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Optimization of using Baturaja fly ash as a Portland Composite Cement (PCC) additive

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Abstract. There has been researched on the optimization of fly ash Baturaja as a cement additive PCC. The purpose of this research is to know the optimal percentage of fly ash, which can be added to the process of making PCC cement, which still produces excellent quality cement and fulfills SNI and knowing the effect of adding fly ash to physical testing and chemical testing. The test was done physically, Blaine test, setting time test and compressive strength test for three days, seven days, and 28 days. Meanwhile, chemical testing is the Loss of Ignition (LOI) test, Free Calcium Oxide (FCaO) test, and Insoluble Residue test (IR). Based on the result of research, the most optimal percentage is when adding 6% ash fly proportion. The higher the ratio of fly ash, will result in an unstable Blaine value. The higher the proportion of fly ash is added, the compressive strength will be smaller, and the setting time will be longer. Meanwhile, the higher the addition of fly ash, the value of loss of ignition, Free Calcium Oxide, and insoluble residue value will be higher.

Keywords: Fly ash, cement PCC, Blaine, compressive strength, setting time

1. Introduction

Cement is one of the main essential ingredients of building construction, making cement a strategic commodity [1]. Cement is a hydraulic compound or substance which consists of C-S-H (Calcium Silicate Hydrate) compound [2]. Hydraulic binder (hydraulic binder), which means that the compounds contained in the cement can react with water and form new substances that are as adhesives to rocks [3]. The high hydraulic cement content will provide many advantages, including the ability to make mortar mixes to be stronger, denser, more waterproof, faster to harden and also to provide better bonding [4]. In general, cement raw material is dominated by ± 80% limestone, 9-12% clay, 6-9% silica sand, 1-2% iron sand and 3-5% gypsum [5]. One type of alternative cement whose price is relatively lower and simpler manufacturing process technology is the Portland Composite Cement (PCC) [6].

PT Semen Baturaja (Persero) Tbk is a state-owned portland cement producer that controls the market in almost all of South Sumatera to Lampung. Portland cement is a hydrolysis cement that is produced by grinding portland cement slag mainly consisting of hydrolysis and milled calcium together with an additional ingredient in the form of one or more crystalline forms of Calcium

Sulphate compounds and can be added with other additives [7]. Hydraulic means that if a material is mixed with water in a certain amount, it will bind other ingredients into a single mass that can solidify and harden and not dissolve [8]. At PT Semen Baturaja (Persero) Tbk the Baturaja site produces two types of portland cement namely Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC). Portland Cement (OPC) is a cementitious cement produced by smoothing clinkers, which mainly consists of calcium silica, which is hydraulic with commonly used ingredients gypsum [9]. OPC type cement has a higher hydration heat compared to PCC type cement [10].

PCC is a type of cement product that is designed to meet particular needs, both in the technical aspect and in the element of costs that cannot be met by OPC [11]. According to SNI 7064-2014 [12], PCC is a hydrolysis binding material produced by milling together with portland cement slag and gypsum with one or more inorganic materials or the result of mixing between portland cement powder with other inorganic ingredients. Inorganic materials blast furnace slag, pozzolan, silicate, compounds, and limestone with a total inorganic content of 6%-35% of the mass of portland cement. Pozzolan is a material that contains silica and alumina, which is smooth and moist [13] as it is known that limestone contains mostly calcium carbonate minerals, which is around 95% [14].

The ingredients in the form of high-quality limestone, fly ash, and pozzolan. The most widely used component is clinker, while clinker manufacturing process requires considerable costs. So, this study tries to minimize the use of additional materials, namely fly ash. The addition of fly ash in cement production will reduce the percentage of clinker, which can reduce production costs. Fly ash is a material derived from unused residual coal combustion [15]. Fly ash is remaining coal combustion ash which is captured by the Electrostatic Precipitator dust filter from exhaust gas and is pozzolanic which contains reactive SiO2 and Al2O3 compounds, so when added to PCC cement production together with ingredients such as clinker, gypsum, and pozzolan will give the influence on the quality of PCC cement. These materials generally contain reactive amorphous silica components, which in reaction with water and Ca(OH)2 will form calcium silicate hydrate compounds, abbreviated CSH [1].

In a previous study, a study was conducted on the effect of adding fly ash to the physical and chemical quality of PCC cement production by Sefri (2016) [16]. Based on the results of the research that has been done, physics quality in the form of fineness value (Blaine) is obtained 4313 cm^2/g (PCC cement without the addition of fly ash) to 4657 cm^2/g (PCC cement with 28% the addition of fly ash), while for the quality of mortar compressive strength there was a decrease in 3 days mortar compressive strength from 281 kg/cm^2 (PCC cement without the addition of fly ash) to 244 kg/cm^2 (PCC cement with 28% the addition of fly ash) and 7 day mortar compressive strength of 350 kg/cm^2 (PCC cement with 28% addition of fly ash) to 302 kg/cm^2 (PCC cement with 28% the addition of fly ash). However, the results obtained for 28 day mortar compressive strength actually increased from 423 kg/cm^2 (PCC cement without the addition of fly ash) to 440 kg/cm^2 (PCC cement with 7% addition of fly ash) and decreased to 407 kg/cm^2 (PCC cement with 21% addition of fly ash). In terms of chemical quality, there was an increase in SiO_2 content from 27,2% (PCC cement without the addition of fly ash) to 32,28% (PCC cement with 28% the addition of fly ash) and Al_2O_3 in cement from 5,86% (PCC cement without the addition of fly ash) to 10,81% (PCC cement with 28% the addition of fly ash) and a decrease in CaO content of 59,74% (PCC cement without the addition of fly ash) to 50,85% (PCC cement with 28% the addition of fly ash) and SO_3 content from 1,98% (PCC cement without the addition of fly ash) to 1,55% (PCC cement with 28% the addition of fly ash).

Based on the description above, a study was conducted on the optimization of the use of Baturaja fly ash as an additive for PCC cement. This is done to find out more about the effect of fly ash on physical and chemical testing and to know the optimal percentage of fly ash that can still be added to the process of making PCC cement to produce quality and meet SNI.

2. Materials and Methods

The research flow chart is shown in **FIGURE 1**.

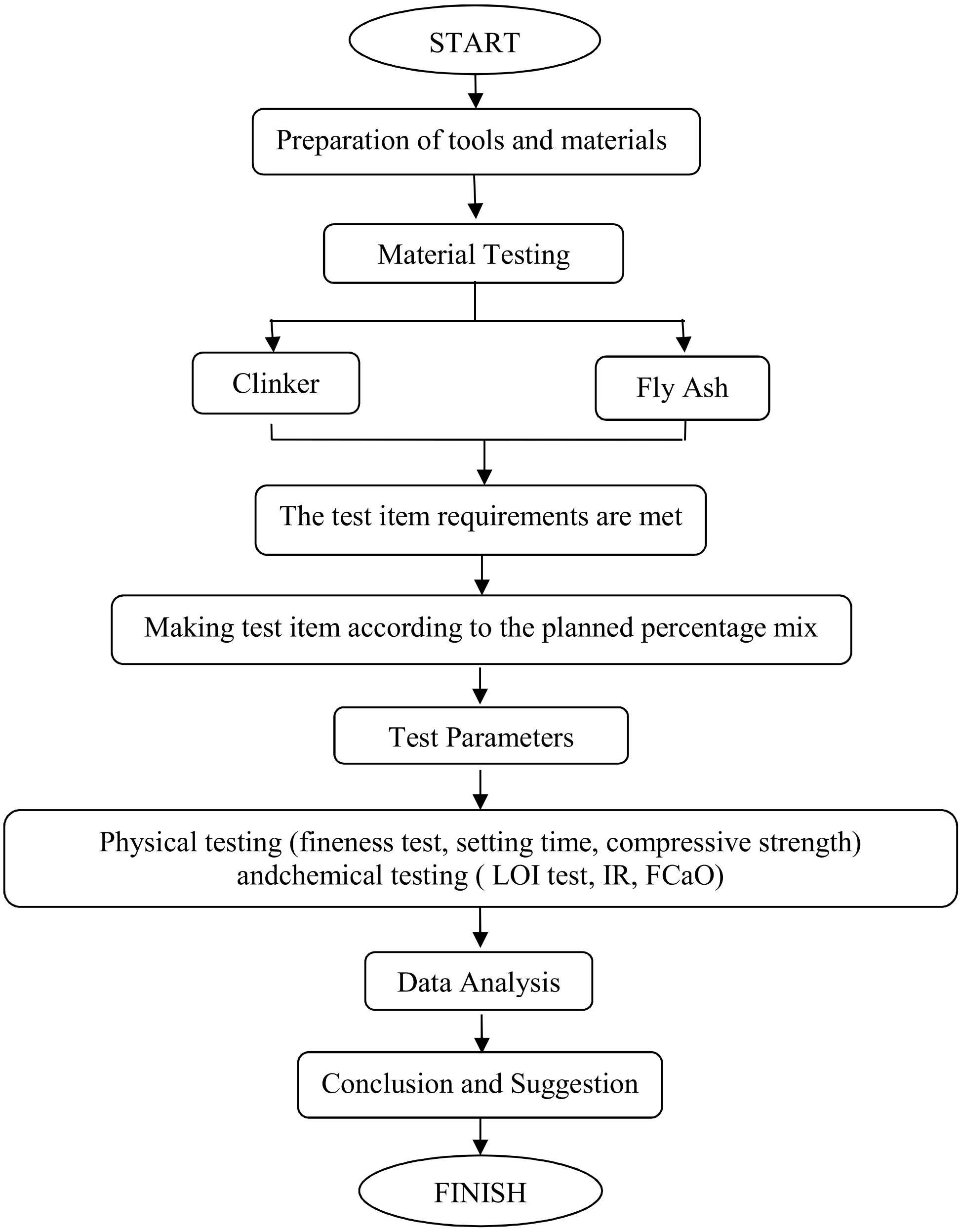

FIGURE 1. Flow Chart of Research

The analytical method used in this study is based on established standards, namely SNI 7064-2014, concerning Portland Composite Cement. This research was conducted with a concentration of fly ash as much as 6%, 10%, and 14%. In this physical study, testing and chemical testing were carried out. Physics testing includes Blaine test using Blaine apparatus, setting time test using the Vicat tool, and compressive strength test using compressive strength tools. Meanwhile, chemical testing includes lost of ignition test by purifying cement at 975 ºC in a saucer, FCaO test using powder $BaCl_2$ is mixed with Glycerol Ethanol solution which is heated on the stove and the titrated using Ammonium Nitrate solution, and testing the insoluble residue using Chloride Acid mixed with distilled water and then heated on a hot plate until boiling then filtered using Whatman 41 filter paper. After filtering, then in the furnace at 975 ºC.

Results and discussion

Based on the results of research that has been done, can be obtained several observations as follows:

TABLE 1. The Results of Blaine Test

Fly Ash Proportion (%)	Grinding Time (menit)	R45 µm (%)	Blaine (cm^2/gram)
6	120	12,56	3302,6
10	110	12,88	4168,5
14	90	12,92	3761,0

TABLE 2. The Results of Setting Time Test

Fly Ash Proportion (%)	Initial Setting Time (minute)	Finish Setting Time (minute)
6	101	147
10	118	163
14	117	174

TABLE 3. The Results of Compressive Strength Test

Fly Ash Proportion (%)	Standard Compressive Strength SNI 7064: 2014 (kg/cm^2)			Compressive Strength (kg/cm^2)		
	3 days	7 days	28 days	3 days	7 days	28 days
6				166,0	265,7	395
10	min. 130	min. 200	min. 280	165,8	254,1	398
14				138,3	237,6	359

TABLE 4. The Results of Lost of Ignition Test

Fly Ash Proportion (%)	Standard Lost of Ignition SNI 7064: 2014 (%)	Lost of Ignition (LOI) (%)
6		9,36
10	-	9,71
14		10,0

TABLE 5. The Results of Free Calcium Oxide Test

Fly Ash Proportion (%)	PTSB Internal Standard Free Calcium Oxide (%)	Free Calcium Oxide (FCaO) (%)
6		0,71
10	max. 2	1,07
14		1,42

TABLE 6. The Results of Insoluble Residue Test

Fly Ash Proportion (%)	Standard Insoluble Residue SNI 7064: 2014 (%)	Insoluble Residue (IR) (%)
6		7,72
10	-	10,03
14		12,94

Blaine Test Analysis

According to SNI 7064-2014, cement is declared to pass the Blaine test if the minimum amount is 2800 cm^2/gr with a residue 12 ± 1%. The result obtained from this study can be seen in TABLE 1. When viewed from the results of the research, the proportion of fly ash added as an additive in the manufacture of PCC cement still meets SNI.

Setting Time Test Analysis

Setting time testing is done to regulate the speed of cement in the hardening process to make it easier for work. Based on the observations obtained, as shown in TABLE 2, the initial setting time and final setting time still meet the specified standards. The standard is determined based on SNI 7064-2014 for the initial setting time of at least 45 minutes, and the final setting time is a maximum of 375 minutes. The more beautiful the cement granules, the more time it takes for the cement to harden [17]. The faster the hydration reaction, the binding and hardening reaction takes place quickly too [18].

Compressive Strength Test Analysis

According to SNI 7064-2014 about Portland Composite Cement, mush has compressive strength within three days minimum 130 kg/cm^2, within seven days at least 200 kg/cm^2, and within 28 days at least 280 kg/cm^2. When viewed from the observations that have been obtained as shown in TABLE 3, the addition of the proportion of fly ash will reduce the compressive strength both within three days, seven days, and 28 days. The more percentage of fly ash added, the smaller the compressive strength produced. To further clarify, the relationship between the addition of the proportion of fly ash and compressive strength can be seen in **FIGURE 2**.

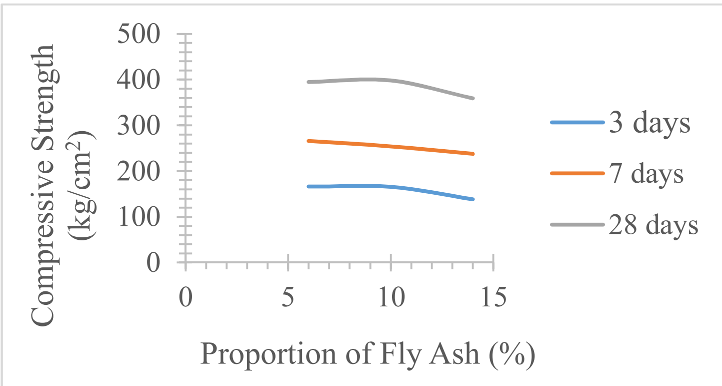

FIGURE 2. Graph of the relationship between the proportion of fly ash with compressive strength

Based on the chart in **FIGURE 2**, the relationship between the percentage of fly ash with compressive strength for three days, seven days, and 28 days is the higher proportion of fly ash added; the compressive strength will be smaller. Factors affecting compressive strength include the smoothness of the cement. The more beautiful the cement, the higher the compressive strength, and vice versa, the coarser the cement, the lower the compressive strength [19,20].

Loss Of Ignition Test Analysis
LOI is the level of lost incandescent of cement or substance that will be released as gas when heated or burned [21]. This test is carried out to reduce the shrinkage in cement. Because of the reduction in large cement will result in low compressive strength. Based on the results of observations, as shown in TABLE 4, a relationship that is directly proportional to the addition of the proportion of fly ash with the magnitude of the loss of ignition is obtained. The higher value of the loss of fire in the cement will result in low compressive strength [13].

Free Calcium Oxide Test Analysis
This test is carried out to control the expansion of cement. When the value of Free Calcium Oxide on large cement, development of cement will also be significant. Significant development of cement can cause cracks or compressive strength below. According to the internal standards of PT Semen Baturaja (Persero) Tbk, the value of Free Calcium Oxide is a maximum of 2%. The observations obtained are shown in TABLE 5 and still meet the internal standards of PT Semen Baturaja (Persero) Tbk.

Insoluble Residue Test Analysis
The test is carried out to control the compressive strength of the cement. If the value of the insoluble residue is high, the compressive strength produced will below. Based on the results of the research, as shown in TABLE 6. The proportion addition of 4% fly ash (from 10% to 14%) results in a distance of 2,91%. The higher the proportion in the fly ash, the higher value of the insoluble residue of the cement.

3. Conclusions
Based on the research, it can be taken as a conclusion as follows: the most optimal percentage of fly ash to be added as an additive to PCC cement is as much 6% fly ash proportion. The higher the balance of fly ash, the smaller the compressive strength and the longer setting time of the cement.The higher the percentage of fly ash, the greater the value of the loss of ignition, free calcium oxide, and insoluble residue.

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