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Preliminary study on early compressive strength of foam concrete using Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC)

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Preliminary study on early compressive strength of foam concrete using Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC)

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Abstract. The purpose of this study is to determine the initial characteristics of foam concrete mixtures. This performance, using Ordinary Portland Cement (OPC) and Portland Composite Cement (PPC) were examined for its density and compressive strength on day 1, 3 and 7. In addition, the production process was initiated by formulating a mix of foam solvent, simultaneously creating the mortar, with the use of OPC or PPC, followed by the individual integration of a foaming solvent. Furthermore, after density evaluation, a specimen is produced with the cylinder cast, in a diameter of about 150 mm, and length of 300 mm, containing individual water and atmosphere curing. The density obtained was higher than the outcome of air curing tests, which decreased continuously with the concrete age. Furthermore, the compressive strength measured was relatively lower in water curing testing, using PCC, and on day 7it w was up to 3.46 MPa, or 73.5%, which seems to be lower than the record obtained with the use of OPC, which was about 3.94 MPa. At similar age, the value obtained for air curing with PCC reached 4.52 MPa or 96.0%, exhibiting a lesser value than OPC (4.71 MPa).

1. Introduction

In recent times, there has been a continuous demand for construction and infrastructural development that utilize natural resources, e.g., cement as the primary material in a concrete formulation, needed for related activities. This, therefore, makes it the primary contributor to greenhouse gas, because 6-7% of the total CO2 gas is sent to the earth each year. Furthermore, there is need for enhancing the efforts that capably downgrade the bad impact on the environment, which entails replacing the source of primary substance during the creation of the cement or its product. In addition, based on the mutual substantial, some of the factories have replaced the Ordinary Portland Cement (OPC) production with Portland Composite Cement (PCC), which is more economical and eco-friendly, subsequently improving production capacity. One of the materials added in its production is fly ash, which is categorized as “pozzolon” with the siliceous or aluminous content possessing limited cementitious as Portland cement.

The standard of fly ash specification refers to [1], and its waste management being of Hazardous and Toxic Material (B3) often becomes a serious problem in storage, potentially evoking environmental pollution. Hence, efforts are being made to apply it as additional material in the production of PCC, in an attempt to reduce the impact on the surrounding, subsequently enhancing economic value. Based on the aspect of cement derivation, this foam concrete development was initiated to form cement emission or mortar, consequently defined as light. This tends to possess a density of about 400–1,850 kg/m3, with random air cavity, made from the integration with a foaming agent, and the result has a high flowability, low cement utilization degree, and also the efficient use of aggregate [2].

Compressive strength is the maximum power that is possibly applied to the mortar for each extensive unit work, and its testing is conducted based on [3], alongside density, which are the most two important parameters in deciding the performance foam concrete.[4] Based on the description, their initial characteristics were determined by testing the density and compressive strength on day 1, 3 and 7, respectively, using water and air curing systems. Therefore, it is expected that the study outcomes are used as a basis for further investigation, in order to obtain mixtures that meet technical specifications involving the utility of materials that are less expensive and more environmentally friendly.

2. Material and methods

2.1. The creation of foam concrete material

The Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC) used were obtained from the same factory source in Maros, South Sulawesi, then their chemical and physical characteristics were obtained, and showed in table 1. The silica sands, which occur in the form of fine aggregate, were attained at the Pinrang River, South Sulawesi, Indonesia, which were characterized prior to the conduction of mortar production, using testing methods that are in accordance with [5-9].

Table 1. The chemical and physical characteristics of cement.

Properties	OPC		PCC	
	Result	Specification SNI 2049:2015	Result	Specification SNI 7064:2014
Chemical Properties				
SiO_2	20.23		19.62	
Al_2O_3	5.64		5.89	
Fe_2O_3	3.57		4.30	
MgO, %	1.87	Max. 6.0	1.85	
SO_3, %	1.53	Max. 3.5	1.70	Max. 4.0
Hilang Pijar, %	3.38	Max. 50		
Bagian tak larut, %	0.76	Max. 3.0		
C_3S, %	67.69		50.05	
C_2S, %	6.93		18.49	
C_3A, %	8.92		8.33	
Physical Properties				
Fineness/Blaine meter m2/kg	346	Min. 280	448	Min. 280
Autoclave expansion %	0.11	Max. 0.80	0.06	Max. 0.80
Time of setting (Vicat test)				
- Initial Set	125	Min. 45	138	Min. 45
- Final Set	260	Max. 375	260	Max. 375
Compressive strength				
- a. 3 days (kg/cm^2)	188	Min. 135	154	Min. 130
- b. 7 days (kg/cm^2)	266	Min. 215	223	Min. 200
- c. 28 days (kg/cm^2)	359	Min. 300	300	Min. 280
Final Set, final penetration, %	83.66	Min. 50	86.57	Min. 50
Air Content, % volume	4.53	Max. 12	4.97	Max. 12
Specific Gravity	3.15		2.94	

The production of materials with high compressive strength requires the addition of superplasticizers, e.g., Chelcem75RS, based on naphthalene sulfonate. In addition, some advantages of using these additives include the very high degree of workability, water reduction, and early strength, as well as low shrinkage and creep. Furthermore, applying the correct dose of superplasticizer increases workability [10], subsequently improving foam concrete pressure strength by up to 25%, in contrast with those deprived. [11] Hence, the creation of foam mixture requires the use of an agent termed Tamsoil 200CF.

2.2. Design and mixture of foam concrete

A mortar mixture of the foam concrete was made by integrating sands and cement, at a weight scale ratio of 2 : 1. In addition, the dose of foaming agent used in the mixture was 10% of the water utilized, and Table 2 shows the composition of the material in each variation.

Table 2. Foam concrete composition (per 1 m^3).

Code	Curing type	OPC (kg)	PCC (kg)	Sand (kg)	Water (kg)	Super plasticizer (kg)	Foam agent (l)	Wet Density (kg/m^3)
OPCWC	Water	276.49	0	553.97	165.89	4.70	51.9	1,187
OPCAC	Air	276.49	0	553.97	165.89	4.70	51.9	1,187
PCCWC	Water	0	276.46	552.93	165.88	4.70	41.5	1,174
PCCAC	Air	0	276.46	552.93	165.88	4.70	41.5	1,174

OPCWC = OPC Water curing; OPCAC= OPC Air Curing; PCCWC= Water curing; PCCAC = PCC Air Curing

2.3. The process of mixture foam concrete production

The gradual process of mixture production is shown in figure 1. This encompasses the foaming solvent, obtained by dissolving the agent into the water crock, at a ratio of 1:10. These solvents are then stirred, using propeller for 2 minutes, up to the point where they take shape.

- Simultaneously, there are 2 different kinds of mortar production, based on the type of cement used, including (1) the first that contains silica sands, water, and superplasticizer, added to the Ordinary Portland Cement (OPC), (2) the second entails the same materials but with the integration of Portland Composite Cement (PCC) instead. In addition, all the materials in each were stirred using a mixer individually in a dry condition for 2 minutes, followed by the addition of superplasticizers, then the subsequent dissolution in water and subjection to further stirring for 1 minute up to the point where the slump is obtained.
- The foaming solvent mixture is subsequently added in both mortars within the individual mixer, subsequently stirred back in 3 minutes until becoming the foam concrete mixture.
- After checking the density foam concrete, two types of specimen were made based on the mortar, by pouring the foam concrete in a cylinder cast, possessing a diameter of 150 mm, and 300 mm in length. Therefore, the compression was conducted by agitating its cast.
- After 1 x 24 hours, the specimen was removed from the cast to treat with the curing, which was either water or air.

2.4. Density test and compressive strength at the specimen

After curing the specimen, caping is given according to [12] and the density assessment was conducted with the [13]. In addition, the test required the use of 3 specimens, which were prepared for each variation of OPC and PCC foam concrete mixes on day 1, 3 and 7. Hence, 18 were obtained in total, with water and air curing treatments, each.

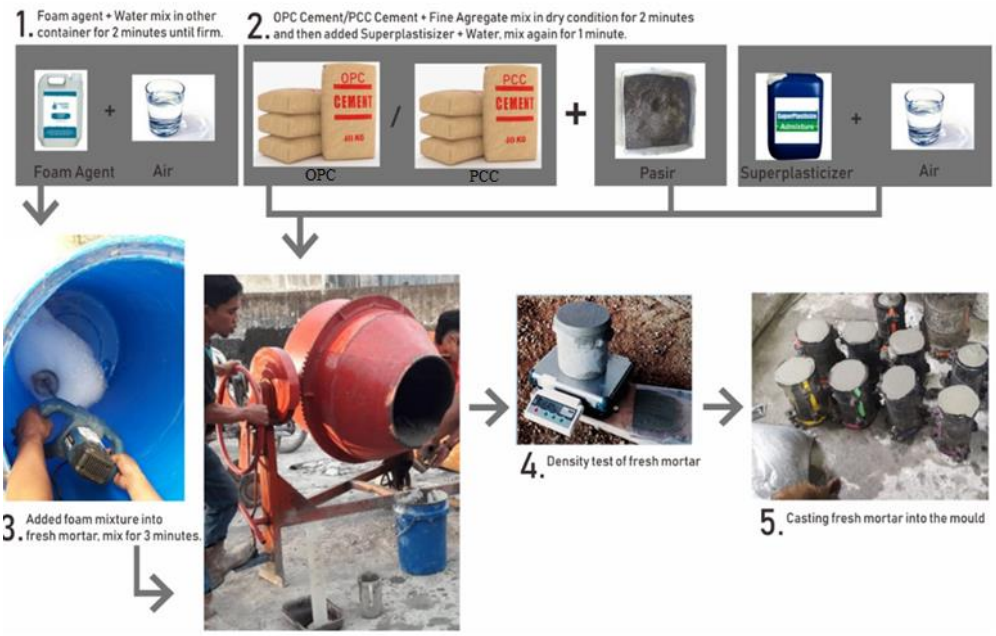


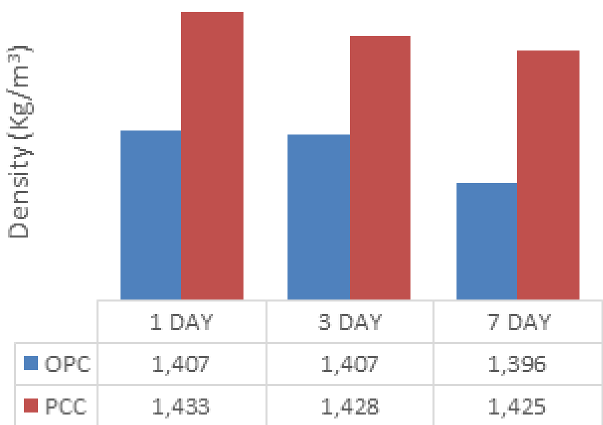
Figure 1. Process of mixture production.

3. Result and discussion

Prior to conducting the mortar production, fine aggregate characterization was performed, and the result exhibited a specific gravity of about 2.649 and fineness modulus (FM) of about 1.256 in saturated surface dry condition (SSD).

3.1. Density

Figure 2 and 3 show a specimen density of about 1,235 – 1,433 kg/m3, although specimen density with the water curing treatment is was higher than the result in air curing treatment. Meanwhile, based on the water that gained entrance into the cavity of the testing object, the value of specimen density within 7 days was about 1,235 kg/m3, up to the point where 1,425 kg/m3, or about 52.6% to 60.6% lower than the normal concrete density. According to [14], normal concrete is one which has a density of about 2,200 kg/cm3 up to 2,500 kg/cm3, made using natural aggregate that were capable of separating like cracked stone or integral nature aggregate. This concludes that the specimen of second-density types tend to decrease along with the age, air or water curing treatment.



	1 DAY	3 DAY	7 DAY
OPC	1,407	1,407	1,396
PCC	1,433	1,428	1,425

Figure 2. Density on water curing.

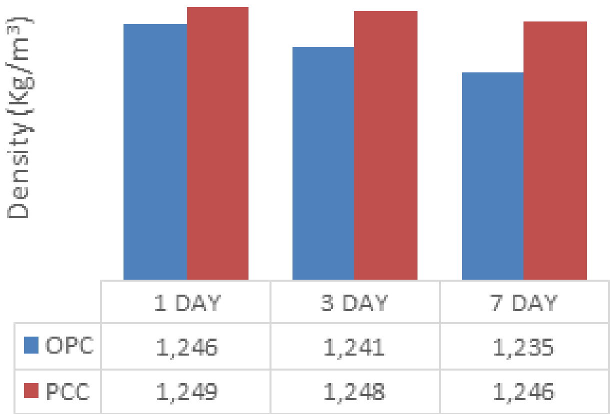


Figure 3. Density on air curing.

3.2. Compressive strength

The research on the compressive strength of specimens involved the use of OPC or PCC individually, and the result collected on the first, third, and seventh day observation period with water curing is shown in figure 4, and 5.

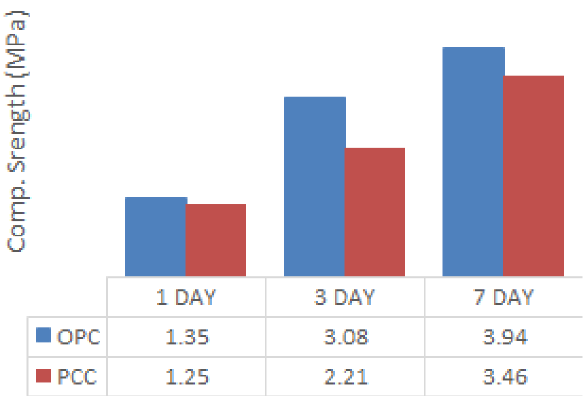


Figure 4. Compressive strength on water curing.

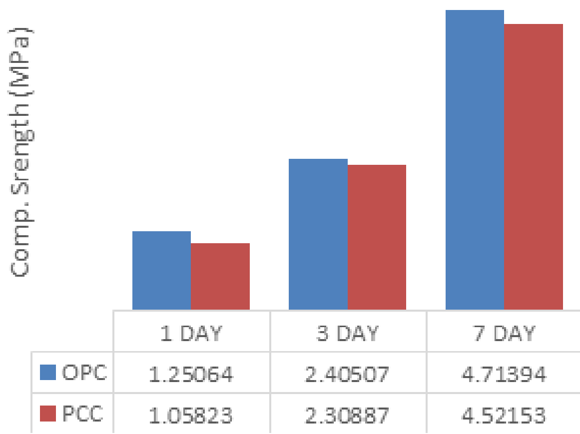


Figure 5. Compressive strength on air curing.

Figure 4 explains the use of specimen compressive strength with water curing and PCC at the age of seven days was up to 3.46 MPa, or 73.5%, which is lower than that of employed in OPC, of about 3.94 MPa. Therefore, on day 1 and day 3, the compressive strength used for OPC was about 34.2%, and 78.2% in day 7, which was about 36.1% and 63.9% for PCC.
In addition, on day 7, the compressive strength with air curing (Figure 5) that involved the use of PCC was up to 4.52 MP a, or 96.0%, toward while that contained in OPC was about 4.71 MPa. In addition, those that used OPC were 26.5% and 51.2% on day 1 and 3, in relation with the 7 days, while that for PCC was 23.5% and 51.1%, respectively.
According to [15], the light concrete are, further, divided into three types on day 28, which is based on density, compressive strength, and aggregate types used, into (1) Low-Density Concrete, encompassing the light variety with density between 300 kg/m3 - 800 kg/m3 and compressive strength about 0.69 MPa-6.89 MPa, usually used as a conductor insulation concrete. (2) Moderate Strength Concrete, this occurs at a density between 800 kg/m3 – 1,440 kg/m3, and compressive strength of about 6.89-7.24 MPa, which is usually used as a light structure or a filler, and (3) Structural Concrete, with values of 1,440 kg/m3 until 1,850 kg/m3for density, applied for use as the structural type when the compressive strength is more than 17.24 MPa. Therefore, the density of all specimen is fulfil the requirements within the moderate category, with a density of about 800 kg/m3 to 1,440 kg/m3.

4. Conclusion

The speciment test results indicated the density value obtained through the use of both cements ranged from 1,235 kg / m3 to 1,425 kg / m3, thus attaining the technical specifications of a light weight concrete. In addition, OPC treated with water curing on day 1, 3, and 7 were 34.2%, 78.2%, 100%, respectively, while that with air was 26.5% and 51.2%, 100%. Moreover, specimens that used PCC with water curing exhibited values of 36.1%, 63.9%, and 100%, with water, and 23.5% and 51.1%, 100%, respectively, with air.

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