IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Effect of the available amount of CaO in Pozzolanic Binders on enhancing physical characteristic of concrete

Effect of the available amount of CaO in Pozzolanic Binders on enhancing physical characteristic of concrete

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Abstract. Various binders such as pozzolanic binder fly ash, Silica Fume already known for its ability on enhancing the physical characteristic on concrete or soil stabilization. Pozzolanic reaction requires several primary factors to provide maximum improvement on physical characteristic. CaO is one of the most important factors that capable to enhance the strength gained. This research is aimed to identify the quantity of the available amount of CaO content in the binders used, and the effect of the available amount on increasing the physical characteristic of the concrete. In this study two type of pozzolanic binders such as Fly Ash are used, to identify the amount of available CaO content, the researcher used Chapelle Test. The engineering test such as unconfined compressive strength is realized to determine the effect of amount of CaO. The results show that binder with higher amount CaO increase the strength development.

1. Introduction

Pozzolanic reaction is already well known to improve the engineering properties on civil engineering work. In development of concrete the pozzolanic binders is already use for the last 20 years. The unique process of pozzolanic reaction on providing the additional strength, already studied. Beside in concrete, pozzolanic binder already utilized to stabilize problematic soil, such as high polluted soil. Previous studies working on stabilizing contaminated sediment using pozzolanic binder such as fly ash. [1][2] Siham *et al*, in his research stabilizing contaminated dredged sediment, in this research, silica fume is used as binder to stabilize the sediment and to improve the engineering properties of the sediment [3]. The use of pozzolanic binders to stabilize problematic (polluted) soil is done by several researcher [4][5]. While common hydraulic binders could not increase the engineering performance of contaminated sediment, the pozzolanic binder mixed with hydraulic binder proved to enhance Geotechnical characteristic of the contaminated sediment. Dubois [6] investigated the use of pozzolanic binder to be mixed with marine dredged sediments, in goal of reusing the dredged sediment in pavement work. The result of this research found out that with pozzolanic binder addition, the physical characteristic of the marine dredged sediment increases and assumed it can be used as material in road pavement work. Wakeman and Themelis [7] trying to find out how to reutilize of dredged sediment from New York Harbour. This is the main reason why pozzolanic binders becomes very popular in problematic soil improvement work. Unfortunately, only several researches tried to investigate about the pozzolanic reaction. A research done by Pfeifer *et al* [8] investigate the effect of pozzolanic reaction on silica fume. In this study, the silica fume is utilized as a binder in ultra-high-performance concrete (UHPC). This study stated that the pozzolanic reaction of silica fume enhance the strength in

IOP Conf. Series: Materials Science and Engineering **420** (2018) 012011 doi:10.1088/1757-899X/420/1/012011

very rapid time. A research by Jeong *et al* [9] investigated the effect of the temperature on the reactivity of the pozzolanic reaction. The result of this study confirms that, the high temperature generates more intense pozzolanic reaction. This study concentrates on determining the effect of CaO content in the admixture and determining its role on enhancing the strength of concrete.

2. Materials

2.1. Materials

The main goal of this research is to identify the effect of CaO in pozzolanic binder, thus fly ash as pozzolanic binder is utilized in this research. Two type of fly ash will be used, each initial characteristic is different from others, in visual observation, the different of these fly ashes can be identified. The color of the fly ash is totally different. Fly ash type A (FA_A) is taken from coal mining of Surchiste, the fly ash type B (FA-B) is taken from coal mining in southern France. These two types of fly ashes are still not commercialized in the market. The fly ashes can be considered as a raw waste material. Two identify the initial characteristics of theses two types several tests are performed and presented in this paper.

2.2. Initial Characteristics.

2.2.1. Particle Size Distribution.

Physical characteristics is one of the most important factors in concrete. Physical characteristic directly affects the admixture at time the binders mixed. Particle size distribution is one of the most physical characteristics that commonly performed by sieving methods. Due to its fine particle size, to identify the particle size distribution, the test is performed using Laser Granulometric. With this machine capable to determine the percentage content until <2 µm.

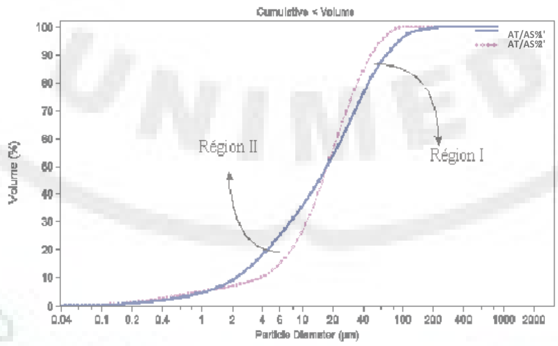

Figure 1. Particle size distribution of fly ashes.

Figure 1 presents the curve of particle size of fly ash type A (FA_A) and fly ash type B (FA_B). From the figure we can observe that there two different regions, the first regions are between 20µm and 120µm, the second region is between1.8 µm and 17 µm. This region represents the particle size scope for each fly ash. This figure shows that fly ash type B (FA_B) has more percentage particle in size between 1.8 µm and 17 µm than fly ash type A (FA_A). Silitonga [10]in his research using two type of silica fume. The research stated that silica fume with finer particle size distribution provides higher strength on unconfined compressive strength than others. Based on this result, it assumed that FA_B will be more reactive than FA_A and will provide higher engineering performances.

2.2.2. X-Ray Diffraction Test (XRD).

This test is realized to identify the mineralogical properties of the fly ash utilized in this study. The samples subjected in to powder size then sample will be scanned. The table 1 shows the result of XRD test. The fly ash type A (FA_A) is obtained from mining coal with Circulating Fluidized Bed. Fly ash type A can be considered as an Alumina silicate fly ash. On the other hand, fly ash type is taken from mining coal with normal burning method, fly ash type B (FA_B) can be considered as a Silica alumina fly ash. Based on XRD test, it can be concluded that the fly ash type B (FA_B) own much more percentage of CaO_{free} then fly ash type A (FA_A). Silitonga [11] stabilized polluted sediment with silica fume. The result reveals that the silica fume with higher content of $CaOf_{ree}$ increased the engineering performance of the stabilized soil.

Table 1. Particle size distribution of fly ashes

Parameters	*FA_A*	*FA_B*
SiO_2	47.36	20.38
Fe_2O_3	7.09	1.91
$Al2O_3$	21.63	11.7
MgO	3.32	1.07
MnO_2	0.62	SiO_2
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

2.2.3. Mix Composition

There 3 type of binders utilized in this study, hydraulic binders (cement and lime) and pozzolanic binder (fly ash). As shown in previous chapter, two type of fly ashes are used in this study, fly ash type A (FA_A) and fly ash type B (FA_B). To identify the effect of percentage fly ash on the admixture two quantity of fly ash are performed in this study (80% and 75%).

Table 2. Mix composition of admixture

	FA_A	FA_B	Lime1	Lime2	Semen
80FA_A(Lime1)	80	-	15	-	5
80FA_A(Lime2)	80	-		15	5
80FA_B(Lime1)	-	80	15	-	5
80FA_B(Lime2)	-	80		15-	5
75FA_A(Lime1)	75	-	15		5
75FA_A(Lime1)	-	75	15	-	5

As known that pozzolanic binder reacts when the pH of the soil increase, this is the main raison why we used two type of lime, (lime 1 and lime 2). Type of cement utilized in this study is the common type utilized in concrete work (type 1), the quantity of cement is fixed 5%.

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3. Result and Analysis

3.1. Lime reactivity test

Lime plays an important role on promoting pozzolanic binder. Lime hydration increase the pH. With the increase of pH, all the substitutions for pozzolanic reaction will dissolve from the soil and form C-S-H (Calcium Silicate Hydrated) and C-A-H (Calcium Aluminate Hydrated). The increase of the pH depends on how reactive the lime is. In this study we utilized two types of lime (lime 1 and lime 2). After the water added in to the lime, the temperature will increase spontaneously, the temperature and the time will be measured and will be compared. The reactivity of the lime depends on how high the temperature produces and how fast the time is. In table 3 the result of lime reactivity test is presented. From the result we can observe that the temperature is measured every 5 minutes

Table 3. Lime reactivity test

Time	Lime1	Lime2
5 Minutes	43°C	65°C
10 Minutes	60°C	72°C
15 Minutes	63°C	74°C
20 Minutes	68°C	75°C
25 Minutes	70°C	76°C

The result from table 3 shows that the temperature produces by lime 2 is higher than produces by lime 1. Based on the result we can concluded that lime 2 is more reactive than lime 1, and the pozzolanic reaction of sample of lime 2 will be more intense and assumed will increase higher strength than others.

3.2. Identifying the available CaO_{free}

Mertens *et al* [12] working on zeolite and determining the pozzolanic reaction and parameters that effecting its reactivity. The result shows that there several parameters play an important role in promoting the pozzolanic reaction. In this study, the researcher tries to identifying the effect of available CaO_{free} on helping provide the needs of pozzolanic reaction.

Table 4. Test to identify the available CaO_{free}

CaO free(%)	***FA_B***		***FA_A***	
	24 hours	48 hours	24 hours	48 hours
Average (%)	68,73	67,02	77,17	63,63
Standardeviasi (%)	4,91	8,99	8,07	5,59

Table 4 presents the result of the test, it can be observed that after 24 hours test, FA_A produces more CaO_{free} (77.17%) than FA_B (68.74%). And after 48 hours test FA_A still produce higher CaO_{free} than FA-B. Based on this result we can concluded that, FA_A will helps promoting its pozzolanic reaction to produces more C-S-H (Calcium Silicate Hydrated) and C-A-H (Calcium Aluminate Hydrated), and assumed will produces higher strength than FA_B. This result is contrary to XRD test, as shown before in XRD test, FA_A possess more CaO_{free} content than FA_B.

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3.3. Unconfined Compressive Strength

Unconfined compressive strength test is realized to determine the effect of the availability of Cao_{free} on producing additional strength on concrete. After being mixed, the sample will be subjected to unconfined compressive strength test according to its curing age (7, 14, 28, 60, and 90 days)

Table 5. Result of unconfined compressive strength

Name	7 days (MPa)	14 days (MPa)	28 days (MP.a)	56 days (MPa)
80FA_A(Lime1)	3.9	6.8	12.3	17.6
80FA_A(Lime2)	5	8.4	13.4	19.1
80FA_B(Lime1)c	3.2	6.2	9.3	16.4
80FA_B(Lime2)	4.5	8	11.8	18.2
75FA_A(Lime2)	4	7.6	12.8	16.5
75FA_B(Lime2)	3.7	7	11.6	15.7

The result of compressive strength test presents in table 5, Based on this result we can observe that at teen age curing period (7-28 days) all the samples mixed with lime 2 have higher unconfined compressive strength compared to sample treated with lime 1. As described in chapter lime reactivity test, lime 2 produces higher temperature than lime 1, this means lime 1 has more intense hydration than lime 2, we can assume that lime 2 will provide more strength gained than lime 1. The unconfined compressive strength result confirmed this theory. Based on this result, it is proven that lime with more intense reaction will promote pozzolanic reaction and will produce higher strength development. The effect of different type of fly ash can be determine from the result of unconfined compressive strength. The result in table 5 reveal that almost all the sample composed with fly ash type 2 (FA_B) gain higher unconfined compressive strength value than samples mixed with fly ash type 1 (FA_A). This higher strength gained can be assumed because the available amount of $CaO_{free}$of Fly ash type A (FA_A). The available amount of CaO_{free} proven can promote the pozzolanic reaction in to establish additional strength by producing C-S-H (Calcium Silicate Hydrated) and C-A-H (Calcium Aluminate Hydrated). Silitonga[13] in his work find out that the amount of C-A-H and C-S-H plays an important role on improving the strength development of the soil improvement work. The strength development still remarkably increases up until 56 days of curing age, this result state that all materials needed (CaO_{free}) to continue the pozzolanic reaction until 56 days is still available. The conventional concrete will not show that remarkable strength development

4. Conclusion

The main goal of this is to identify the effect of amount of CaO_{free} on improving the physical characteristic of the concrete. In this study two type of fly ash are utilized as a binder, each fly ash has its own characteristics. The laser granulometric test show fly ash type A has slightly an advantage on finer particle size. Even though there is a contrary between XRD test and identifying CaO test concerning the amount of CaO_{free}. The researcher selects to compare the identifying CaO test with unconfined compressive strength. The final result of unconfined compressive strength confirmed the important role of amount of CaO_{free} on fly ash to enhance the physical characteristic (strength) of the concrete.

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