

The effect of fly ash and coconut fibre ash as cement replacement materials on cement paste strength

R Bayuaji*, R W Kurniawan, A K Yasin, H AT Fatoni and F M A Lutfi

Departement of Civil Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia 60111

*Corresponding author: bayuaji@ce.its.ac.id

Abstract. Concrete is the backbone material in the construction field. The main concept of the concrete material is composed of a binder and filler. Cement, concrete main binder highlighted by environmentalists as one of the industry are not environmentally friendly because of the burning of cement raw materials in the kiln requires energy up to a temperature of 1450° C and the output air waste CO₂. On the other hand, the compound content of cement that can be utilized in innovation is Calcium Hydroxide (CaOH), this compound will react with pozzolan material and produces additional strength and durability of concrete, Calcium Silicate Hydrates (CSH). The objective of this research is to explore coconut fibers ash and fly ash. This material was used as cement replacement materials on cement paste. Experimental method was used in this study. SNI-03-1974-1990 is standard used to clarify the compressive strength of cement paste at the age of 7 days. The result of this study that the optimum composition of coconut fiber ash and fly ash to substitute 30% of cement with 25% and 5% for coconut fibers ash and fly ash with similar strength if to be compared normal cement paste.

1. Introduction

Concrete material is the fundamental material in the construction area. In the other side, Indonesia is very famous with local materials but they have not been fully utilized in concrete technology primarily for binder and filler material. Cement, concrete main binder highlighted by environmentalists as one of the industry are not environmentally friendly because of the burning of cement clinker raw materials requires energy with temperatures up to 1450° C and the output air waste CO₂. A fact which needs serious attention to environmental issues that in the production of every ton of cement produces one ton of CO₂ emissions released into the air [1]. On the other hand, Indonesia is one of the country's largest producer of foodstuffs, such as rice, maize, sugar cane and coconut. Indonesia has the largest oil fields in the world to the region approaching the 3.74 ha [2]. Coconut is one of the human needs that the value of commodity consumption is high, various preparations can be made from coconuts.

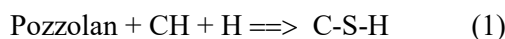
Coconut Fibre Ash (CFA) performed Center for Environmental Health Engineering, obtained by the composition of the compound Silica (SiO₂) amounting to 67.55%. This composition proves that CFA has the potential to collaborate with fly ash (FA) as a cement replacement materials (CRMs). Previous studies that the characteristics of local pozzolan concrete example: rice husk ash [3-5], Mud Sidoarjo's ash [6], Bromo Volcanic's ash [7] and other materials. These innovations reduce the impact of CO₂ emissions in the cement manufacturing process. Positive effect on concrete technology covers still meet



the standards of strength, economical and environmentally friendly This research will discuss the effect of the use of composite CFA and FA to substitute cement materials.

2. Fundamental Theory

Pozzolan materials are defined as cementitious materials that commonly compose silica or alumina and silica [8]. The pozzolan material as cement material replacement was classified by their chemical and mineralogical composition and particle characteristics [9]. The one of significant parameter that have effectiveness to react chemically with Calcium hydroxide, Ca(OH)_2 , and to form Calcium Silicate Hydrate is the fineness of pozzolan material particle. In addition, this parameter affects the strength and durability of concrete [10]. Pozzolan reaction is defined that composing a pozzolan (S) and calcium hydroxide (CH) in the presence of water (H). The simple equation shown in Equation (1) [11].



The pozzolan materials have ability to convert calcium hydroxide to calcium silicate hydrate (C-S-H). This concept give opportunity for concrete technology, to reduce cement as binder. Furthermore, the capillary voids are either eliminated or reduced in size. This in turn increases cement-concrete material such as strength and durability of the hydrated paste.

This concept makes the standpoint of alternative materials to reduce the use of cement and automatically reduce energy and resource that to produce cement.

3. Methodology

To achieve the purposes of this research, an experimental laboratory study in the Laboratory of Civil Engineering Diploma ITS was developed using the following materials:

The Ordinary Portland Cement (OPC) Type 1 was used throughout this research. The physical and chemical properties as listed in Table 1. Type 1 was chosen because of the observation on mortar properties could be done in normal hydration process without any addition of admixture to the concrete, hence the advantages of CFA and FA usage in cement paste can be maximally observed. The cement density and the surface area were found to be 3.15 and 359 m^2/kg respectively. The composition of the cement (in oxides) is presented in Table 1.

TABLE 1 Cement Properties [12]

Parameter	SNI 15-2049-2004	Test Result
Chemical Composition		
Al_2O_3		6.03
SiO_2		20.65
Fe_2O_3		3.44
CaO		65.96
MgO	Max 6.00	2.05
SO_3	Max 3.50	2.22
Loss on Ignition	Max 5.00	3.96
Free Lime		1.09
Insoluble residue		2.37
Alkali ($\text{Na}_2\text{O}+0,658\text{K}_2\text{O}$)		0.38
X-Ray Diffraction Properties		
Tricalcium Silicate (C3S)		56.68
Dicalcium Silicate (C2S)		11.00
Tricalcium Aluminate (C3A)		7.72

Parameter	SNI 15-2049-2004	Test Result
Tetracalcium Aluminate Ferrite (C4AF)		8.91
Physical Properties		
Fineness		
-Blaine specific surface (m ² /kg)	Min 280	359
Time of setting, Vicat Test:		
- Initial set (minutes)	Min 45	125
- final set (minutes)	Max 375	240
Autoclave test:		
-Expansion (%)	Max 0.8	0.10
Compressive strength:		
- 3 days (kg/cm ²)	Min 125	255
- 7 days (kg/cm ²)	Min 200	316
- 28 days (kg/cm ²)	Min 280	411
False set (%)	Min 50	77,36

One of the CRMs materials of cement paste is obtained from burning FA Paiton with the physical and chemical test results. Physical and chemical test data shown in Table 2

Table 2 Physical and chemical test results of Fly Ash

Chemical test results	
Silica (SiO ₂)%	54,5
Alumina (Al ₂ O ₃)%	23,0
Oksida Besi (Fe ₂ O ₃)%	5,3
Kapur (CaO)%	9,5
Oksida Magnesium (MgO)%	2,0
Sulphuric Anyhydrate (SO ₃)%	0,5
Others %	5,2
Physical test results	
Fineness (m ² /kg)	287
Specific gravity (gram/cm ³)	2,49

Coconut husk used in this study is a waste of coconut on Pasar Mangga Dua, Wonokromo, Surabaya. This study used coconut husk which has been dried and then performed some process that consists of combustion, grinding and sieving to obtain available chemical and mineralogical composition of coconut fibre ash CFA as cement replacement materials.

The combustion process carried out in the laboratory of Concrete and Building Material Department of Civil Engineering ITS Sukolilo with a total time of burning 6 hours and a maximum temperature of 600° C.

To obtain the chemical and mineralogical composition of coconut fibre ash CFA as cement replacement materials. Because of that, the temperature was raised gradually as long as combustion process. There were three steps temperature 100°C, 300°C and 600°C. It was shown completely in Figure 1.

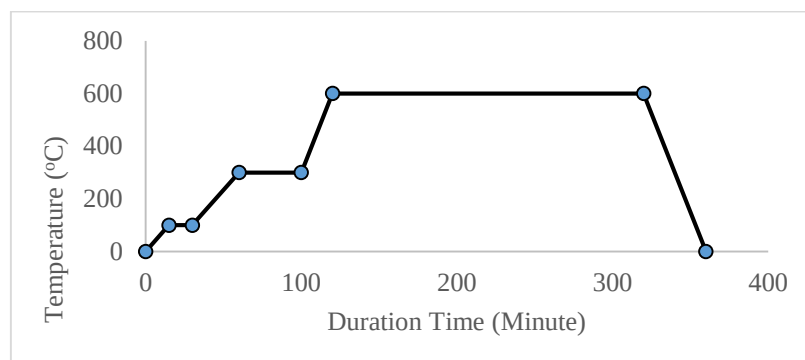


Fig. 1: The heat profile for coconut husk burning.

To accomplish the optimum mix proportion of cement paste that utilizing CFA and FA are used a identification test: compressive strength testing standard, SNI-03-1974-1990[13]. Pasta sample with a cylinder, diameter and height 2.5 cm and height 5 cm respectively. Comparison of water cementitious ratio (w/c) used fixed at a value of 0.3 as a control variable is OPC cement 100%. The hardened samples were then cured with soaked in fresh water then to conduct compressive strength test at 7 days using Universal Testing Machine UTM. The constituent cement paste using CFA and FA is described in Table 3.

Table 3. Mix proportion of cement paste using CFA and FA

No	Percentage by weight (%)			Weight of each material (gram)			
	Cement	FA	CFA	Cement	FA	CFA	Cement
1	100,00	0,00	0,00	14,73	108,97	0,00	0,00
2	90,00	0,00	10,00	14,73	98,07	0,00	4,37
3	80,00	0,00	20,00	14,73	87,18	0,00	8,73
4	70,00	0,00	30,00	14,73	76,28	0,00	13,10
5	90,00	5,00	5,00	14,73	98,07	4,23	2,18
6	80,00	5,00	15,00	14,73	87,18	4,23	6,55
7	80,00	10,00	10,00	14,73	87,18	8,46	4,37
8	80,00	15,00	5,00	14,73	87,18	12,68	2,18
9	70,00	5,00	25,00	14,73	76,28	4,23	10,91
10	70,00	10,00	20,00	14,73	76,28	8,46	8,73
11	70,00	15,00	15,00	14,73	76,28	12,68	6,55
12	70,00	20,00	10,00	14,73	76,28	16,91	4,37
13	70,00	25,00	5,00	14,73	76,28	21,14	2,18

4. Results and Discussion

Compressive strength test was used to identify the effectiveness of CFA and FA as cement replacement materials on cement paste strength. In this session to elucidate the result of strength and simple mechanism of CFA and FA on cement paste. The result of paste cement compressive strength that contain OPC, CFA and FA on 7 days was shown on Table 4.

Table 4. The compressive strength of cement paste using CFA and FA at 7 days

No of samples	Compressive Strength (MPa)
	7 days
1	66,18
2	15,27
3	10,18
4	15,27
5	81,45
6	78,77
7	76,05
8	67,91
9	66,2
10	61,08
11	45,82
12	15,27
13	5,09

The compressive strength of number of sample 9 was composed CFA and FA 30% by weight of cement. This result had similar result with control (number of sample 1). This is a proof that CFA and FA be able to convert calcium hydroxide on cement paste to calcium silicate hydrate (C-S-H) as strength product. SNI 15-2049-2004 determine the minimum strength of cement paste on 7 days is 20 MPa.

5. Conclusion

The pozzolan materials of CFA and FA have ability to convert calcium hydroxide on cement paste to calcium silicate hydrate (C-S-H) as strength product. Furthermore, the capillary voids are either eliminated or reduced in size. This in turn increases cement-concrete material such as strength and durability of the hydrated paste. To sum up the study of CFA and FA characteristic that these materials can be utilized as cement replacement material on cement paste. They can substitute cement 30% by weight on cement paste with similar strength if to be compared normal cement paste.

Acknowledgment

The authors would like to thank DIKTI for provided financial assistance to complete this laboratory research grants. In addition, the support of Laboratory of Testing Materials of Diploma Civil Engineering Program ITS is greatly appreciated.

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