning process with temperature between 500-1250^{0}C and can be used for lightweight structural concrete with specific gravity with ranges from 1400-2000 kg / m^3.

The clay should fulfill the requirements such as, containing alumina silicates and dissociated substances which may produce gases above its melting temperature. Because the weight is very light then the concrete produced will be lighter than normal concrete. Aggregates gradation requirements for lightweight concrete using ALWA following ASTM C330-89 standard (Standard Specification Aggregate for Structural Concrete) can be seen in table 1 below:

Table 1: Gradation of ALWA ASTM C330-89

Sieve Size Range	Passing percentage (%)
50	100
38	100
25	100
19	90-100
12,5	-
9,5	10-50
4,75	0-15
2,38	-

The basic ingredients of lightweight aggregate ALWA are clay soils. Clay used as aggregate is first destroyed and mixed with rice husk ash about 15% from the weight of clay soils. Then clay formed in to granular shape with grain size +16 mm and burned with temperature between 500-1250 ^{0}C. After burning for several hours, then the ALWA aggregate is cooled at room temperature. The aggregate ALWA then soaked in to the water for 24 hours, in order for the aggregate to be in saturated surface dry condition. After soaking, ALWA aggregate is ready to be used as light aggregate in concrete.

Figure 2: Artificial Lightweight Aggregates (ALWA)

2.2.2 Testing of Physical Properties of Aggregates

Aggregates used in concrete mixtures can be either natural aggregates or artificial aggregates. Sand and gravel are natural while artificial aggregates are derived from processed products first such as the result of blast furnace slag, fraction tile, concrete waste, fly ash, clay soil and so on. Examination of aggregate physical properties includes examination:

- Specific gravity
- Absorbtion
- Bulk Density
- Sieve analysis

2.2.3 Mixture Proportions

Mix design of normal concrete and artificial aggregate concrete (ALWA) planned using American Concrete Institute method (ACI 2I1.1-91) with concrete strength of 25 MPa. The Planning is based on the method of weight comparison between concrete material component.

2.2.4 Concrete Mixture Work

Normal concrete work begins with mixing of concrete-forming materials (sand, gravel, cement and water). Then the material is placed into concrete mixer. Slump test measurement for fresh concrete is carried out. The mix was then placed into the mold for 24 hours.

In lightweight artificial aggregate concrete substitution (ALWA) processes, materials such as sand, gravel, aggregate ALWA and cement are mixed first according to their own percentages. Then the material is placed into concrete mixer and water added. Slump test measurement for fresh concrete is carried out. The mix was then placed into the mold for 24 hours.

After 24 hours, the concrete were taken out from every mold and then they were submerged in the water tank in the Laboratory of Public Works of West Aceh. Testing of compressive strength is carriet out after the concrete reaches the age of 28 and 56 days. Concrete is loaded vertically or parallel to the cylinder slowly until the test object is destroyed. The total number of test specimens is 24 cylindrical pieces (Ø15 cm, T = 30 cm) with various percentage of aggregate, shown in table 2.

Table 2: The number of concrete specimen

[redacted]

3 RESULTS AND DISCUSSION

3.1 Results

This section presents the results analysis from the examination of aggregate physical properties, the design of the proportion of concrete mixtures and the test results of compressive strength. The description of the results of the analysis is presented in the form of tables and graphs, in order to be easy to understand.

3.1.1 Physical Properties of Aggregates

The results of examination of aggregate physical properties indicate that the aggregate used qualifies as concrete forming material.

- **Bulk Density**

The result of theaverage of bulk density calculated for each type of aggregate is shown in Table 3.

Table 3: Bulk Density of Aggregates

No	Types of Aggregate	Volume Weight (Kg/l)	References	
			Orchard (1979)	ASTM
1	*Coarse Aggregate*	1.828	-	1,6-1,9
2	*Fine Sand*	1.679	>1.445	-

The fine aggregate used in this study can be used as a concrete-forming material with a volume weight of 1.679 kg / L. As suggested by Orchard (1979), he thinks that the weight of a good aggregate volume is greater than 1,445 Kg / L. Based on ASTM the weight of the aggregate aggregate volume also meets the specification of 1,828 kg / L, ranging from 1.6-1.9 kg / L.

- **Specific gravity and absorption**

Table 4: Specific Gravity

No	Types of Aggregate	Spesific Gravity		References	
		SG (SSD)	SD (OD)	Toxell (1968)	ASTM
1	*Coarse Aggregate*	2.65	2.60	-	1,6-3,20
2	*Fine Sand*	2.43	2.36	2 - 2.6	

The results of the calculation of specific gravity and absorption obtained for each type of aggregate are presented in the following tables 4 and 5.

Table 5: Absorption

No	Types of Aggregate	Absorbtion %	References	
			Orchard (1979)	ASTM
1	*Coarse Aggregate*	1.987	0.4-1.9	0,2-4,0
2	*Fine Sand*	3.148		-

From table 4 it can be seen that the specific gravity of the Saturated Surface Dry aggregates (SSD) used comply with the requirements indicated by ASTM, ie for gravel 2.65 kg / L and 2.60 kg / L dry aggregate weight (OD), for the specific gravity of the Saturated Surface Dry aggregates (SSD saturated sand aggregate (SSD) is 2.43 kg / L and 2.36 kg / L dry sand aggregate (OD). this aggregate has also met the requirements specified by Troxell (1968) ranging from 2.0 kg / L -2.6 kg / L and ASTM 1.6 kg / L -3.20 kg / L.

Furthermore, in table 5 it can be seen that the coarse aggregate absorption value obtained is 1.987. Absorption of coarse aggregate is still in accordance with absorbency value determined by ASTM that is 0,2-4,0. While for fine aggregate absorption is 3,148. Fine aggregate absorption did not match Orchard's determined 0.4% -1.9% and ASTM 0.2% -2.0%.

- **Gradation of Aggregates**

Table 6: Fineness Modulus (FM)

No	Types of Aggregate	Fineness Modulus (FM)	References ASTM
1	*Coarse Aggregate*	6.28	5.5 - 8.0
2	*Fine Sand*	2.33	2.2 - 2.6
3	Agregat campuran	5.09	4.0 - 7.0

3.1.2 Casting of Concrete Specimens

The following table shows the proportion of mixture for 1 m3 of concrete.

Table 7: Mix Proportions

W/C Ratio	Aggregates Percentage	Material (Kg)				
		Water	Cement	Coarse Aggregates	Fine Aggregate	ALWA
0.518	0%	186.760	360.82	1362.74	527.94	0
	10%	186.998	361.00	1041.46	468.39	167.76
	20%	186.998	361.00	803.41	430.71	308.53
	30%	186.998	361.00	598.50	397.11	426.69

3.1.3 Slump Test

Data obtained from the execution of slump values on each foundry are showed in Figure 3.

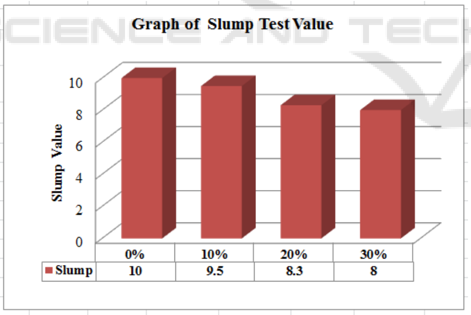

Figure 3: Graph of Slump Test

From the slump test graph above, shows that the slump form will be different according to the aggregate percentage of ALWA. Slump results in 0% percentage is 10 cm, 10% percentage is 9.5 cm, 20% percentage is 8.3 cm, and the percentage of 30% is 8 cm. This shows that the higher percentage of ALWA aggregates used, the concrete water absorption will increased.

3.1.4 Compressive Strength Test Result

Testing of concrete compressive strength is completed when the test object is 28 days and 56 days. Prior to the test, the object is removed first from the tank, then stood until the specimen is on the surface dry state, weighing the specimens after that.

- **Tests of concrete compressive strength of 28 days**

The results of concrete compressive strength test at age 28 days are showed in table 7 and figure 4 below:

Table 7: Mix Proportions

Percentage of ALWA	Number 0f Specimen	Volume of Cylinders (cm3)	Weight of Concrete (kg/m3)	Load (P) (KN)	Compressive Strength (MPa)		Classification SNI 03-6468-2000
					f'c	f'c (average)	
0%	BU.1	0.0053	2384.26	450	25.48	25.67	Structural Concrete
	BU.2	0.0053	2493.66	460	26.04		
	BU.3	0.0053	2461.60	450	25.48		
10%	BU.A.1	0.0053	2341.82	410	23.21	23.40	Structural Concrete
	BU.A.2	0.0053	2263.54	415	23.50		
	BU.A.3	0.0053	2225.81	415	23.50		
20%	BU.B.1	0.0053	2148.47	315	17.83	18.02	Structural Concrete
	BU.B.2	0.0053	2169.22	320	18.12		
	BU.B.3	0.0053	2159.79	320	18.12		
30%	BU.C.1	0.0053	2056.05	280	15.85	15.29	Non Structural Concrete
	BU.C.2	0.0053	2046.61	250	14.15		
	BU.C.3	0.0053	2091.89	280	15.85		

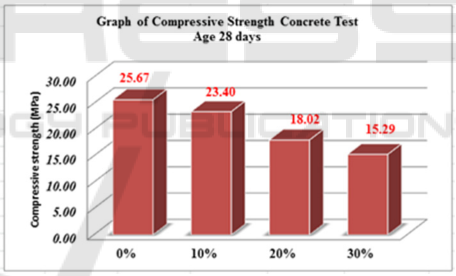

Figure 4: Graph of Compressive Strength Concrete Test Age 28 Days

From Table 7 and Figure 4, showed the compressive strength of concrete reduced when the proportion of aggregates ALWA increased. However, the weight of the concrete will be lighter in proportion to the increasing of aggregate ALWA. On specimens with 0% percent aggregate ALWA has an average compressive strength of 25.67 MPa and weight of 12.97 kg. While on the specimen with the percentage of 30% aggregate ALWA has an average compressive strength of 15.29 MPa and weight 10.95 kg.

- **Compressive strength concrete of 56 days**

The concrete compressive strength test results at age 56 days are showed in table 8 and the figure 5 below:

Table 8: Compressive strength test age 56 days.

Percentage of ALWA	Sample Test	Cylinder Volume	Concrete Weight	Load (P)	Compressive Strength (MPa)		Classification
		cm	kg/m3	kN	f'c	f'c (Average)	
0%	BU. I. 1	0.0053	2480.46	460.00	26.04	25.95	*Structural concrete*
	BU. I. 2	0.0053	2472.91	455.00	25.76		
	BU. I. 3	0.0053	2429.53	460.00	26.04		
10%	BU. I. A. 1	0.0053	2271.08	420.00	23.78	23.87	*Structural concrete*
	BU. I. A. 2	0.0053	2301.26	425.00	24.06		
	BU. I. A. 3	0.0053	2286.17	420.00	23.78		
20%	BU. I. B. 1	0.0053	2180.54	320.00	18.12	18.49	*Structural concrete*
	BU. I. B. 2	0.0053	2188.09	340.00	19.25		
	BU. I. B. 3	0.0053	2184.31	320.00	18.12		
30%	BU. I. C. 1	0.0053	2145.64	260.00	14.72	15.85	*Non Structural Concrete*
	BU. I. C. 2	0.0053	2099.43	300.00	16.99		
	BU. I. C. 3	0.0053	2074.15	280.00	15.85		

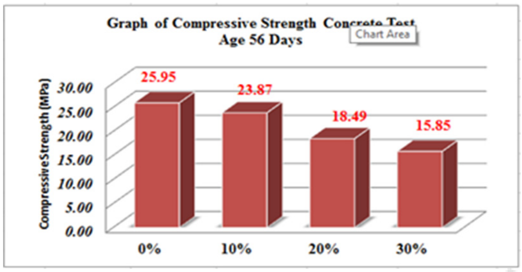

Figure 5: Graph of Compressive Strength Concrete Test Age 56 Days

Based on Table 8 and Figure 5, showed the decreases of concrete compressive strength due to the higher proportion of aggregates ALWA. The weight of the concrete will be lighter based on proportion increases of aggregate ALWA. On specimens with 0% percent aggregate ALWA has an average compressive strength of 25.95 MPa and average weight of 13.05 kg. While on the specimen with the percentage of 30% aggregate ALWA has average compressive strength of 15.85 MPa and average weight of 11.17 kg.

3.1.5 Comparison Results of Concrete Compressive Strength

The comparison results of compressive strength of concrete at age 28 days and 56 days are showed in table 9 and figure 6 below.

Table 9: Comparison of compressive strength of 28 and 56 days old concrete

Age	f'c (Mpa)			
	0%	10%	20%	30%
28 Days	25.48	23.21	17.83	15.85
	26.04	23.50	18.12	14.15
	25.48	23.50	18.12	15.85
56 Days	26.04	23.78	18.12	14.72
	25.76	24.06	19.25	16.99
	26.04	23.78	18.12	15.85

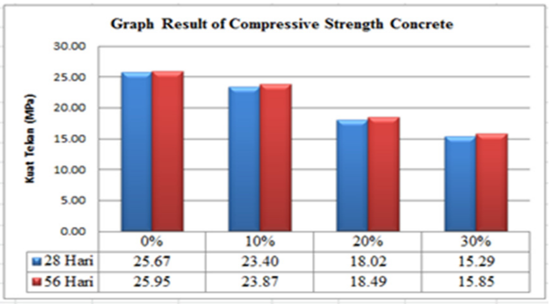

Figure 6: Graph of Compressive Strength Concrete Days and 56 days

From the table and figure shows the compressive strength of concrete has increased. However, the increasing in strength is not too large, because the concrete has reached the compressive strength of the plan at the age of 28 days.

3.1.6 Relation of Volume Weight with Compressive Strength of Concrete

The weight of the concrete volume has a great effect on the compressive strength of the concrete, this can be seen in graph 7 below:

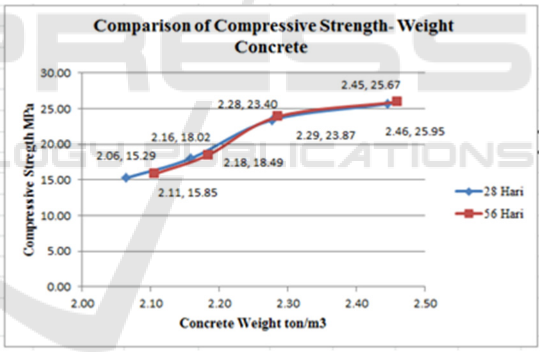

Figure 7: Graph of average compressive strength of concrete aged 28 and 56 Days

Based on Figure 7, weight of the concrete was 2.45 ton/m3 at 28 days and compressive strength of 25,67 Mpa. Concrete weight at age 56 days was 2,46 ton/m3 have compressive strength of 25,95 MPa. Then on concrete weighing 2.06 ton / m3 at age 28 day have compressive strength 15,29 MPa, and weight of concrete at age 56 day with weight 2,11 ton/m3 have compressive strength 15,85 MPa. In other words, normal concrete with a large volume weight has a large compressive strength, while the lighter concrete, its compressive strength smaller than normal concrete.

3.2 Discussion

The results of the aggregate inspection conducted at the West Aceh Public Works Laboratory indicates that the aggregate used has fulfilled the requirements as concrete-forming materials based on ASTM C33, Troxell (1968) and Orchard (1979). Instead of the absorption of fine aggregate does not meet the criteria implied by Orchard (1979) which ranges from 0.4-1.9. The result of slump test at 0% percentage was 10 cm, 10% percentage was 9.5 cm, percentage 20% was 8,3 cm, and percentage 30% equal to 8 cm. The slump test results showed decreases in slump value. In other words, the higher the percentage of ALWA aggregates used the higher the water absorption of concrete. The concrete produced in this study indicates that the concrete is below the normal concrete limit, but not including the lightweight concrete specification. Because based on SNI-03-2847-2002 lightweight concrete has a unit weight of not more than 1900 kg / m3. Based on SNI 03-6468-2000 concrete with 10% aggregate substitution ALWA at 28 and 56 days can be used for structural purposes, since the compressive strength is in the range of 21-40 MPa. Meanwhile, according to Tjokrodimuljo (1996) aggregate substitution ALWA 20% - 30% can still be used for structural purposes, because according to the strength of medium quality concrete press for the use of the structure that is 15-40 MPa.

4 CONCLUSION

From the results of research and data processing that has been carried out, concrete with artificial lightweight aggregate substitution gives the effect of lightness to the concrete itself. It can be seen on aggregate ALWA usage of 10%, 20% and 30% weight average of test specimens continues to decrease. The use of 10% at age 28 and 56 days, aggregate ALWA resulted in the compressive strength of concrete close to the compressive strength of the plan was 23,40 MPa and 23,87 MPa, with average weight 12,07 kg and 12,12 kg. The aggregate usage of ALWA 30% at age 28 and 56 days of compressive strength of concrete average 15,29 MPa and 15,85 MPa with average weight 10.95 kg and 11,17 kg, but still can be used as structural concrete. Preparation of artificial lightweight aggregate concrete has economic value, because concrete-making materials are obtained easily. However, in the aggregate stages ALWA has several obstacles, due to the equipment used and the process itself is still simple.

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