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Investigation of The Dominant Factors on Promoting Pozzolanic reaction of Fly Ash Based Aluminosilicate

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Abstract: ***A pozzolanic binder generates pozzolanic reaction; in this study the pozzolanic binder used is Fly ash based aluminosilicate. In order to achieve the maximal result from pozzolanic reaction there are several factors that play an important role in the process. The main goal of this study is to identify the most dominant factors on promoting the pozzolanic reaction, because more reactive the pozzolanic more strength will be gained. To identify the important factors, identifying the initial characteristic of the fly ash is realized using several tests. The particle size distribution, its mineralogical content is very important on gaining the strength. The type of the hydraulic additional binder is also investigated in this study. From the result, it is remarked that the reactivity of the lime is very significant on promoting the pozzolanic binder. Chapelle test is realized to identify the percentage of CaO available in the fly ash to provide the pozzolanic reaction to reacts. The result shows that mineralogical content of the fly ash is more dominant on increasing the strength compared to its particle size distribution. The amount of CaO free plays very significant role on promoting the success of pozzolanic reaction on improving the unconfined compressive strength of the concrete.***

Keywords: Pozzolanic reaction, fly ash, lime hydration, Chapelle test and unconfined compressive strength

1. Introduction

The pozzolanic reaction is well known as a secondary reaction that provides the additional strength. The used of pozzolanic binder such as a binder to stabilize the problematic soil is already realized [1][2]. The result shows that the Silica Fume can increase the strength and can reduce the micropollutants content in the waste sediment. The addition of silica fume clearly shows a significant increase on unconfined compressive strength. From result of the Toxicity Characteristic Leaching Procedures (TCLP) the samples with silica fume shows a reduction on micropollutants on heavy metal[3][4],. The utilization of pozzolanic binders as replacement, automatically reduces the utilization of cement, and clearly can reduce the amount of CO_2emitted. Besides known for its capabilities on increasing the engineering properties, pozzolanic reaction also known need a longer time on reaching its maximal results. Silitonga stabilized waste sediment with silica fume. The result shows the sample with pozzolanic binders shows a significant increase of compressive strength after 28 days [5] The addition of silica fume is realized because according to the result of Silitonga, the common hydraulic binders are not capable to improve the engineering properties of contaminated sediment [6]. The present of the micropollutants obstruct the hydration of cement or lime.Several studies already done concerning the pozzolanic reaction, He et al [7], in his research worked on pozzolanic reaction of clay mineral, the result show that the microstructure of the raw clay has an important impact on its unconfined compressive strength value of the sample, the calcination process also plays an important role on improving the unconfined compressive strength.Tironi et al, concluded that, type of the clay, the nature and the amount of the clay mineral is the most important factors on enhancing the pozzolanic activity based from clay [8]. The effect of aging condition of the calcined clay shows an increase of unconfined compressive strength and flexural strength of the sample with 20% of aged calcined clay than sample without calcined clay [9]. Fernandez et al worked on the effect of decomposition of clay with 600^0C treatment on pozzolanic activity of calcined clay. This treatment showsimportant advantages on increasing the activity of the sample compared to the sample with calcined clay mixed with cement [10]. This treatment with high temperature is proven on enhancing the reactivity of the pozzolans and it generates the increase of engineering properties of the sample.

2. Material and Method

Pozzolanic binder used in this study is a fly ash based aluminosilicate from circulate fluidized bed. This fly ash is byproduct from local mining and never been subjected to any treatment to enhance its properties. This fly ash is not in the market yet. One of the goals of this this study is to identify the possibilities of using this fly ash.There are two type fly ashes used in this study. Fly ash type A (CV_A) and Fly ash type B (CV_B). Both fly ashes came from different locations, with different mineralogical content but come form the local mining with Circulating Fluidized Bed method.

2.1. Particle size

Due to its fine particles, to identify the particle size of fly ashes,a test is performed by using Laser Granulometric. The Laser GranulometricLS200 is capable to identify the particle size distribution up to t 2 µm. The result of the particle size distribution test is presented in Table 1.

Table 1: Particle size distribution of fly ashes

Parameters	*CV_A*	*CV_B*
< 1 mm (%)	3.2	4.7
1 à 5 mm (%)	10.5	17.5
5 à 74 mm (%)	74.6	69.4
74 à 200 mm (%)	9.7	7.5
200 à 400 mm (%)	1.3	0.2
D10 (mm)	3.4	2.1
D50 (mm)	19.2	17.5
D90 (mm)	83.4	68.2

The fineness of the particle of pozzolanic binder is one of the most important factors related to pozzolanic reaction. Table 1 we can observe that Fly ash type A (CV_A) has more coarser particle than Fly ash type B (CV_B), this can be seen from D90 where the more presented particle size of CV_A is 83.4 mm and 68.2 mm for CV_B. From table 1 we can see that the highest percentage size content in fly ash is size between 5 à 74 □ m, 74.6 % for CV-A and 69.4 for CV_B. The finest particle size (< 1 □ m), CV_B possess more volume than CV_A, the same with particle size between 1 à 5 □ m, the CV_B still shows the highest percentage content.

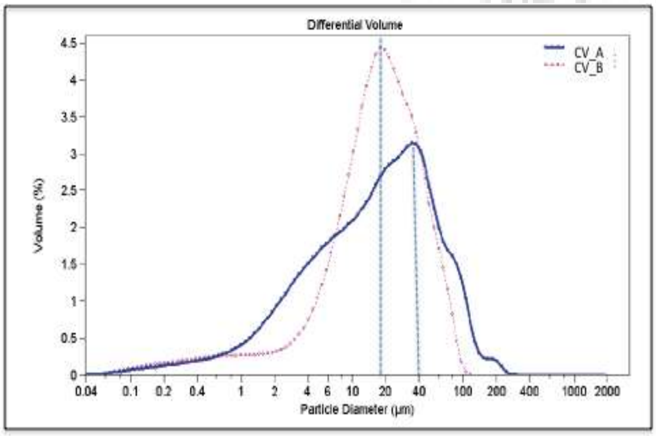

Figure 1: Particle size distribution of fly ashes

Contrary to that result, CV_A possess higher percentage for coarser particle size (74 à 200 □ m) (200 à 400 □ m)According to this result we can expect that CV_A need higher water content to achieve best workability because miner the particle size higher the Blaine specific surface and higher the w/c value to acchivied the best workability [11][12]. And this means that CV_A is less resistance to sulfate attack compared to CV_B

2.2. Mineralogical Characteristic

This test is to identify the mineralogical the fly ashes used in this research. CV_B is considered as asilico-aluminous fly ash, it is taken from combustion in a flowing bed Circulating low temperature (850 ° C). On the other hand, CV_A is considered as a sulpho-calcic fly ash, waste from the combustion in a flowing bed circulating at low temperature (850 ° C).

Table 2: Mineralogical characteristic of fly ashes

Parameters	*CV_A*	*CV_B*
SiO_2	47.36	20.38
Fe_2O_3	7.09	1.91
Al_2O_3	21.63	11.7
MgO	3.32	1.07
MnO_2	0.62	0.03
CaO_{total}	8.52	35.31
CaO_{free}	0.9	13.35
Na_20	0.46	0.13
K_20	4.35	17.1
SO_3	4.02	17

Table 2 presents the mineralogical characteristics of CV_A and CV_B. the CV_A. From the results we can observe that CV_B contains higher percentage (more than two times) of SiO_2, Al_2O_3 and Fe_2O_3 than CV_A. The high percentage of SiO_2, Al_2O_3 and Fe_2O_3 provided a positive effect on the evolution of the mechanical performances of the samples [13][14]. SiO_2plays an important rule on contributing the production of Calcium Silicate Hydrate (C-S-H), once hydrated produced, it leads to a bonding between sediment particles [15]. In contrary, CV_A has a higher percentage of CaO_{free} percentage than CV_B. CaO is very important for the pozzolanic reaction. With this percentage of free CaO of the fly ash is added the quantity coming from the hydration of the lime.

2.2. Lime

The dissolution of lime is modeled by the following reaction.

$$CaO + H2O \rightarrow Ca2+ + 2OH \qquad (1)$$

This dissolution of lime leads to the saturation of water and to contributes to increase the pH up to values greater than 12. This high pH value allows the dissolution of the silica and alumina. These silica and alumina content in the fly ash and in the clinker can promote the pozzolanic reaction. Part of the quicklime CaO will hydrate to form the slaked lime or calcium hydroxide $Ca(OH)_2$.

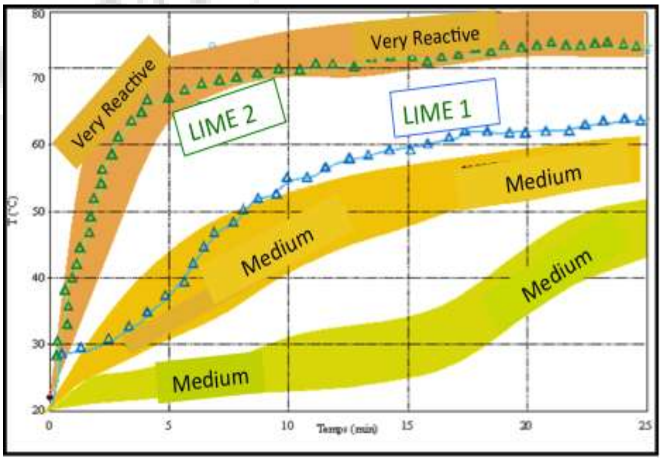

Figure 2: Heat evolution of different type of lime hydration

A test is realized to identify the reactivity of the lime associated with the temperature during its hydration. The reactivity of the lime can be detected by measuring the heat produces during the hydration. Figure 2 shows the evolution of heat during the test. The result shows that there is a remarkable different of heat evolution between Lime type 1 (LIM1) and Lime 2 (LIM2). We can observe the heat evolution of lime 1 (LIM1) is started at 18°Cat 0 minute and end at 63°Cat 25 minutes. Lime 1 (LIM1) is categorized as a lime with medium reactive. The heat evolution of lime type 2 (LIM2) is started at 20°Cat 0 minute and 72°Cat 25 minutes. This heat evolutionis located in the area of very reactive of lime; this means the lime type 2 (LIM2) is classified as a very reactive lime.

2.3. Mix composition

Composition of binder is designed according to the purpose of the study, to investigate the effect of one binder one the mixture.The composition of binder is presented in table 3

Table 3: Mineralogical characteristic of fly ashes

Name	*CV_1*	*CV_2*	*LIM1*	*LIM2*	*Semen*
80CV_1_LIM1	80	-	15	-	5
80CV_1_LIM2	80	-	-	15	5
80CV_2_LIM1	-	80	15	-	5
80CV_2_LIM2		80	-	15	5
70CV_1_LIM1	70	-	15	-	5
70CV_1_LIM1	70	-	-	15	5
Cement_5	-	-	-	-	5

The percentage of fly is devised in two amounts, 70% and 80%, this sample is realized to identify the effect of the increase of percentage of fly ash. The different type of fly ash can be noticed with the sample with CV_1 and CV_2. The influence of two type of lime with different reaction intense is used in this study.

3. Results and Analysis

3.1 Chapelle Test

Chapelle test is realized to determine the available amount of CaO_{free} to promote the pozzolanic reaction, and can identify the concentration amount of OH^-. The CaO_{free}reaction creates a bonding and helps to reduce the acidity level of sample. This means creates a condition where the pH increases from 7 to 12. This condition is very important to start the pozzolanic reaction and produces C-S-H and C-A-H. The reaction is modeled by the following reaction:

$$Ca^{++} + 2[OH]^- + SiO_2 \rightarrow C\text{-}S\text{-}H \quad (2)$$

$$Ca^{++} + 2[OH]^- + Al_2O_3 \rightarrow C\text{-}A\text{-}H \quad (3)$$

microstructure of CSH gel is one of the most dominant to increase the strength of the mortar. Silitonga in his research [16]presented that the silica content in fly ash, reacts with CH after several seconds create CSH gel. The result of Chapelle test is presented in table 3

Table 3: Amount of CaO_{free} after Chapelle Test

CaO_{FREE} (%)	***CV_1***		***CV_2***	
	24 hours	*48 hours*	*24hours*	*48 hours*
Average (%)	77,17	63.6	68,73	67
Standar deviation (%)	4,91	5.59	8,07	8.99

From table 3 we can observe that CV2 possess more percentage of CaO free after 24 hours the percentage of CaO for CV_1 and CV_2 still show a percentage more than 50%, this means the reaction is not very intense, this is why the amount available after 24 hours still more than 50%. Although the quantity of CaO_{free} available on CV_B is less than CV_A, but after 24 hours CV_B provides more CaO_{free}After 48 hours the percentage CV_2 still 67%, this result shows that CV_B provides more quantity of $CaO_{free}$to promote the pozzolanic reaction than CV_A.

3.2. Unconfined compressive strength

The most common test used to determine the strength of the concrete is unconfined compressive strength. This test realized with sample at 7, 14, 28,60 and 90 days.

3.3.1. The effect of fly ash addition

The increase of the evolution strength of samples with fly ash content is very intense compared to sample content only with cement. This evolution of strength shows a significant increase started from 7 days and up until 90 days still shows an intense increase of strength. Contrary for the sample content only with cement, the evolution of compressive strength becomes less intense after 28 days. The strength evolution of all the samples is presented in figure 4.

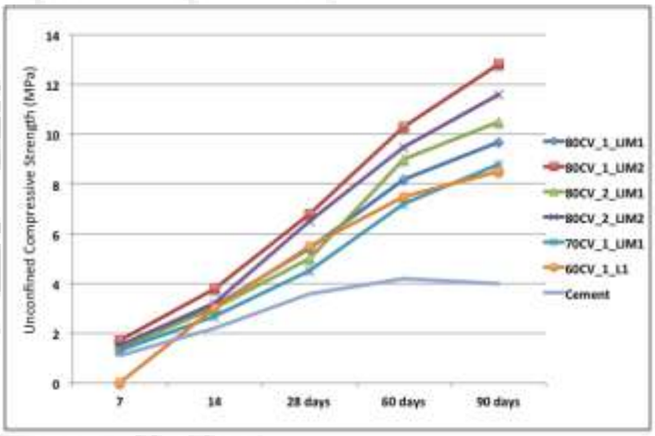

Figure 4: UCS result for al the samples

3.3.2. The effect of different quantities of fly ash

Figure 5 shows the evolution of strength between different types of fly ash (type 1 and type 2). As shown in figure 5, the evolution of strength is presented from 28 days, not from 7 days, this is because the evolution of strength of sample with fly ash addition starts to show an significant different since 28 days. From the particle size opoint of view, the CV_B possess finer particle size than CV_A.

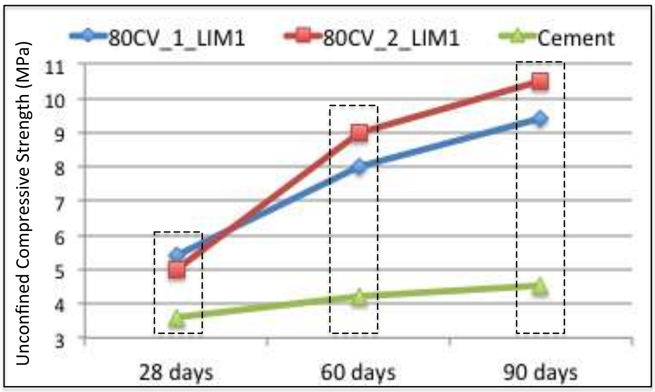

Figure 5: UCS result for samples with different fly ash types

According to this result, fly ash type 2 (CV_B) is considered more reactive than CV_A, this means CV_B should generates higher unconfined compressive strength than CV_A. The UCS test result confirms this theory, CV_B own higher compressive strength than CV_A. From mineralogical content point of view, table 2 shows that CV_B contains almost two times of percentage of SiO_2, Al_2O_3 and Fe_2O_3than CV_A. According to previous study [17], the high percentage of SiO_2, Al_2O_3 and Fe_2O_3 provide a positive effect on the evolution of the mechanical performances. In contrary, CV_A has a higher CaO_{free} percentage than CV_B. CaO is very important for the pozzolanic reaction. With this percentage of free CaO of the fly ash is added the quantity coming from the hydration of the lime. The result shows that CV_B possess higher compressive strength than CV_A. this result confirms that the content of SiO_2, Al_2O_3 and $Fe_2O_3$is more dominant on strength evolution than content of $CaOf_{ree}$. The result of Chapelle test concerning the amount of available CaO_{free}confirms the result. According to Chapelle test, CV_B provides more CaO_{free}thanCV_A provides more quantity of $CaO_{free}$to promotes the pozzolanic reaction to achieve its maximum result.

3.3.3. The effect of different types of lime

Two different types of lime are utilized in this study. The test to identify the lime reactivity is realized. As known that the reactivity of lime is very important to increase the pH up to 11-12, which is the needed condition to start up the pozzolanic reaction. The result shows Lime type 2 (LIM2) releases higher temperature during the test than Lime type 1 (LIM1). This results means that LIM2 is more reactive than LIM1, and assumed LIM2 will provide higher strength than LIM1. The result of unconfined compressive strength for different types of lime is presented in Figure 5. All the samples mixed with lime 2 (80CV1_LIM2 and 80CV2_LIM2) show a higher compressive strength than sample treated with lime 1 (LIM1). The intense reactivity of lime 2 clearly shows positive effect on compressive strength evolution..

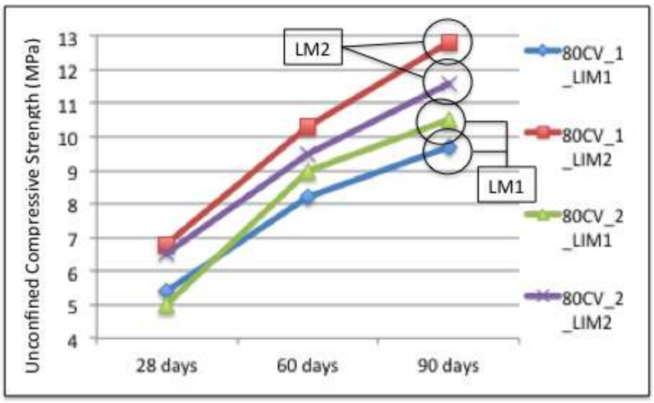

Figure 6: UCS result for different types of lime

The hydration of lime increases the pH level; with the high pH level this condition generates the dissolution of the silica and alumina. Silica and alumina contentpromotes the pozzolanic reaction. As shown in figure 6, the different types of fly ash show less significant less than the different types of lime. From this result we clearly can remark that the hydration of lime plays an important role on promoting the success of pozzolanic reaction.

4. Conclusion

The main goal of this experimental study is to identify the dominant factor on promoting the pozzolanic reaction of fly ash.The initial characteristic is determined with various test. The majority of particle size distributionof fly ash is classified as sand size (5 à 74 mm)and the particle size of fly ash type 1 (CV_1) has coarser particle size than CV_2. The mineralogical test shows sample with fly ash type 2 (CV_B) contains higher percentage of SiO_2, Al_2O_3 and Fe_2O_3than fly ash type 2 (CV_2) contrary to this result, CV_A has a higher percentage of CaO_{free} percentage than CV_B.According to the test result, lime type 2 (LIM2) has more intense reactivity than lime type 1 (LIM1). This lime reactivity is determined according to the temperature produces by the heat during the lime hydration. Chapelle test presents that the lime type fly ash type 2 (CV_2) provides more CaO_{free} than fly ash type 1 (CV_1). The amount of $CaO_{free}$is very important to promote the pozzolanic reaction to achieve the maximum result. The unconfined compressive strength test confirms which factors that have an important role on promoting the pozzolanic reaction. The results confirm that the reactivity of lime is the most dominant factor on ensuring the success of pozzolanic reaction. The mineralogical content of fly ash is the second most important factor. The amount of SiO_2, Al_2O_3 and Fe_2O_3has more influent than CaO_{total} on promoting the pozzolanic reaction. The fly ash with more quantity of CaO_{free} available for pozzolanic reaction performs higher strength than other sample with less amount of CaO_{free}.

References

[1] E. M. Silitonga, "Experimental research of stabilization of polluted marine dredged sediments using silica fume" Matec web of conf., CXXXVI, 2017

[2] E. M. Silitonga, "Stabilization solidification of polluted marine dredged sediment of port en Bessin France" IOP conference series, material science and engineering, V (6), 2016.

[3] E. M. Silitonga, “Impact of pozzolanic binder addition on stabilization polluted dredged sediment on its potential reuse as a new resource material for road construction in Basse Normandie, France” IOP conference series, material, science and engineering, CCCIX, 2018

[4] E. M. Silitonga, “Stabilisasidanidentifikasisedimenhasilpekerjaanpengerukanpelabuhan,” Journal of Educational Building, II (2), pp. 50-58, 2016.

[5] E. M. Silitonga, “Reutulisasisedimenhasilpekerjaansebagai material barudalampekerjaanpembangunanjalan,” Educational BuildingUnimed, II, pp. 96-105, 2016.

[6] E. M. Silitonga, “Identifikasipengaruh semen dankapurpadastabilisasilimbahterpolusilogamberatpada pekerjaanpengerukanpelabuhan” JurnalpenelitianSaintika, XVIII (1), pp. 69-75, 2017

[7] C. He., B., Osbaeck, E., Makivicky, “Pozzolanic reaction of six principal clay mineral: activation, reactivity assessments and technological effects” Cement and Concrete Research, XXV, pp. 1691-1702, 1995

[8] A., Tironi, M., Trezza, A., Scian, E., Irassar“Assessment of pozzolanic activity of different calcined clay” Cement and Concrete Composites, XXXVII, pp. 319-327, 2013

[9] R., Gmur, K., Thienel, N., Beuntner, “Influence of aging condition upon the properties of calcined clay and its performance as supplementary cementitious material” Cement and Concrete Composites, LXXII, pp. 114-124, 2016.

[10] R., Fernandes, F., Martirenaa, K., Scrivenerb “The origin of the pozzolanic activity of calcined clay minerals: a comparison between kaolinite, illite and montmorillonite” Cement and Concrete Composite, XXXXI, pp. 113-122, 2011.

[11] S. Ferreiro, D., Herfort, J., S., Damtoft “Effect of raw clay type, fineness, water to cement ratio and fly ash addition on workability and strength performance of calcined clay limestone Portland cements” Cement and Concrete Research, CI, pp. 1-12, 2017

[12] Y., Dhandapani, M., Santhanam “Assessment of pore structure evolution in the limestone calcined clay cementitious system and its implications for performance” Journal of Cleaner Production, LXXXIV, pp. 36-47, 2017.

[13] J., K., Weng, B., W., Langan, M., A., Ward “Pozzolanic reaction in Portland cement, silica fume and fly ash mixture” Canadian Journal of Civil Engineering, XXIV, pp. 754-760, 1997

[14] W., Mechtia, T., Mnifa, M., Chaabounib, J., Rouisa. “Formulation of blended cement by the combination of two pozzolans: calcined clay and finely ground sand” Construction and Building Materials, L, pp. 609-616, 2014.

[15] S., Sánchez, A., Berriela, E., Favierb, I., Domíngueza, R., Sánchez, U., Machadoa, K. Heierlic, F., Scrivenerb, MartirenaHernándezaG., Habertd “Assesing the environmental and economic potential of limestone calcined clay cement in Cuba” Journal of Cleaner Production, CXXIV, pp. 361-369, 2016.

[16] E. M. Silitonga, “ Identifikasijumlah CaOfreedalamcampuranbetondenganmempergunakana genpozzolanic ” PenelitianSaintikaUnimed, XVIII, pp. 108-113, 2017

[17] E. M. Silitonga, “Pengaruhkontaminasilogamberatpadasedimenhasilpekerjaanpengerukansebagai material barudalampekerjaanpembangunanjalan” Proceeding Seminar NasionalTeknikSipil, XII Surabaya Indonesia, 2016