Effect of Initial Characteristic on Promoting the Pozzolanic Reaction in Soil Solidification Work

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Abstract: The effect of binders on concrete admixture has been investigated for several years. Pozzolanic reaction has been known for its ability to enhance the concrete performance. Pozzolanic reaction needs various parameters to provide an additional concrete performance. The physical, and mineralogical characteristic on the pozzolanic reaction has its different impact on enhancing concrete performance. The main goal of this study is to determine which characteristics that influence the most to the concrete strength performance. Two different type of fly ash are used as pozzolanic binder each fly ash has its initial properties Particle size distribution of fly ash is realized in goal to identify the physical characteristic, Mineralogical characteristic is determined with XRD test. The effect of the addition of the pozzolanic binders is identified with UCS test. The test result identified that the particle size distribution is the most influenced properties. The binder with higher available CaO content produces greater concrete strength. The binder with higher percentage of SiO_2, Fe_2O_3 and Al_2O_3 provides higher UCS value than binder with CaO content.

1 INTRODUCTION

The used of pozzolanic binders such as fly ash, silica fume in concrete work has been popular for decade. Due to its initial characteristics the pozzolanic binders is known for its capability to increase the concrete performance. Several studies have been done concerning this pozzolanic binders. Work realized by Fernandez (Fernández-Jiménez, Palomo and Criado, 2005) studied the effect of microstructure of alkali activated of fly ash. The study shows that due to its microstructure, alkali activated of fly ash can increase the strength of the sample. Becquart.(Bernal, 2011) in his research working on slag (can be considered as a fly ash). bottom ash as a binder to enhance the performance of the admixtures. The mineralogical properties of the bottom ash are helping to provide the needs of pozzolanic reaction to reacts and produces additional strength to the sample. In this study the slag is subjected to alkali activation process.

Beside in concrete work, fly ash is used in soil stabilization work. Silitonga (Silitonga, Levacher and Mezazigh, 2010) added fly ash to stabilized dredged sediment from port of Cherbourg. The heavy metal content of this dredged sediment is very high, and block the cement hydration to provides the strength. The present of the fly ash in the admixtures shows an increase of unconfined compressive strength on stabilized soil. Due to its micro filler capability, the fly ash contributes additional strength. A study conducted by Weber (Weber, 2015) investigated the characteristic of soil derived from fly ash after the revegetation process. This study determine the effect of revegetation process on stabilized soil with fly ash. Another previous work using fly ash as a soil stabilization binder is done by Goswani (Goswami and Mahanta, 2007) tried to identify the properties of the soil stabilized by fly ash. The leaching test is realized to determine the influence of the fly ash on soil stabilization process. Previous study on mechanical and microstructure characteristic of alkali activated fly ash is done by Komljenovic. This study shows the effect of characteristic of each fly ash on strength development gained. (Komljenović, Baščarević and Bradić, 2010)

Other pozzolanic binder such as silica fume is also known for its capability to produces additional strength. Study done by (Pfeifer, 2010) working on effect of silica fume oh high performance concrete. The experiment result shows that the addition of silica fume produces a significant strength increase on unconfined compressive strength. Silitonga (E.

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Silitonga, 2017) (Ernesto Silitonga, 2017) tried to stabilize a heavy metal contaminated sediment. Silica fume is used to encounter the high percentage of pollution in dredged sediment. The studies demonstrate that the addition of Silica fume can increase the strength of the stabilized soil than others samples.

2 MATERIALS AND METHOD

Pozzolanic binder used in this study is fly ash. Two type fly ash is added in to the admixture. To determine the influence of the initial characteristics, two types of fly ash (FA1 and FA2) are utilized in this experiment. Each fly ash has its own physical and mineralogical characteristic. The Soil is `taken from Harbor of Cherbourg Basse Normandie Franc. The soil sampling is realized from 4 locations (HoC_1, HoC_2, H0C_3, and HoC_4.

2.1 Initial Characteristic of Materials

Initial Characteristics of binders are devised in two types. Physical type and mineralogical type. Physical characteristic is represented by particle size distribution size determined with Laser Granulometric Diffractometer. The Mineralogical characteristic is determining with XRD test.

2.1.1 Particle Size Distribution

Particle size distribution is one of the most important strong point of the pozzolanic binders. Due to its fine particle size distribution, fly ash can penetrate and fill the empty space in the microstructure and increase the strength of the sample.

Table 1: Particle size distribution of the untreated soill

Parameters	HoC_ 1	HoC_ 2	HoC_ 3	HoC_ 4
D50(µm)	8.4	10.2	7,6	9,6
<2 µm (%)	1.7	2.9	3.3	1.9
2 à 63 µm (%)	76.4	72.9	77.8	79.8
> 63 µm (%)	21.9	24.2	18.9	18,4

The particle size distribution is realized with the help of Laser Granulometric Diffractometer, this machine is used because of the fine particle size of soil and the fly ash. With this machine the particle size less than 2 µm can be identified. The result of Laser Granulometric can be seen in table 1. The result shows that the particle size distribution of the material (soil) taken from 5 different locations is in the same class. The majority percentage of the particle is classified between 2 à 63 µm. This result proves the homogeneous of the soils. The homogenous of the soil will help the analysis of the result.

Table 2: Particle size distribution of the fly ash

Parameters	FA1	FA2
D50(µm)	12	17,5
<2 µm (%)	16.4	7.40
2 à 63 µm (%)	80	89
> 63 µm (%)	3.8	3.8

The particle size of fly ash is described in Table 2, this result shows that the particle size of the fly ash is larger than common fly ash that used in the concrete work. This is because the fly ash utilized in this study is a raw fly ash from coal mining. These fly ashes are not commercialized yet. The goal of using this raw fly ashes is to identify its potential use. Normally, the majority percentage of the particle size of the fly ash is <2 µm. The Majority of the particle size of fly ashes used in this study is around 2 à 63 µm. From this result it can be assumed that

2.1.2 Mineralogical Characteristic

Determine the quantity of the mineral on the binder is the main goal of this test. The quantity of the binder plays an important role on strength development. The Mineralogical characteristic is identified using XRD. The mineralogical characteristic of fly ashes is described in table 3

Table 3: Mineralogical characteristic of fly ash

Name	SiO_2 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO Total (%)	CaO free (%)	SO_3 (%)
FA1	45	9	20	9	1	5
FA2	21	2	12	36	14	16

From table 3 we can that fly ash named FS_1 has more SiO_2, Fe_2O_3 and Al_2O_3 than FS_2. On the other hand, FA_2 consist more CaO total then FA_1. The result of study done by Silitonga, (Silitonga, 2018) stated that SiO_2, Fe_2O_3 and Al_2O_3 content plays an important role on improving the engineering performance of stabilized soil. Comparing the mineralogical characteristic test and previous study, t we can assumed that FA_1 will produces higher strength than FA_2. On the other hand, FA_2 possess higher CaO than FA_1. Silitonga in his study used fly ash (Silitonga, Levacher and Mezazigh, 2009) on enhancing the soil contaminated b heavy metal. The result of this study stated that the fly ash with CaO content produces higher unconfined compressive strength than fly ash with lower CaO content. On this point of view, we assumed that the fly ash FA_2 will provides higher strength than FA_1. This theory will be confirmed by the result of this study.

2.1.3 Formulation

The soil utilized has very high-water content (70-80%), before the treatment begins, the soil subjected to the dewatering process. The dewatering process is realized with the help of the sun (in open area). After the water content reach the point needed, the soil crushed int to the small pieces and mixed with binders with various composition. The formulations of the binder are presented in Table 4. Several compositions were designed to identify the effect of binders with its special characteristics. The sample without any binder content (PS) is realized as a guide to determine binder effect. Various percentage of fly ash is realized to verify the effect of the amount of binder.

Table 4: Particle size distribution of the untreated soil

Name	Sand (%)	Cement (%)	Lime (%)	FA1 (%)	FA2 (%)
PS	15	5			
5510FA1	15	5	5	5	-
5515FA1	15	5	5	15	-
5520FA1	15	5	5	20	-
5510FA2	15	5	5		10
5515FA2	15	5	5	-	15
CMT	15	8	5	-	-

3. RESULT AND ANALYSIS

3.1 Unconfined Compressive Strength

The unconfined compressive strength is realized to determine the engineering performance. This test is realized at five different time of curing ages (7, 14, 28, 60 and 90 days). The sample is subjected with simple compression machine. The result of unconfined compressive strength is given in table 5. As shown in table 5, the sample without any binders (PS), the unconfined compressive strength value is not available, this result because of the sample is to weak to be subjected to compressive strength test.

The strength development pattern of sample without any binder (PS) is not very significant, especially after 28 days of curing age. This result shows that increase of the strength after the solidification process is very low. The strength value at 90 days (0.79 MPa) is not fulfil the requirement as a material in road pavement work. At teen curing age (728 days) Sample with only cement content (CMT) that provides highest compressive strength compared to other samples. This result obtained because of the quick hydration of cement, as soon as the water introduce in to the cement, directly the hydration cement starts and produces According to study done by Silitonga in his previous study (Silitonga., 2018)the hydration of cement continuously provides significant development of compressive strength until 60 days, at 90 days the development strength becomes insignificant.

Table 5: Unconfined Compressive strength test

Name	7 days Mpa	14 days Mpa	28 days Mpa	60 days Mpa	90 days Mpa
PS	-	0.6	0.75	0.7	089
5510FA1	08	0.9	1.16	1.4	1.8
5515FA1	0.3	0.9	1.15	1.6	2.1
5520FA1	0.7	08	1.2	1.4	2
5510FA2	-	0.6	0.75	0.7	0.8
5515FA2	0.7	0.81	1	1.6	1.88
CMT	0.8	0.97	1.24	1.3	1.35

On the other hand, the sample mixed with pozzolanic binder (fly ash) starts to show a significant increase of compressive strength. According to Mertens, (Mertens, 2009) the pozzolanic reaction reaches its maximum reaction is after 60 days of curing age. This confirm the result, where the compressive strength value of all the sample with fly ash start exceed the strength value of sample consists only with cement (CMT). This result because of the excess of fly ash content in the soil. Due to its fine particle size distribution, a role of fly ash as a filler is very important on enhancing the engineering performance. This effect as filler has very significant impact on strength gained especially at teen curing age (7-28 days). As cement hydration starts to reacts and harden the sample, the fly ash penetrates in to the microstructure and fulfil the empty space. Due to these two processes at teen age of curing time, explain why sample with only cement content (CMT) shows the highest compressive strength. From the quantity of the binder point of view, we can observe that at teen curing age, the sample with the highest (20%) content of fly ash shows the lowest compressive strength value. As mentioned before that the role of fly ash as a filler is the most important effect at 7-14 days of curing age. Sample with 20% fly ash, has a problem to mix because of the excess of the quantity of fly ash. Besides that, because of the present of high quantity of material with fine sediment (fly ash) the specific surface of the sample increase.

From the point of view of different type of fly ash (with each different initial characteristic), we can observe that, at teen age curing time (7-28 days) sample with fly ash FA_1 shows higher compressive strength value than sample with FA_2. As mentioned in previous paragraph that at 7-28 days of curing age, the most important role of binder is as a filler. This filler effect is very influenced by the particle size of the binder (fly ash). Compared the result of particle size distribution and Unconfined compressive strength test (presented in table 2 and 5), we can conclude that, the sample possess the particle size with greater quantity of particle with size of <2 µm (FA_1) produces higher compressive strength. Silitonga in his research working on fly ash with different particle size (Silitonga, Matondang, 2018). This result of this study done by Silitonga, shared the same patterns with the result above. Pozzolanic binder with higher percentage of particle size <2 µm produces higher strength (especially compressive strength).

The unconfined compressive strength result at 60-90 days curing age presents different pattern than the previous curing age. (7-28 days). At 60 days, the pozzolanic reaction assumed already reach its maximum reaction. At this age, the sample with fly ash content produces higher compressive strength value than sample consist only with cement (CMT). The pozzolanic reaction need more time to reach its maximum reaction, on the opposite the cement hydration already finish reacts, because there is no more calcium and the silicate available in the cement. On the other hand, due to its pozzolanic reaction, the produced of C-S-H and C-A-H, that enhance the bond between the particle and automatically provide additional strength of the admixture. As long as the pH of the environment reach 9 or more, the pozzolanic reaction can always proceed. The pH value 9 release the calcium and the silicate that available in the soil, and with the help of CaO then form C-S-H and C-A-H, which plays an important role on increasing the strength by strengthen the microstructure of the sample.

Unlike at teenage curing time (7-28 days), the mineralogical characteristics of the fly ash plays important role at this age of curing (60-90). At previous chapter (table 3) we can observe that the named FS_1 has more SiO_2, Fe_2O_3 and Al_2O_3 than FS_2. On the other hand, FA_2 consist more CaO total then FA_1. The unconfined compressive strength result proves that the sample with FA_2 possess higher strength value than FA_2. This result confirms that the present of SiO_2, Fe_2O_3 and Al_2O_3 promotes the pozzolanic reaction better than the CaO content. The present of the SiO_2, Fe_2O_3 and Al_2O_3 on fly ash, provides substance to initiate the pozzolanic reaction. Beside the amount of SiO_2, Fe_2O_3 and Al_2O_3 that available in the soil, the present of SiO_2, Fe_2O_3 and Al_2O_3 on the fly ash helps to provides for pozzolanic reaction. The CaO content also provides CaO for initiate the pozzolanic reaction. Based on this result we can confirm that the content of the SiO_2, Fe_2O_3 and Al_2O_3 on the binders has greater influence than the present of CaO.

4 CONCLUSIONS

The main goal of this study is to determine which initial characteristics that affect the pozzolanic reaction on enhancing the engineering properties of the sample. The physical characteristic is represented by particle size distribution and the mineralogical characteristic is identified by XRD test. The physical properties show that, due to its finer particle size, the fly ash (FA_1) has a higher possibility to increase the strength than FA_2. According to the mineralogical test, FA_1 has more SiO_2, Fe_2O_3 and Al_2O_3 than FA_2, on the opposite the FA_2 has more CaO content than FA_1. Each result has a possibility to increase the engineering performance. In order to confirm this theory, unconfined compressive strength is realized. The Analysis of this compressive strength devised in two period of time, teen age of curing time)7-28 days and long-term condition (60-90 days). The result demonstrates that, binder with finer particle size distribution has higher engineering performance (compressive strength) than other. The result of long-term period of time demonstrate that, the present of SiO_2, Fe_2O_3 and Al_2O_3 on the mixture plays more important role to enhance the strength than the content of CaO. We can conclude also that with addition of fly ash, the soil utilized can be used and fulfil the criteria to be reused in as material in road construction.

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