

THE EFFECT OF ADDITION SILICA FUME, SUPERPLASTICIZER, AND BONDING TO REACHING HIGH QUALITY LIGHTWEIGHT CONCRETE

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ABSTRACT

In this research, a lightweight concrete mixture was made with foam and made use of the remaining broken rock from the Crusher Machine process, which was washed ashes. Other added ingredients used in the mixture are Silica Fume, Superplasticizer (Admixture Type F) and Bonding. This reseach uses a mix design from Circular Letter Number: 44 / SE / M / 2015 Concerning Design Guidelines for Mixing Light Material with Foam Mortar for Road Construction, Ministry of PUPR. Trial mix variations carried out are in proportion (SF 5%; BO 0.5%), (SF 10%; BO 0.5%), (SF 5%; BO 1%), (SF 10%; BO 1%), as well as foam agents with variations 1:20 and 1:40. The treatment process (curing) of the test object is immersed in a water bath, and the testing of the compressive strength of the test object is carried out at the age of 7 days, 14 days and 28 days. By using stone ash, lightweight concrete was obtained with an average specific gravity of 1722 kg / m³ to 1884 kg / m³. From the research results obtained the highest average compressive strength with the percentage of material that is in the variation of the SF 10% ; BO 0.5% and ratio foam (1) : water (40) only for K 190.6 kg/cm² or FC 15.82 MPa. In each specimen the value of quality efficiency with the most optimum weight variation at SF 10% ; BO 0.5% with a coefficient value of 10.03%.

Keywords: lightweight concrete, foam, stone ash, silica fume, superplasticizer, and bonding.

INTRODUCTION

Concrete is one of the most important elements in building structures. Indonesia is an archipelago that is developing infrastructure development and almost all construction uses concrete. According to SNI 2847: 2013, concrete is a mixture of portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water with or without additives. The development of science and technology has led to the emergence of various kinds of innovations in the field of construction. The types of concrete in construction are very varied, can be reinforced concrete, prestressed concrete, mortar concrete, pre-cast concrete, and lightweight concrete.

Lightweight concrete based on unit weight (SNI 03-2847-2002) is concrete which has a density or unit weight <1,900 kg / m³ consisting of cement, sand, water, foam agent, or other added materials. Lightweight concrete consists of two types, namely Autoclaved Aerated Concrete (AAC) and Cellular Lightweight Concrete (CLC), lightweight concrete with AAC type in its mixing using aluminum paste while for CLC lightweight concrete in mixing using foam.

Foam concrete material in cellular lightweight concrete is one of the construction materials that has been developed lately. The thing that should be considered in the

manufacture of cellular lightweight concrete is the use of foam agents that function to trap voids in mortars, so that dry densities between 500 kg / m^3 - 1600 kg / m^3 are obtained (Jitchaiyaphum, K, et. Al, 2011 : 1157). The mixture in cellular lightweight concrete is cement, fine aggregate, water, foam agent and other added materials needed in its manufacture. Fine aggregate used is Abu Batu, which utilizes the results of the rest of the process of breaking the stone with a Crusher Machine.

Additives Type F, Silica Fume and Bonding are other added ingredients to achieve high-quality cellular lightweight concrete. Type F additives are used to obtain the desired level of consistency or specifications by reducing water weight by >12%. Bonding is a mixture of concrete adhesives that serves to increase the adhesion of concrete so that the concrete becomes solid and air cavities are reduced. Silica fume is a very fine pozzolan material and partly consists of silica element, which is produced from a furnace as a by-product of the silicon metal industry (ASTM C 1240-93). Silica fume is physically finer than cement and chemically contains a high SiO_2 element, which increases the strength of concrete when used as an additive to concrete.

In accordance with the description in the research background above, the writer can formulate the problem to be discussed :

1. Is using stone ash and foam agent able to produce lightweight concrete?
2. Is the addition of Silica Fume, Type F additives and bonding able to affect the quality and achieve high quality lightweight concrete?
3. What is the compressive strength produced in concrete with the addition of Silica Fume, Type F additives and bonding?

LITERATURE REVIEW

High quality lightweight concrete is concrete which has a specific gravity ranging from 350 kg/ m^3 - 1900 kg / m^3 with compressive strength exceeding 6000 psi (40 Mpa). Lightweight Concrete Mixture Material According to the Ministry of Public Works and Public Housing Design Guidelines for Mixing Lightweight Mortar-Foam Materials for Road Construction, lightweight concrete using a mixture of Portland cement or other hydraulic cement, fine aggregate, foam, and water, with or without additives (admixture).

Fine Aggregate is an aggregate of not more than 5 mm in size, so it can be natural sand or sand from rock breaking resulting from rock breaking (stone ash). According to (SNI 03-6819-2002) the grains produced by fine aggregates must be hard and durable, must not contain mud, clay and loose material / more easily destroyed by more than 5%. Fine aggregate must be free from charcoal, wood objects and other unwanted impurities.

According to the Indonesian Industrial Standards (SII. 0013 - 81) Cement is a hydraulic cement produced by smoothing clinkers which mainly consists of calcium silicates which are hydrolyzed together with additives which are usually used in casts. The composition of materials in cement consists of Silicon dioxide (SiO), Aluminum oxide (AlO), Calcium oxide (CaO), Magnesium oxide (MgO), Sulfur trioxide (SO), Sodium Oxide (NaO).

Foam is a foam liquid containing vegetable protein or the like that can produce stable separate bubbles so as to produce a mixture of lightweight materials that meet technical specifications. Foam making material is foam agent and water, to make foam, mixing foam fluid and water using a foam generator and compressor.

According to the standard "Specification for Silica Fume fauna Use in Hydraulic Cement Concrete and Mortar" (ASTM.C.1240.1995: 637-642), silica fume is a smooth pozzolan material, where more silica composition is produced from higher kilns or residual production silicon or silicon iron alloy (known as a combination of micro silica with silica fume). The use of silica fume is always the same as High Range Water Reducer (Superplasticizer). Due to

the use of water in concrete and the presence of silica fume which fills the pores and is pozzolanic, it causes the concrete to become impermeable, durable and of high strength.

According to ASTM C 494 and British Standard 5075, Superplasticizer is a highly effective water-reducing chemical additive. With the use of these additives obtained a mixture with a lower cement water factor at the same mortar viscosity value or obtained with a thinner viscosity with the same cement water factor, so that the compressive strength of concrete is higher. Superplasticizer also has a great influence in increasing workability.

Material Test Analysis

Analysis of cement specific gravity (ASTM C 188 - 89)

Objective: Determine the specific gravity of cement.

How to calculate :

Cement Weight = (w1) gram

Cement weight + oil + measuring flask = (w2) grams

Measuring pumpkin weight + oil = (w3) grams

$$\text{Then } B_j = \frac{0,8 w_1}{(w_1 + w_3 - w_2)} \dots\dots\dots(1.1)$$

Cement Volume Weight Analysis (ASTM C 188 - 89)

Objective: Determine the volume weight of cement in a loose or bound state.

How to calculate :

Cylinder weight = (w1) gram

Cylinder weight + cement = (w2) gram

Cement weight = (w2-w1) gram

Cylinder volume = (v) dm³ (liter)

$$\text{Then the volume weight} = \dots\dots\dots(1.2)$$

Sieve analysis (ASTM C 136 - 95A)

Objective: To determine the grain size distribution / gradation of stone ash.

Calculation Method:

Calculative cumulative weight retained = cumulative retained weight of the filter above + the amount of retained weight of the filter underneath.

$$\text{Percentage on hold} = \frac{\text{Komulatif berat tertahan}}{\text{Berat contoh}} \times 100\% \dots\dots\dots(2.1)$$

Analysis of specific gravity (ASTM C 128 - 93)

Objective: Determine the specific gravity of stone ash.

Calculation Method:

Weight of pumpkin + stone ash + water = (w1)

Stone ash weight = 500

Pumpkin weight + water = (w2)

$$\text{Then the specific gravity of stone ash} = \frac{500}{(500 + w_2) - w_1} \dots\dots\dots(2.2)$$

Analysis of rock ash absorption (ASTM C 128 - 93)

Objective: To determine the water content of rock ash infiltration.

Calculation Method:

SSD sand weight = 500

Sand weight (oven) = (w1)

$$\text{Then the rate of absorption of sand} = \frac{500 - w_1}{w_1} \times 100\% \dots\dots\dots(2.3)$$

Analysis of Cleanliness of Stone Ash on Organic Materials (ASTM C 40 - 92)

Objective: Determine the levels of organic matter in the aggregates used in concrete mix.

How to experiment levels of organic substances:

The volume of stone ash + 200 grams was given a NOH solution of 3%, shaken for 10 minutes and allowed to stand for 24 hours.

Analysis of Ash Stone Cleanliness for Mud (Washing) [ASTM C 117 - 95]

Objective: To determine the amount of mud content in rock ash.

How to count:

Dry sand weight = (w1) gram

Weight of dry clean sand = (w2) gram

$$\text{Mud Content} = \frac{(w1 - w2)}{w1} \times 100 \% \dots\dots\dots(2.4)$$

Rock Ash Volume Weight Analysis (ASTM C 29 / C 29 M - 91)

Objective: Determine the volume weight of stone ash in both loose and solid conditions.

How to calculate :

Cylinder weight = (w1) ... kg

The weight of the cylinder + sand = (w2) ... kg

Sand weight = (w2 - w1) ... kg

Cylinder volume = (v) ... liters (dm³)

$$\text{Volume weight} = \dots\dots\dots(2.5)$$

Treatment / curing in lightweight concrete that is immersed in a tub / curing tub and testing is carried out for 7 days, 14 days and 28 days. Concrete compressive strength value is determined when the concrete reaches the age of 28 days. The strength of concrete will increase rapidly until the age of 28 days, but after that the increase is not too significant. Generally at the age of 7 days the compressive strength reaches 65% and at the age of 14 days reaches 88% - 90% of the compressive strength of the concrete age of 28 days.

For the calculation of compressive strength of test specimens according to SNI 03-1974-2011 article 7, using systematic calculations can be written as follows:

• Concrete Compressive Strength: $fc' = \frac{P}{A}$

Where :

P = Axial Compressive Force (N)

A = Test area (mm²) cross-sectional area

fc' = Concrete compressive strength (N / mm²)

• Average Compressive Strength: $fcr = \frac{\sum_{i=1}^n fci}{n}$

Where :

P = Axial Compressive Force (N)

A = Test material cross-sectional area (mm²)

fc' = Concrete compressive strength (N / mm²)

fcr = Average compressive strength of concrete (N / mm²)

fci = concrete compressive strength obtained from the test results (N / mm²)

n = Number of test specimens

RESEARCH METHODOLOGY

Time and Place of Research

Research time is planned within a period of 6 months from August 2019 - January 2020. The research was conducted at the Concrete Laboratory of PT. Varia Usaha Beton Gresik, East Java.

Preparation of Materials and Tools

The materials used in this research are:

- a) Type 1 OPC cement produced by PT. Semen Indonesia;
- b) Fine aggregate in the form of Abu Batu imported from Pandaan District, Pasuruan Regency, East Java;
- c) Silica Fume comes from PT Sika Indonesia;
- d) Foam comes from PT Erta Tekno Indonesia;
- e) The added ingredients used are:
 - Superplasticizer or often called Type F production of PT. Concrete Varia Enterprises
 - Bonding came from PT Erta Tekno Indonesia
- f) Water used for making concrete water that is clean and contains no chemicals.

Material Testing

Fine Aggregate Testing (Stone Ash) in the form of:

1. Fine aggregate filter analysis, based on (ASTM C 136 - 95A)
2. Fine aggregate specific gravity analysis, based on (ASTM C 128 - 93)
3. Analysis of fine aggregate infiltration, based on (ASTM C 128 - 93)
4. Fine aggregate hygiene analysis of organic materials, based on (ASTM C 40 - 92)
5. Sand Cleanliness Analysis for Mud by (Washing) method, based on (ASTM C 117 - 95)
6. Weight Analysis of fine aggregate sand volume, based on (ASTM C 29 / C 29 M - 91)

Mix Design Planning

In this research the mix design planning uses Circular Letter Number: 44 / SE / M / 2015 concerning Guidelines for Designing Mixed Mortar-Foam Light Material for Road Construction, Ministry of Public Works and Public Housing.

Target Concrete Specific Gravity, Foam & Slump Flow Test Specific Gravity

The target specific gravity is $<1900 \text{ kg / m}^3$, the target specific gravity foam (0.055-0.085 t / m^3), and the target flow mortar foam $180 \pm 200 \text{ mm}$.

Trial Mix Process and Manufacture of Test Objects

In this study the making of test specimens using cylinders 15cm x 30cm, with a total of 4 trial variations and each variation amounted to 9 test specimens.

Table 1.
Trial Variation and Number of Test Objects

Kode	No	Uji Kuat Tekan (KN)			KET
		7 Hari	14 Hari	28 Hari	
Normal	1				Normal
	2				
	3				
BRMT 1	1				SF 5%+BO 0,5%
	2				
	3				

BRMT 2	1				SF 10%+BO 0,5%
	2				
	3				
BRMT 3	1				SF 5%+BO 1%
	2				
	3				
BRMT 4	1				SF 10%+BO 1%
	2				
	3				

Concrete Treatment of Test Objects (Curing)

Concrete curing / maintenance aims to maintain and guarantee the quality of the concreting. In this study the steps taken are as follows:

Dismantling the test specimen is done \pm 24 hours after making it;
 The specimen is immersed until the age of 7 days, 14 days and 28 days;
 The test object is taken / dried the day before the test day.

Concrete Compressive Strength Testing

Press test procedure:

The test object is placed on a press machine sentries;
 The machine is running, press with a constant increase in load ranging from 2 to 4 kg / cm³ per second.

RESULTS AND DISCUSSION

Table 2
Volume Weight Analysis (ASTM C 29 / C 29 M-91)

PERCOBAAN	SATUAN	LEPAS	GOYANG	ROJOKAN
Berat Moulding (W1)	gr	3800	3800	3800
Berat Moulding + Abu Batu (W2)	gr	8100	8400	8500
Berat Abu Batu (W3 = W2- W1)	gr	4300	4600	4700
Volume Moulding (V)	cm ³	3000	3000	3000
Berat Volume = (W2- W1)/V	gr/cm ³	1,43	1,53	1,57
Berat Volume Rata-Rata	gr/cm ³	1,51		

Table 3
Sieve Analysis (ASTM C 136-95 A)

Sieve Size (mm)	Weight Retain (gr)	Retain (%)		Passing Cumulative (%)
37,50	0	0	0	100
25,40	0	0	0	100
19,50	0	0	0	100
12,50	0	0	0	100

9,50	0	0	0	100
4,75	0	0	0	100
2,38	406	40,60	40,60	59,40
1,19	374	37,40	78,00	22,00
0,60	163	16,30	94,30	5,70
0,30	42	4,20	98,50	1,50
0,15	1	0,10	98,60	1,40
0,08	10	1,00	99,60	0,40
Pan	4	0,40	100	0
Total	1.000,0			
	Fm =	4,10		

Table 4
Specific Gravity Analysis (ASTM C 128-93)

PERCOBAAN	SAT	1	2	Rata-rata
Berat Abu Batu kering permukaan jenuh (SSD)	gr	500	500	500
Berat Labu ukur + Air (B)	gr	1029	1029	1029
Berat Labu ukur + Abu Batu (SSD) + Air (Bt)	gr	1333	1334	1333,5
Berat Jenis Kering Permukaan Jenuh = $500/(B+500-Bt)$	gr/cm ³	2,551	2,564	2,558

Table 5
Infiltration Rate Analysis (ASTM C 128-93)

PERCOBAAN	SATUAN	HASIL
Berat Awal Abu Batu kering permukaan jenuh (A)	gr	500
Berat kering oven (B)	gr	475
Resapan = $(A-B)/B * 100$	%	5,26

Table 6
Ash Stone Cleanliness Analysis of Mud (ASTM C 117)

PERCOBAAN A (TANPA DICUCI)	SATUAN	HASIL
Berat Abu Batu kering (W1)	gr	1000
Berat Abu Batu bersih kering (W2)	gr	863
Kadar Lumpur = $(W1-W2)/W1*100$	%	13,70
PERCOBAAN B (DICUCI 4 - 5 KALI DALAM MIXER MOLEN)	SATUAN	HASIL
Berat Abu Batu kering (W1)	gr	1000
Berat Abu Batu bersih kering (W2)	gr	988
Kadar Lumpur = $(W1-W2)/W1*100$	%	1,20

Compressive Strength Testing

Table 7
Concrete Compressive Strength Test Results Normal

Nama Trial	7 Hari			14 Hari			28 Hari		
	KN	Kg/cm2	Mpa	KN	Kg/cm2	Mpa	KN	Kg/cm2	Mpa
BETON NORMAL K-300	332	221,010	18,34	398	262,942	21,82	440	305,80	25,38
	316			367			445		
	306			370			435		

Table 8
Lightweight Concrete Compression Strength Test Results (1)

FOAM	No	Nama Trial	7 Hari			14 Hari			28 Hari		
			KN	Kg/cm2	Mpa	KN	Kg/cm2	Mpa	KN	Kg/cm2	Mpa
1:20 (1 liter FOAM + 20 liter AIR)	1	BRMT 1 (BO 0,5%, SF 5%)	33	33,128	2,75	86	76,450	6,35	136	92,203	7,65
			34			111			105		
			76			133			157		
	2	BRMT 2 (BO 0,5%, SF 10%)	111	80,157	6,65	174	114,212	9,48	131	126,722	10,52
			74			98			176		
			161			221			240		
	3	BRMT 3 (BO 1%, SF 5%)	138	82,473	6,85	186	102,860	8,54	199	121,857	10,11
			115			118			152		
			103			140			152		
	4	BRMT 4 (BO 1%, SF 10%)	103	67,647	5,61	86	68,573	5,69	134	89,192	7,40
			91			111			113		
			98			99			138		

Table 9
Lightweight Concrete Compression Strength Test Results (2)

FOAM	No	Nama Trial	7 Hari			14 Hari			28 Hari		
			KN	Kg/cm2	Mpa	KN	Kg/cm2	Mpa	KN	Kg/cm2	Mpa
1:40 (1 liter FOAM + 40 liter AIR)	1	ULANG BRMT 1 (BO 0,5%, SF 5%)	126	95,910	7,96	160	116,992	9,71	182	132,945	11,03
			148			193			219		
			140			152			173		
	2	ULANG BRMT 2 (BO 0,5%, SF 10%)	199	136,915	11,36	244	167,727	13,92	277	190,598	15,82
			203			241			274		
			189			239			272		
	3	ULANG BRMT 3 (BO 1%, SF 5%)	176	120,235	9,98	188	127,648	10,59	214	145,055	12,04
			169			161			183		
			174			202			230		

4	ULANG BRMT 4 (BO 1%, SF 10%)	168	111,200	9,23	200	131,355	10,90	227	149,267	12,39
		160			184			209		
		152			183			208		

Based on the table above, the highest quality is found in 1:40 ratio variation (foam: water) using Silica Fume 10% and 0.5% Bonding which achieves quality K 191 kg / cm² or FC 10.82 MPa.

Table 10
Normal Concrete Specific Gravity

Nama Trial	7 Hari		14 Hari		28 Hari		Rata-Rata Kg/m ³
	Berat	Density Aktual Kg/m ³	Berat	Density Aktual Kg/m ³	Berat	Density Aktual Kg/m ³	
BETON NORMAL K-300	12,7	2403	12,6	2390	12,7	2409	2400,419
	12,7		12,7		12,8		
	12,8		12,7		12,8		

Table 11
Lightweight Average Concrete Species

No	Nama Trial	7 Hari		14 Hari		28 Hari		
		Berat Kg	Density Aktual Kg/m ³	Berat kg	Density Aktual Kg/m ³	Berat Kg	Density Aktual Kg/m ³	Density Rata-Rata Kg/m ³
1	BRMT 1 (BO 0,5%, SF 5%)	8,2	1629	8	1692	9,2	1673	1722
		8,7		9,5		8,4		
		9		9,4		9		
2	BRMT 2 (BO 0,5%, SF 10%)	9,8	1811	10,5	1805	9,6	1811	
		8,6		9		8,9		
		10,4		9,2		10,3		
3	BRMT 3 (BO 1%, SF 5%)	9	1742	9,5	1792	9	1717	
		9,4		9,4		9,3		
		9,3		9,6		9		
4	BRMT 4 (BO 1%, SF 10%)	8,4	1623	8,6	1686	8,8	1679	
		8,3		9,2		9,1		
		9,1		9		8,8		
5	ULANG BRMT 1 (BO 0,5%, SF 5%)	9,8	1862	10	1893	10	1893	
		9,9		10		10,1		
		9,9		10,1		10		
6	ULANG BRMT 2 (BO 0,5%, SF 10%)	10	1893	10	1899	10	1899	
		10,1		10,1		10,1		
		10		10,1		10,1		

7	ULANG BRMT 3 (BO 1%, SF 5%)	9,9	1881	10	1893	10,1	1893
		10		10,1		10	
		10		10		10	
8	ULANG BRMT 4 (BO 1%, SF 10%)	9,7	1836	9,9	1881	9,9	1881
		9,7		10		10	
		9,8		10		10	

Based on the results of the trial obtained an average density or specific gravity above in accordance with the requirements of $<1900 \text{ kg / m}^3$, in the first trial with a foam ratio of 1:20 obtained an average of 1722 kg / m^3 and a second trial of foam ratio of 1:40 obtained an average of an average of 1884 kg / m^3 .

CONCLUSION

On the results of research and discussion that has been carried out several conclusions can be drawn as follows:

1. The use of ash stone material and foam agent (foam) in this study was able to produce concrete weighing $<1900 \text{ kg / m}^3$, as evidenced in the average results in the first trial mix with the ratio of foam: water (1:20) to get the result of specific gravity 1722 kg / m^3 and the second trial mix with a ratio of foam: water (1:40) yielding a specific gravity of 1884 kg / m^3 .
2. The addition of silica fume, superplasticizer (type f), and bonding can affect quality but do not reach the K-300 quality target. In this study the addition of optimum silica fume at a proportion of 10%, the more additions it will add to the strength of concrete. The addition of type f in this study is optimum in the proportion of 0.6% because it can reduce water use by 12%. Whereas the addition of optimum bonding is in the proportion of 0.5% because if the bonding is mixed with foam / foam even though the proportion added does not really affect the strength of the concrete.
3. In this research, normal concrete with K-300 quality compared to lightweight concrete whose composition is cement, stone ash, silica fume, type f, and bonding. The results of normal concrete compressive strength obtained quality K 305.80 kg / cm^2 or FC 25.38 MPa, whereas for lightweight concrete obtained with a foam: water composition ratio (1:40), the proportion of silica fume use 10%, 0.5% bonding with compressive strength of K 190,6 kg / cm^2 or FC 15,82 Mpa. In each specimen the value of quality efficiency with the most optimum weight variation is SF 10% ; BO 0.5% with a coefficient value of 10.03%.

SUGGESTION

In order to produce research that will later become better in further research the authors suggest paying attention to the following matters:

1. There needs to be another trial and error in order to get the right lightweight concrete mixing and the quality to reach the desired target;
2. Use stone ash which has a uniform grain size and has a standard mud content by washing it first;
3. Add additives and admixture that can reduce more water so that the quality of concrete is in accordance with the target;
4. Pay attention to the moisture content test for the material because it affects the use of the amount of water in the concrete mixture;
5. Pay attention to the density foam to fit the requirements of 0.055 t / m^3 - 0.085 t / m^3 .

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