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Enhancing the Engineering Characteristics of Polluted Sediment Solidified with Pozzolanic binder Ernesto Silitonga 1Departemnt of Engineering, Universitas Negeri Medan, ernestosilitonga@unimed.ac.id Abstract—Since the France regulation about dredged waste sediment in respect of environmental issues has been established, the ancient method such as rejection the dredged material waste is not applicable anymore. According to previous project, the disposal site method cost very expensive.

This is the main reason why the reutilization of this dredged sediment waste should be realized as soon as possible. This paper intended to identify the possibilities of the reuse of dredged polluted sediment in road construction work. The first step is to identify the characteristics (physical and chemical) of dredged sediment waste.

The second step is to determine the ideal type of binders and its composition. This step is to determine the capability of binders used to improve the geotechnical performance of dredged sediment and can satisfy the requirement need in work construction work. Fly ash used in this study, is a raw waste of local coal mining.

The various test were performed and the result shows that the addition of Fly ash in the mixture capable to improve the strength in geotechnical properties and confirmed that even though the content of heavy metal is very high, the stabilization process can achieve the requirement needed in work construction Keywords—Waste Sediment, engineering characteristics, unconfined compressive strength, tensile strength INTRODUCTION The classical method by throwing the waste in to the sea is not allowed anymore.

Due to the environmental issues this method is forbidden and according to the previous study [1] it is proved that action of throwing the waste in to the sea can contaminate the environmental and hazardous to human. The France regulation concerning dredged waste material stated that all dredged material is consider as a waste. The dredged material should be placed in disposal site and after the test result shows that the heavy metal content is not harmful for the environ and human than the dredged waste material can be reuse as a new material. Previous work [2], show that the disposal site cost very expensive and need a very large site.

And because the large volume of dredged sediment increase every year, the reuse of this dredged waste sediment, as a new material need to be realized. In this study the dredged sediment. Waste is subjected as a alternative material in road construction work. This is realized because in France, the road construction work used almost more than 60 % of material.

The reuse of dredged sediment waste should fulfill several requirements in geotechnical point of view. Because its high content of heavy metal, it will be difficult to achieve the requirements needed without any addition of binders. Binder that can provide the additional strength need to be utilized in order to satisfy the requirements.

Mezazigh [3], in his research tried to stabilize the dredged sediment of port of Port en Bessin with hydraulic binder that normally used in stabilization work. Stabilization of dredged sediment waste with various types of additives already realized. Besides fly ash, other pozzolanic binder such as Silica fume, Mezazigh realized a study on stabilization of dredged sediment of Port de Honfleur using Silica fume.

Mezazigh in his research stabilized dredged sediment waste using hydraulic binders and Silica Fume. The result shows that the binder pozzolanic such as Silica Fume is capable to improve the geotechnical characteristic of dredged sediment of Port of Bessin in France. Due to its heavy metal content, the hydraulic binders are not sufficient to stabilize the dredged sediment.

Silitonga realized a research to stabilized polluted sediment using Fly ash combined with Silica fume [4]. The reason using this binders is because this two binder well known on to provide additional strength. The result proved that these two binders improve the Geotechnical properties of polluted sediment almost 25% than sample using hydraulic binders.

MATERIAL AND METHODS In this study, the material used is waste sediment taken from dredging project from port of Cherbourg France. Cherbourg is a industrial city located in the northwestern of France. It is considered as one of the most port in France. There is a heavy industrial activity in this city of Cherbourg.

The waste sediment is taken from four different location in Port area, assumed that it can present the real situation and condition. After being dredged, the waste sediment transported to the disposal area. The 1,1 hectares area is designed specially to accommodate waste material, to protect the environment from disperse of heavy metal content in waste sediment.

The hydraulic binder used in this study is the normal binder normally used in stabilization soil work. The pozzolanic binder such as fly ash utilized in this study is a local waste from the mining coal production. This fly ash is not commercialized yet in the market. The main goal of this study is to stabilize waste with a waste, so the reutilization of the waste can be optimized.

The physical characteristic of this waste sediment is presented in Table 1. 2.1. Physical Characteristics Dredged waste sediment content of a very fins particle. The physical identification is realized with a Laser Granulometric Diffractometre. The particle size distribution of dredged sediment and Fly ashes described in Table 1.

In order to identify the particle size distribution of dredged waste sediment, the samples are taken from two different locations. As shown in Table 1, the particle size distribution of dredged waste sediment of Cherbourg two samples of dredged waste (Cher1 and Cher2) were taken from two locations. The result shows the similarity on both particle size distributions of two samples of dredged waste.

This indicates that the homogeneity of dredged waste is very important. TABLE 1. Particle size of dredged waste sediment and two types of fly ashes Parameters _Cher 1 _Cher 2 _FA1 _FA2 _ _D10 (μm) _8.5 _11.2 _68.2 _48,2 _ _D50 (μm) _7,6 _9,6 _12 _17,5 _ _D90 (μm) _60.9 _55.3 _2 _3,8 _ _<2 μm _3.30% _1.90% _16.4% _7.40% _ _2 - 63 μm _77.80% _79.80% _80% _89% _ _> 63 μm _18.90% _18,4% _3.50% _3.80% _ _ From Table 1 we can see that the dredged waste consists of majority particle size between 2- 63 μm, this is categorized as a silt fraction size.

The result also shows the particle size distribution of fly ash. It consists of particle size with range between 2- 63 μm. From Figure 1, we can conclude that the waste sediment from dredging work of Port of Cherbourg classified as a silt loam. Silitonga in his study [5][6], working with waste sediment from dredging work of Port en Bessin stated that the waste sediment also classified as silt loam, work with them dredging sediment of Port le Havre and find out that waste sediment situated in silt class [Figure 1].

The Fly ash utilized in this study is considered coarser than normal fly ash specially produced for engineering used. This is because fly used in this study is not yet treated with special treatment _ Figure 1. Soil texture triangle with various textural classes and particle size scales The main reason of fly ash utilization is to stabilize waste with a local waste.

The fly ash type 1 (FA1) has more percentage of fine particle (`<2µm) than fly ash type 2 (FA2). According to precedent research fine particle can provide additional strength. Previous study [7] work with fly ash and the result show that the strength of unconfined compressive test tends to decrease as the mean particle size decrease, this trend happened in all the curing ages of the sample. From this . 2.2.

Chemical Characteristics In France, the waste sediment that were taken from medium or large size industrial port, after being dredged is automatically consider as a hazardous waste material. According to France regulation, Hazardous material should be disposed in special designed dispose area, and be identified and stabilized, after the heavy metal content (according to European regulation, see Table 3) categorized as a inert or nonhazardous waste, then it can reused as a new material.

In this study, the TCLP (Toxicity Characteristic Leaching Procedure) is realized to identify the chemical characteristics, and the heavy metal content in the waste sediment. TABLE 2. Result of TCLP (Toxicity Characteristic Leaching Procedure) Micropollutant _Cher 1 _Cher 2 _ _As (mg/kg) _1.2 _1.8 _ _Cd (mg/kg) _2.1 _1.3 _ _Cr (mg/kg) _53.6 _61.2 _ _Cu (mg/kg) _0.58 _0.31 _ _Hg (mg/kg) _0.17 _0.28 _ _Pb(mg/kg) _7.3 _11.9 _ _Ni (mg/kg) _4.9 _7.2

_ _Zn (mg/kg) _52 _84 _ _The result of TCLP is showed in Table 2. In order to determine the level of pollutant in dredged sediment, European Council has been established a reference of pollutant level. The reference divided in 3 classes; inert waste, non-hazardous waste and hazardous waste, these classes can be observed in table 3. TABLE 3.

Threshold of level of pollution according to European regulation [8] Micropollutant _Inert _Non Hazardous Waste _Hazardous Waste _ _As (mg/kg) _0.5 _2 _25 _ _Cd (mg/kg) _0.04 _1 _5 _ _Cr (mg/kg) _2 _50 _100 _ _Cu (mg/kg) _0.01 _0.2 _2 _ _Hg (mg/kg) _0.01 _0.2 _2 _ _Pb(mg/kg) _0.5 _10 _50 _ _Ni (mg/kg) _0.4 _10 _40 _ _Zn (mg/kg) _4 _50 _200 _ _ The regulation stated that volume of micro pollutants in the material.

Comply with France regulation, before being used as new material, the micro pollutant volume should classified in inert waste level. In this study case, due to its contamination level, the dredged sediment waste must be treated first until the its pollution level decline to inert waste level, then it can be used as new material and considered safe for environ.

MATERIAL AND METHODS The waste sediment waste after dredging process then disposed in special in intension of reducing its high water content. This goal realize with dewatering process. After the water content reaches the desired point, the next step is to break the material and sieve it to 2 mm sieve size. The mixing process start, and with designed quantities of binders such as cement, lime and fly ash (in a dry condition), then the water is introduced in to the composite and mixed with a mechanical moving machine at a speed of 1-8 mm/s for 5-8 minutes.

Then the composite taken out and store in the curing room for a designed period time depending on the test that will be realized. 3.2. Mix Composition The mix compositions of admixture are prepared and design with goal to identify the effect of binders on enhancing physical characteristics of stabilized dredge sediment waste. Table 4. Mix Composition of admixtures.

Name _Sand _Cement _Lime _FA1 _FA2 _ _ _ _ _ _ _ _ _UWS _0 _x _x _x _x _ _5510FA1 _15% _5% _5% _10% _x _ _5515FA1 _15% _5% _5% _15% _x _ _5520FA1 _15% _5% _5% _20% _x _ _5510FA2 _15% _5% _5% _x _10% _ _5515FA2 _15% _5% _5% _x _15% _ _5515FA2 _15% _5% _5% _x _20% _ _CEM _15% _8 _5 _x _x _ _ The various formulas are presented in Table 4. The various percentage of fly ash is realized to identify the effect of volume binder on stabilization result.

The sample without any fly ash content in the admixtures (CEM) is realized in order to determine the strength of admixtures provides only by cement. This sample (CEM) can be used as a benchmark of stabilization process. Samples with untreated Waste Sediment (UWS) are realized in order to identify the initial performance of the waste sediment without any binders.

RESULTS AND ANALYSIS 3.2. Unconfined Compressive Strength Unconfined compressive strength is one of the most common tests in construction work. This test is realized to determine the strength of composites. The required minimum unconfined compressive strength for highway construction is 1 MPa for curing period 28 days.

The result of unconfined compressive strength is presented in Table 5. The results show all the strength value of 7, 14, 28 and 60 days of curing period. The Untreated Waste Sediment (UWS) cannot pass the minimum requirement (1 MPa) for 28 days (and even for 60 days) curing age. This confirmed that, the raw dredged sediment waste is not compatible if directly been used as a material in road construction.

The sample only with cement (CEM1) establishes a highest strength in 7 days of curing age. This high strength generated by the quick reaction of cement. As known that the hydration of cement starts directly once the water introduce to the admixture. Part of the clinker sulphates and gypsum dissolve and generate an alkaline, sulfate solution.

Once the admixture mixed the C3S process that generates aluminate rich gel, and then this gel reacts with sulfate the available in solution to from ettringite. This reaction occurs in period of several hours. At the end of this reaction, alite and belite start to react with the form of calcium silicate hydrate and calcium hydroxide; this is the period where the admixture gains the strength [9] TABLE 5.

Unconfined compressive strength for different days of curing Name _7 days (MPa) _14 days (MPa) _28 days (MPa) _60 days (MPa) _90 days (MPa) _ _UWS _0.47 _0.6 _0.73 _0.7 _0.78 _ _5510FA1 _0.67 _0.74 _0.89 _1.29 _1.7 _ _5515FA1 _0.72 _0.83 _1.05 _1.58 _2.05 _ _5520FA1 _0.65 _0.78 _1 _1.41 _1.86 _ _5510FA1 _0.61 _0.69 _1.02 _1,37 _1.77 _ _5515FA2 _0.7 _0.8 _0.93 _1.52 _1.86 _ _5520FA2 _0.58 _0.72 _1.1 _1.69 _1.97 _ _CEM _0.81 _0.96 _1.22 _1.29 _1.32 _ _ The amount of fly ash percentage (10%, 15% and 20%) didn't show a important difference on strength gained.

The Figure 2, show the result of UCS with different percentage of fly ash. The sample with 10% (5510FA1) of fly ash and 20% of fly ash (5520FA1) produced almost the same value of strength gained on unconfined compressive strength. At these teen-age days of curing period (7 days) the Pozzolanic reaction is still not started yet.

At this period of time, the cement hydration of cement and the filler effect of fly ash is the most dominant to provide strength. The reaction of 5% of cement in the mixture that provide the strength gained at teen age of curing period. The sample with 15% of fly ash type 1 (5515FA1) show a highest strength gained at curing age 7 and 14 days.

This result is not suitable to the percentage of fly ash, in theory; the highest percentage of fly ash (20%) should have the highest strength. These case maybe the result of the excessive of fly ash content in the mixture. According to the result, 15 % of fly ash type 1 is the best composition to provide strength.

On the contrary for fly ash type 2, the sample with 20% of fly ash (5520FA2) content show the highest strength gained among the sample with fly ash content type 2. _ Figure 2. UCS result with different percentages of fly ash at 28 days and 90 days of curing ages. This sample (5520FA2) established the highest unconfined compressive strength from curing age of 7 days to 90 days if compared to other sample with 10% (5515FA2) and 15% (5520FA2). This result confirmed that the percentage of 20% fly ash type 2 (FA2) is the most compatible amount to provide the strength.

But in the end, the sample with 15% of fly ash type 1 (5515FA1) still show the highest strength gained since teen curing age (7-14 days) to 90 days 3.2. Tensile Strength Tensile test is one of the most important test in road construction work. This test is performed to identify the direct tensile strength and the Elastic Modulus of the sample.

The geotechnical performance evaluated through the tensile strength and elastic modulus. In order to interpret the result, the France classification NF P 98 114 3 [10] concerning the material in work construction is used in this study. To identify the possibility the use as a material in road construction, the value of performance utilized in this classification is the value of sample with 360 days of curing ages.

According to France regulation when the curing age of the sample does not reach 360 days of curing age, the value of elastic modulus and tensile strength can be determined at 28 days and 90 days of curing age. The result of 90 days of curing age can be estimated using the empiric's coefficient given by equations (1) _ .... (1) The results presented on the diagram of France qualification of material used in work construction.

In Figure 3 the result is considered as value of sample with 360 days of curing age with based from result of sample at 90 days of curing age. We can she from the result that, the value of untreated waste sample (UWS) is not high enough to be presented in this diagram. As we can see in Figure 3, the sample with only cement content (CEM) shows the lowest value of tensile strength and Elastic Modulus and located at level S1.

This result of tensile test confirmed that, the sample constituted only with cement is doubtful to be used as a material in sub base or base-course layer, this mixed only can be used as material in sub grade layer. Contrary with this result, the other sample consists of fly ash (5510FA1, 515FA1, 520FA1, 5510FA2, 5515FA2 and 5520FA2). All this samples constituted with fly ash are situated at class S2.

This result stated that all the samples mixed with fly ash, secure to be utilized as a material in sub grade and sub base course, in component of the road structure. The present of fly ash if compared to the sample consists only with cement, clearly able to provide the additional strength after 28 days of curing ages. The influence of fly ash as filler effect (at teenage curing day) and its pozzolanic reaction (long term) are the main reason of this increase of the performance _ Figure 3.

Result of Tensile strength test at 60 days of curing age The result of sample with 20% of fly ash type 2 (FS2) shows the highest performance, although it is still in the same level as well as other sample (level S2), the value of direct tensile strength and Elastic Modulus of 5520FA2 is still the highest. The sample with fly ash type 2 shows a in line pattern as theory, the highest percentage of fly ash provides the highest strength [11].

This opposite happened with sample with fly ash type 1 (FS1). The sample with highest percentage of fly ash type 1 (5520FA1) does not show the best performance, however the sample with 15% of fly ash that possess the highest strength. This result is similar with the result of unconfined compressive strength.

According to the granulometric test (Table 1) the fly ash type 1 have almost two times more of particles with diameter of < 2 μm than fly ash type 2 (FA2). According to previous study [12] fly ash possess particles with diameter less than < 2 μm will be more reactive (as a filler or in terms of pozzolanic effect) than others. The percentage of 15% of fly ash type 1 (FS1) might be the maximum percentage to provide additional strength.

The amount of 20 % of fly ash type 1 (FS1) consider as a excess portion hence, effect the a degradation on a performance. The excess portion can obstruct the pozzolanic reaction of fly ash and affect on resulting the additional strength addition V. CONCLUSION The primary goal of this study is to stabilize waste material with waste material and the possibility of its reuse in civil engineering works especially in road construction work, and can fulfill the requirement needed. Waste material taken from polluted waste sediment from dredging work.

According to France regulation, the result of TCLP shows that this waste sediment categorized as a non-hazardous waste material. Due to its high content of heavy metal, fly ash introduces in to the mixture, because traditional hydraulic binders (such as cement, lime) could not increase the performance characteristic to achieve the requirements needed in road construction work.

the result shows that in teen age of curing ages (7-28 days) the sample with only consist of cement, shows the best performance in unconfined compressive strength. Contrary, for the long term of curing ages (60-90 days) due to its pozzolanic reaction, the samples mixed with fly ash surpass the strength gained of sample composed only by cement.

The sample with highest percentage of fly ash type 2 (FS2) gained the highest strength, but for fly ash type 1 (FS1) the best sample is sample with 15% of fly ash. From tensile strength test, 1t 60 days of curing age, the result declared that all the sample mixed with fly ash situated in class S2 which means, these composition can be used as a material for sub base layer. Sample composed only by cement only can be used as material for sub grade layer in road pavement structure.

This result clearly stated that the addition of fly ash ameliorate the engineering properties References N. Abriak, R. Zentar “Co-valorization of Dunkirk dredged sediments and siliceous-aluminous fly ash using lime”, Road Material and Pavement Design, vol. 15 (2), 2013, pp 412-431, [2] Ahmadi, B., Al-Khaja, W.,

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