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1 Stabilization / solidification of polluted marine dredged sediment of port en Bessin France, using hydraulic binders and silica fume Ernesto Silitonga Universitas Negeri Medan, Jl Willem Iskandar Pasar V Medan Estate 20221 North Sumatera, Indonesia ernestosilitonga@unimed.ac.id Abstract. A large amount of sediment is dredged in France every year.

Due to the increase of the amount of marine dred ged sediments, envir onmentally reuse of dredged sediment is urgently needed in France. The first objective of this study is to find an application for reuse of marine dredged sediments materials, as new material for road construction. Hence, serial tests need to be realized to identify if marine dredged sediment could be utilized for road construction.

The second goal is to enhance the physical, mechanical and chemical characteristics of the mix, by incorporating binders and sediments, and r evealed the identification of the mechanical characteristics measured on the mixes is compatible with their use as a base course material. The results show th at the treatment by hydraulics binders could satisfy the needed mechanical char acteristics.

The present of Silica Fume is aimed to reduce the pollution level, espe cially the heavy metal content. However, the proportion of hydraulics binders and s ilica fume needed to meet prescribed specification is important, so the reuse of the marine dredged sediments of Port- en-Bessin, France in road construction, as an alternative material could be achieved.

After the geotechnical study in laboratory results shown as expected than the study to identify the chemical characteristic realized. To evaluate the environmental impacts of

the used materi al, leaching test is performed. The leaching test was performed to verify the predicted release of pollutants based on total dissolution.

And for the final part, the test results show that the polluted marine dredged sediments could be safely used (in term of environmental impact) as a new material in road construction. 1. Introduction In France, the Port Authority is encouraged to find the application domain for the reuse of dredged sediments. Furthermore, with European regulation [1], the classical method (rejecting the contaminated dredged sediment in to th e sea) is not an option anymore, regardful to the environmental issues. Availabl e or attainable, there are many constraints on policy implementation need to be designed.

However, before deciding if the dredged material is acceptable for a beneficial use, it is necessary to be realized serial tests to evaluate the capability of marine dredged sediment in its utilization domain. Previous studies with different alternative treatment method to find the domain application for the reuse of marine dredged sediments have been investigated in Europe.

The previous studies utilized Marine dredged sediment, Pempe Ozer-Erdogan et al [2]worked on marine dredged sediments in Turkey, Benyerou et al [3]utilized marine dred ged sediments as a base material for produce the brick, Couvidat et al [4]worked with marine dredged sediment in Marocco, Hurel et al [5] and Levacher [6] stabilized marine dredged se diment in France.This paper concentrate to determine the type and composition of binder to stabilize marine dredged sediments.

The 2 ideal percentage of hydraulic binders needed to meet prescribed specifications is very important. Silitonga in his research using dr edged sediments from Cherbourg (France) [2] claimed that the ideal amount of hydraulic binde r needed to stabilized dredged sediment was between 7%-9%. Behmanesh[7] stabilized dredged sediment of Port du Havre. The amount of hydraulic binder utilized to stabilized dredged sediment was 15%.

Silitonga E., [8] needed 11% of pozzolanic binders (fly ash) to stab ilized dredged sediment from Port de Cherbourg (France). Zhibo[9] in his research stabilized marine dredged with cement and lime, the results show that the ideal percentage of hydraulics binder is 15%. Th e primary goal of this research is to investigate the potential reuse of marine dredged Sediment of Port-en-Bessin as material in road construction.

Road construction needs to meet the requirements. In order to fulfill the requirements, the material has to have mechanical characteristics, furthermore if the material polluted. Consequently, the addition of binders that capable of fulfilling the mechanical

requirements and environmental regulation is needed.

In this study, the binder utilized to enhance the mechanical characteristics and to prevent the pollutants contaminate environment is Silica fume. Silica fume is a by-product of producing certain metals in electric furnaces. Silica-fume, also known by other names such as volatilized silica, micro silica, or condensed silica fume, is a by-product of the induction arc furnaces in the silicon metal industries. 2. Material and Methods 2.1.

Dredged Sediment and Silica Fume This research is realized using marine sediments, which were dredge d from Port-en-Bessin, Basse Normandie France. Theharbour Port-en-Bessin (PEB) is located in the Northwestern France. The sediments were dredged from two different, Bassin no.1 (PeB-1) and Bassin no.2. (PeB-2). The binder utilized in this study is Cement and Lime and Silica Fume.

Hydraulic binders such as cement and lime utilized ar e typical hydraulics binders used in soil stabilization and road construction work. In this study, two different types of Silica Fume (FS) were utilized in this research (FS1and FS2). The Silica Fumes utilized are not commercialized yet. In fact, the Silica Fumes used in this stud y are a prototype of low-cost Silica Fume.

The particle size distribution of this Silica Fume is not as fine as Silica Fume that commercialized in the market. 2.2. Index properties. _____ÿ____

_ ___ ___ __ Due to its particle size distribution, a laser diffractometer Coulter LS200 was used to identify the particle size of marine sediments utilized, Table 1. Particle size distribution of utilized materials PeB 1 PeB 2 PeB 3 PeB4 SF1 SF2 <2 µm (%) 10.7 10.6 13.8 9 2.3 13.8 2 - 63 µm (%) 77.2 78.8 74.8

78.8 18.9 68 > 63 µm (%) 12.6 10.6 11.5 12.2 78.8 18.2 The results as shown in Table 1, confirm that the particle distribution of marine dredged sediments that were taken fro m four different locations (PeB -1, PeB-2, PeB-3 and PeB-4) is almost similar, this means the homogeneity of the marine sediment of PeB.The result shows that dredged marine sediments constituted of a large amount pa rticle with the size between 66,7- 78,4 µm.

The Silica Fume type 2 (SF2) has a finer diameter of particle compared to 3 Silica Fume type 2 (SF2) and Silica Fume type 1 (SF1). According to Silitonga [10], in the previous study on stabilization dredged sed iment with fly ash, showed the Unconfined Compressive Strength (UCS) value tends to reduce as the mean particle size increase.

From a study of the strength contribution potential of Silica fume Gleize et al[11] reported that the particles larger than 45 µm show little or no reactivity under normal hydration conditions and the pozzolanic activity was directly proportional to the amount ofparticles under 10 µm. From this theory, we can observe that SF1 possess co arse particles (>63 µm) more important than SF2 and SF2 has a more important quantity of fine particles (<10 µm) than FS1.

_ In order to identify the level of pollution of Ma rinedredged sediment it is important to assess the environmental risk of the dredged sediment before its land application. The level of pollution is identified using Leaching Test. The results of chemical characteristics are shown in Table 2.

The results presented were taken from several different locations in Port en Bessin area. The amount of Micropollutants measur ed from 2different locations of time was presented in Table 2.In order to identify the le vel of pollution of the marine sediment, the researcher used the reference established by European Council 2003/33/EC.

This reference divided in 3 classes; inert waste, non-hazardous and hazardous waste. Table 2. Leaching test result of dredged sediment from Port en Bessin, France Pollutants PeB 1 PeB 2 European Council Reference Inert Waste Non Hazardous Waste Hazardous Waste As (mg/kg) 14 8.9 0,5 2 25 Cd (mg/kg) 1.33 1.59 0,04 1 5 Cr (mg/kg) 77 58 2 50 100 Cu (mg/kg) 1.41 0.63 0,01 0,2 2 Hg (mg/kg) 0.63 0.73 0,01 0,2 2 Pb (mg/kg) 20.2 17.9 0,5 10 50 Ni (mg/kg) 29.4 30.2

0,4 10 40 Zn (mg/kg) 137 148 4 50 200 These reference values relate to the elements contained in the leachate and not in the raw material. According to Europ ean reference, all amount of micropollutants from 2 different locations are categorized as non-hazardous wast e.From the result shown in table 3, we can confirm that Silica Fume 1 and 2 (SF1 and SF2) constituted a slightly different percentage of SiO 2, Al 2 O 3 , MgO, K 2 O and free Si. Silitonga [8] in his re search confirmed that the chemical properties have an important effect on the mechanical properties of the marine sediment stabilized.

As shown in table 3, SF2 is characterized by a higher content of SiO2, followed by SF1.According to this result, we can assume that SF2 will be more reactive than SF1. Silitonga [10] on his research noticed that type of Silica Fume that possesses higher content of SiO 2 , Fe 2 O 3 or Al 2 O 3 produces higher resistance on Unconf ined Compressive Strength Test. Silica Fume type 2 (SF2) has a higher total amount of free CaO. 4 Table 3.

Chemical characteristic of Silica Fume utilized Parameters SiO 2 Fe 2 O 3 Al 2 O 3 CaO MgO Na 2 OK 2 OC free Si Free CaO SO 3 Silica Fume 1(SF1) 90-92 1,5-2 1 0,5-1 1-1,5 0,5-1 1-1,3 0,5-1 < 0,2 < 1 < 1 Silica Fume 2(SF2) 90-95 1.5-2 1-1.5 0,5-1 1 0.8-1 1.3-1.5 1-1.5 <0.4 <1 <1 2.3.Methods 2.3.1. Preparation of samples and mix design After being dredged, physical characteristics of marine sediment were measured.

The measured initial water content is about 169%. The sample was realized by using cylindrical specimens (ø = 40mm, h = 80mm). Samples with Silica Fume type 1 (SF1) and Silica Fume type 2 (SF2)addition were set in order to investigate the influence of the Silica Fume on the strength gained, the mixtures wererealized with various percentage of Silica Fume content.

The mixture without any Silica Fume content (LIM- CEM) was realized as a reference to identify the effect of Silica Fume addition. 3. Results and Analysis 3.1 Tensile Strength The Tensile Strength is the most important test to identify the capability of a material to be used in road construction. In this study the Tensile Strength was realized beside to identify the tensile strength gained is to calculate th e elastic modulus obtaine d.

The elastic modulus is obtained using a stress–strain curve of an unconfined compression test. Firstly, the maximum compression strength of the mixture is measured. Then the elastic modulus, E, is measured on another sample. In order to not damage the cylinders, the maximum effort applied corresponds to 30% of the maximum compression strength.

The results of tensile test are presented in figure 1. As shown in the figure , only the samples with 7% Silica Fume located in class S3 (G and F). According to Scheme of road section and recommended engineering characteristics, the samp les with 7% Silica fume are secure to be utilizedas material on sub base and Foundation. Figure 1.Tensile test result for sample realized.

The result showed that, the sample with Sili ca Fume addition, produces ahigher Elastic Modulus and higher Tensile strength value than sample without Silica Fume (LIM CEM). The _ _ _ _ _ _ _ _

5 sample without Silica fume LIM-CEM (A) is situ ated within the limit of S0 and S1 classes, it means the reuse for sub base need to be c onsidered.

On the other hand the samples with 3%and 5% Silica fume (B, C, D and E) are situ ated in the same class (S2) yet the Elastic Modulus values of sample with 5% of Silica Fume is higher than samples with 3% Silica Fume. The presents of Silica Fume with its fille r effect, due to its fineness can fit into space and fill the empty space between sediment grains and produces more solid bonds between sediment grain, this is the reason the enhancement of Elastic Modulus because a stiffer material will have higher Elastic Modulus.

The results show that the samples with 3% and 5% of Silica fume (B, C, D and E) could be used as material only in sub base. In the other hand the samples with 7% of Silica fume (H and G) could be reused in sub base and foundation. 3.2 Leaching Test The main objective of this study is to reuse th e marine dredged sediment in road construction as a new material which is fulfil the road regulation criteria and ha rmless to environment.

However, on its application, due to drying an d oxidation process of polluted marine dredged sediment may affect mobility and bioavailabilit y of the land utilized. Therefore Lixiviation Test should be realized to identify the stre ngth or reaction of sample to aggressive environment, such as the extreme change of pH in environment.The Leaching Test refers to the solution containing the sol ubilized elements during the te st, which are performed on the analytical characterization.

In order to identify the pollution level of dredged sediment of Port en Bessin, the researcher decided to used refer ence values established by European Council No. 2003/33 / EC. According to the result (Figure 2), the amount of Cadmium (cd) is 1.33 mg/kg, according to European reference; the quantity of Cadmium categorized as non-

hazardous waste.The result of le aching test (figure 2) shows that, in the case of Cadmium (Cd), sample with or without Silica fume show a reduction of Cadmium content.

The sample without Silica fume; LIM_CEM (Bin Figure 2), show a slight reductionof amount of Cadmium (from 1.33 to 1.25) but it is still in the same level of pollution as the original amount of pollutants (non-hazardous waste level). Figure 2. Leaching Test result for marine dredged sediment for Cadmium.

All the samples mixed with Silica fume established a major reduction on amount of Cadmium; all the samples are situated in Inert Waste. The effect of different quantity of Silica Fume can be noticed in Figure 2.The sample s with 3% percentage of Silica fume ÿ_ÿ_ÿ_ÿ_ÿ ÿ_ _ÿ__ÿ__ÿ ÿ_ÿ_
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__ _____ _ 6 showminimal reduction of Cadmium content compared to samples with 5% (E and F) and 7% Silica Fume (G and H). The samples with 7% of Silica fume show a very remarkable reduction of Cadmium content and established a group with lowest amount of Cadmium.

One of the principle physical effect of silica fume is the filler effect, because of its fineness, Silica Fume can fit into space between sediment grains in the same way that sand fills the space between particles of coarse aggregates and cement grains, fill the spa ce between sand grains. After the pozzolan reaction, Silica Fume iscapable to trap the pollutants, so that the pollutants could not escape from the matrix and pollute the environment.

This is the main reason why the Silica Fume is being used in this study. The different quantity of sand also realized and could be noticed in the result. As shown in Figu re 2, the raise of sand percentage to 15% (J) the result show an increase in Cadmium content if compared to 10% sand (D). The addition of 15 % of sand, make its position located from iner t waste to non hazardous waste (European Council reference).

The result shows that the ra ise of cementpercentage from 5% to 7% (L), and limefrom 3% to 5% (K),can enhance the re duction of Cadmium content.This results is due to the hydration of cement which also produces Ca(OH) 2 , required for the pozzolanic reaction in Silica Fume and for ion exchange in clays, which accelerates the cement and pozzolanic reaction of Silica fume.

The enha ncement of cement/ lime reaction can promote the pozzolanic reaction of

Silica thus produce th e reduction of Cadmium content. According to European reference value for dredged sedime nt, from the environment point of view, after stabilization process with 3% to 7% of Silica fume, the marine dredged sediment categorized as inert waste, hence harmless to environment and could be reused as a material in road construction 4.

Conclusion The main objective of this research is to fulfil the criteria (geotechnical and environment impact point of view) for the reutilization of pollu ted dredged sediment as material in Road construction. The granulometric test shows tha t dredged sediment from Port en Bessin constituted a large amount particle with silt fraction (2 - 63 µm).

The leaching test result state that dredged sediment of Port en Bessin cont ent amount of pollutants is categorized as non- hazardous waste (according to European Refere nce).Test on tensile strength confirmed that the sample with addition 7% Silica fume could t o be used as material in sub base and foundation. In the other hand sample with 3% and 5% Silica fume only can be used as material in sub base.

Leaching test determine that the present of Silica Fume in the specimens (from3% to 7%) remarkably capable to reduce the amount of pollutant (cadmium) and passed from level non-hazardous waste to categorize as inert waste. Hence the marine sediment with 3%-7% Silica fume can be used in road construction and harmless to the environment.

On the other hand, the sample w ithout Silica Fume (LIM_CIM)could not reduce the Cadmium content and still categorized in Non-Hazardous waste. This result confirms the main reason why the researcher used Silica Fume as bi nder. Although the use of Silica Fume cost additional price the result showed that Silica Fu me capable to reduce the pollutant content in the sediment. 7 References 1.

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