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Unit Weight of Foam Concrete Containing Blended Cement and Fly Ash

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Abstract. The rapid development of construction and infrastructure results in increasing demands for natural resources continue. One of the many natural elements required for construction and infrastructure activities was cement, which is the basic ingredient in concrete. This study aims to analyze the unit weight of foam concrete containing blended cement and fly ash. The research approach used in this study was a laboratory experiment. Foam concrete was produced using 4 variations of cement (OPC, PCC-T, PCC-B and OPC+FA), fine aggregate, water and foam. The shape of the test object used was cube with a size of 15 cm × 15 cm × 15 cm. Unit weight test was used to evaluate the foam concrete mixture produced at the age of 3, 7, 28 and 730 days. The results showed that the unit weight of foam concrete in all variations of the specimens: OPC, PCC-T, PCC-B and OPC+FA, met the requirements for the unit weight of lightweight structural concrete based on SNI 03-3449-2002 and ACI 213R3 which was between 800 to 1400 kg/m^3.

Key words: *unit weight, foam concrete, blended cement, fly ash*

INTRODUCTION

The current rapid rate of building and infrastructure development needs the ongoing use of natural resources such as cement, which is one of the many materials necessary for this activity and is the primary material of concrete. t does, however, play a substantial role in greenhouse gas emissions, accounting for 6 to 7% of total CO2 gas emitted into the atmosphere each year [1]. As a result, actions must be taken to reduce the negative environmental effects, such as switching the raw material source for cement production or producing alternative derivative products.

In terms of raw materials, numerous cement plants have moved to Portland Composite Cement (PCC), a more energy-efficient and environmentally friendly alternative to Ordinary Portland Cement (OPC), which is also more cost-effective, allowing for higher production capacity. Fly ash, one of the supplementary elements used in PCC manufacture, is classified as a "pozzolan" material, which is a siliceous or aluminous material with little or no cementitious component, similar to Portland cement, with ASTM C 618-05, 2005 as a standard specification.[2] It is an industrial by-product recognized as an environmental pollutant when coal is combusted for energy, and it is a potential adsorbent for removing a range of pollutants, according to various studies, with its adsorption capacity being improved following chemical and physical activation. The management of fly ash as dangerous waste, as it is currently practiced, is a severe challenge in storage and has the potential to cause environmental pollution. As a result, ongoing efforts have been made to use it as a PCC component to reduce environmental impact while increasing commercial value. In addition to being added to the PCC production process, it can also be used directly in the production of cement-derived products, what's more, it is already being utilized in the manufacturing of ready-mix and precast concrete in the concrete industry.

With regards to cement-derived products, foam concrete, a cement paste or mortar with random air made from a mixture of foam agents in a mortar, defined as a lightweight concrete with a density of 400-1850 kg/m^3, has been developed. [3,4,5,6,7,9] have found that it has great flowability, low cement content, and efficient aggregate use. Furthermore, its density is one of its most essential properties, and this is a fundamental mechanical parameter in the design of concrete structures.

After casting, one of the most critical stages is concrete curing. This is conducted to ensure that the chemical reaction process takes place at room temperature, and to guarantee that the hydration reaction of cement compounds, including additives or substitutes, can occur optimally. Moreover, it is used to prevent excessive shrinkage, which can result in excessive or non-uniform moisture loss that leads to cracks. Subsequently, this research aimed to analyze the density of foam concrete with various cement variations (OPC, PCC-T, PCC-B, and OPC+FA) at the concrete age of 3, 7, 28, and 730 days.

MATERIALS AND RESEARCH METHODS

Physical and Chemical Characteristics of Cement and Fly Ash

In this research, two types of cement were used, namely, OPC from one brand and PCC from two different brands (PCC-T and PCC-B). Physical and chemical testing on all types of cement and fly ash were conducted as part of the cement characteristic tests, and chemical characteristics testing was used to investigate the chemical composition of fly ash and Portland cement type I (OPC), while XRF (X-Ray Fluorescence) testing was performed to determine the chemical composition of the tested material in the form of the constituent elements of the material used to make foam concrete. The physical and chemical properties of cement and fly ash are shown in Tables 1 and 2. The cement used in this research came from local PCC and OPC producers in Indonesia.

Physical and chemical criteria were studied to establish the acceptability of cement as a binder material, as the quality of the cement has a considerable impact on the finished concrete. Table 1 shows that the cement used in this study has met the SNI specifications for the required concrete materials based on the results of the physical characteristics test on PCC-T, PCC-B, and OPC.

The physical characteristics of the fly ash in this study were derived from PLTU (Steam Power Plant) waste in Punagaya Village, Bangkala District, Jeneponto Regency where the chemical content is shown in Table 2, with its specific gravity determined to be 2.1, while the percentage of it that passed filter no. 200 is 90%, according to the filter analysis data. Moreover, fly ash is a type of waste produced by the burning of coal and it is divided into three classes by ASTM C618-05, namely, class N, class F, and class C, where Class N and Class F have a minimum content of SiO_2, Al_2SO_3, and Fe_2O_3 compounds of 70%, whereas class C has a level of 50% to 70%.

TABLE 1. Physical Characteristics of Cement and Fly Ash

Properties	Result			
	PCC-T	PCC-B	OPC	Fly Ash
Water Content, % volume	11,5	-	-	-
Fineness/Blaine meter, m^2/kg	382	448	346	-
Autoclave expansion, %	-	0,06	0,11	-
Compressive strength				
a. 3 days, kg/cm^2	185	154	188	-
b. 7 days, kg/cm^2	263	223	266	-
c. 28 days , kg/cm^2	410	280	359	-
Time of setting (Vicat test)				
a. Initial Set, minute	132,5	138	125	-
b. Final Set, minute	198	260	260	-
False set, final penetration, %	-	86,57	83,66	-
Heat of hydration 7-day, cal/gr	65	-	-	-
Air Content, % volume	-	4,97	4,53	-
Specific Gravity	3,13	2,94	3,15	2,1
Sieve Analysis	-	-	-	90% pass no. 200

TABLE 2. Chemical Characteristics of Cement and Fly Ash

Properties	Content (%)			
	PCC-T	PCC-B	OPC	Fly Ash
MgO	0,99	1,85	2,68	-
SO_3	1,81	1,70	2,13	-
SiO_2	18,39	19,62	-	44,56
Al_2O_3	5,15	5,89	-	-
Al_2SO_3	-	-	-	14,55
Fe_2O_3	3,14	4,30	-	11,83
$SiO_2 + Al_2SO_3 + Fe_2O_3$	-	-	-	70,94
CaO	61,79	-	-	12,74
Loss on ignition	4,61	-	3,38	0,30
Insoluble residue			0,76	
Alkalies			0,32	

Physical Characteristics of Fine Aggregate

Table 3 shows the physical characteristics of Pinrang Regency quartz sand which was used as the fine aggregate, with its specific gravity values determined as 2.58, 2.60, and 2.65 for dry density, SSD (Saturated Sufrace Density), while having water adsorption of 0.91% and mud content of 0.96%. Meanwhile, the density values in the loose and solid conditions were 1.40 and 1.48 kg/lt, respectively. It can be seen that the physical characteristics of the fine aggregate used, meet the SNI specification.

TABLE 3. Physical Characteristics of Fine Aggregate

No.	Properties	Result
	Density	
1.	- Dry Density	2,58
	- SSD	2,60
2.	Water absorption (%)	0,91
3.	Clay content (%)	0,96
4.	Fine Modulus	1,26
	Unit weight (kg/lt)	
5.	-Loose	1,40
	-Solid	1,48
6.	Water Content (%)	3,59
7.	Organic Impurities	No. 1

Mixed design

A mixture of binders (OPC, PCC, and fly ash), fine aggregate, superplasticizer, and foam agent were used to create the mixed design. The binder and fine aggregate are compared as 1 versus 2, followed by four binder variations, namely, OPC, PCC-B, PCC-T, and OPC with fly ash (OPC+FA) added in a 70:30 ratio. Figure 1 shows the steps involved in creating a foamed concrete mixture. In this research, a cube-shaped concrete test object of 15 cm x 15 cm x 15 cm was used, and all specimens were cured and stored in the specimen storage area at room temperature in the laboratory between 25°C and 32°C with humidity of 60 RH – 74 RH until the time of testing, what's more, curing was done on all specimens at 3, 7, 28, and 730 days as shown in Figure 2.

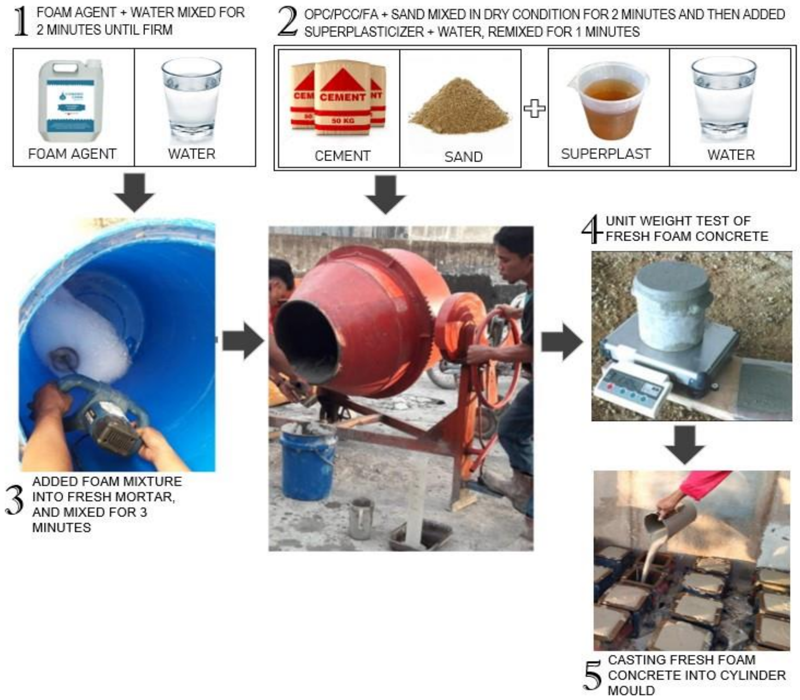


Figure 1. Foam Concrete mixture process

Figure 2. Specimens curing in laboratory

Volume Weight (Density) of Concrete

The concrete density test was performed in compliance with SNI 3402:2008, which specifies how to determine the density of structural lightweight concrete. After 6 days, the specimens were removed from the treatment settings and immersed in water at 23° ± 2°C for 24 hours, while the cylinder is subsequently weighed in water (completely immersed) and the weight was recorded with the code "C," which is the cylinder's weight in water until it was submerged. Thereafter, it iwass removed from the water and placed on a 9.5 mm or coarser size sieve for 1 minute. Water was dried off it with a damp cloth, then weighed and recorded with the code "B," which was the weight of the cylinder in the dry condition of the saturated surface. The cylinders were dried entirely on the surface in a humidity-controlled room at 50% ± 50% humidity and a temperature of 23o C ± 2o C until the weight loss of the test object was less than 0.5% at 28 days. Furthermore, the dry weight of the cylinder was calculated and reported in kg units with the code "A." Equation 1 was used to compute the density of the balanced state:

$E_m = (Ax997)/(B-C)$ (kg/m^3)………..………(1)

A is the weight of the dried cylinder (kg);
B is the weight of the cylinder at dry surface saturation (kg);
C is the weight of the cylinder in water until it is fully submerged (kg).

RESULTS AND DISCUSSION

Foam Concrete Mix Design

In this study, the foam concrete test object was created with four types of mixed variations: the first mixture variation using OPC, the second mixture with PCC-B, the third mixture with PCC-T, and the fourth mixture variation utilizing fly ash, with a 70:30 OPC to fly ash ratio. For the test specimens in this study, Table 4 shows the concrete mix design depicted as a mixed design in units of 1 m3. Furthermore, the ratio of foam agent to water is 3:10, while the proportion of mortar and foam is determined by the density of the materials utilized.

TABLE 4. Foam Concrete mix design (m^3)

Material	Mixed Type			
	OPC	PCC-T	PCC-B	OPC+Fly Ash
Cement	667,41 kg	662,71 kg	662,71 kg	501,38 kg
Sand	1334.8 kg	1325,43 kg	1325,43 kg	1432,51 kg
Fly Ash	-	-	-	214,88 kg
Water	233 kg	232 kg	232 kg	175,48 kg
Admixture 1	16,69 kg	16,57 kg	16,57 kg	12,53 kg
Total	2252,51 kg	2236,71 kg	2236,71 kg	2236,78 kg
LWC density	1325 gr/ltr	1325 gr/ltr	1325 gr/ltr	1325 gr/ltr
Mortar portion	44,4 %	44,4 %	44,4 %	42,8 %
Foam portion	55,6 %	55,6 %	55,6 %	57,2 %
Ratio of foam agent/water	3 : 10			

Behavior of Foam Concrete in Fresh Condition

Figure 1 shows the value of the foam concrete slump test results from all the mixtures used under fresh conditions. The average slump value in all mixtures is 22cm and visual observation reveals that the fresh concrete mix from each mix design is adhesive, indicating that no segregation or bleeding has occurred.

FIGURE 1. Fresh foam concrete slump test results

Density of Hardened Foam Concrete (Hardened Concrete)

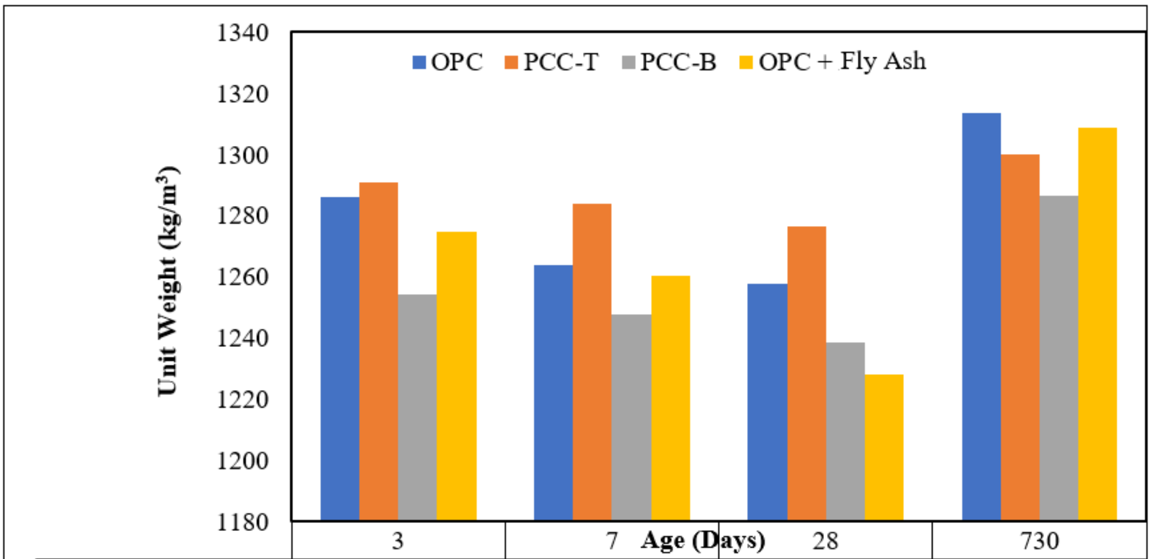
Each specimen's hard concrete density ranged from 1257 kg/m3 to 1265 kg/m3 when using OPC, and from 1238 kg/m3 to 1283 kg/m3 when using Portland Composite Cement B (PCC-B). Meanwhile, the density of hard concrete specimens made using Portland Composite Cement T (PCC-T) ranged from 1283 to 1290 kg/m3, whereas those made with fly ash ranged from 1260 to 1254 kg/m3. Based on the density, all test objects meet the SNI 03-3449-2002 [10] and ACI 213R-87 [11] requirements for the lightweight structural concrete density category, which is between 800 kg/m3 and 1400 kg/m3.

Figure 4 shows a comparison of the increase in curing age and concrete density for each mix design. It can be concluded that the longer the concrete is allowed to cure, the lower the density will be at the age of 3 to 28 days.

However, there was a slight rise in weight volume at 730 days, but it was not significant due to the carbonation process, which occurs when carbon dioxide in the environment combines with hydrated cement minerals and creates carbonates at a particular humidity (for example calcium carbonate). Equation 2 shows the chemical equation for the carbonation process.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$………… (2)

$CaCO_3$ has no detrimental effects on foam concrete, although it can be used to fill in gaps and fissures. Meanwhile, moisture and water seep into the foam concrete's voids, however, the amount is minor and within tolerance limits.



	3	7	28	730
OPC	1285.9	1263.7	1257.8	1313.6
PCC-T	1290.9	1284.0	1276.5	1300.2
PCC-B	1254.3	1247.9	1238.5	1286.4
OPC + Fly Ash	1274.6	1260.2	1227.9	1308.6

FIGURE 2. Unit weight test results

CONCLUSION

Based on this research, it can be concluded that:

1. The density of foam concrete in all variations of the specimen has met the requirements for the density of lightweight structural concrete according to SNI 03-3449-2002 and ACI 213R3 standards which is between 800 and 1400 kg/m3.
2. From 3 to 28 days, the density of foam concrete dropped by 2.3%, 2.0%, 2.5%, and 1.4% for the OPC, PCC-T, PCC-B, and OPC+FA test objects, respectively. However, there was a 0.6%, 3.9%, 1.2%, and 1.0% rise from 28 to 730 days of age, respectively. This increase was caused by the carbonation process.

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