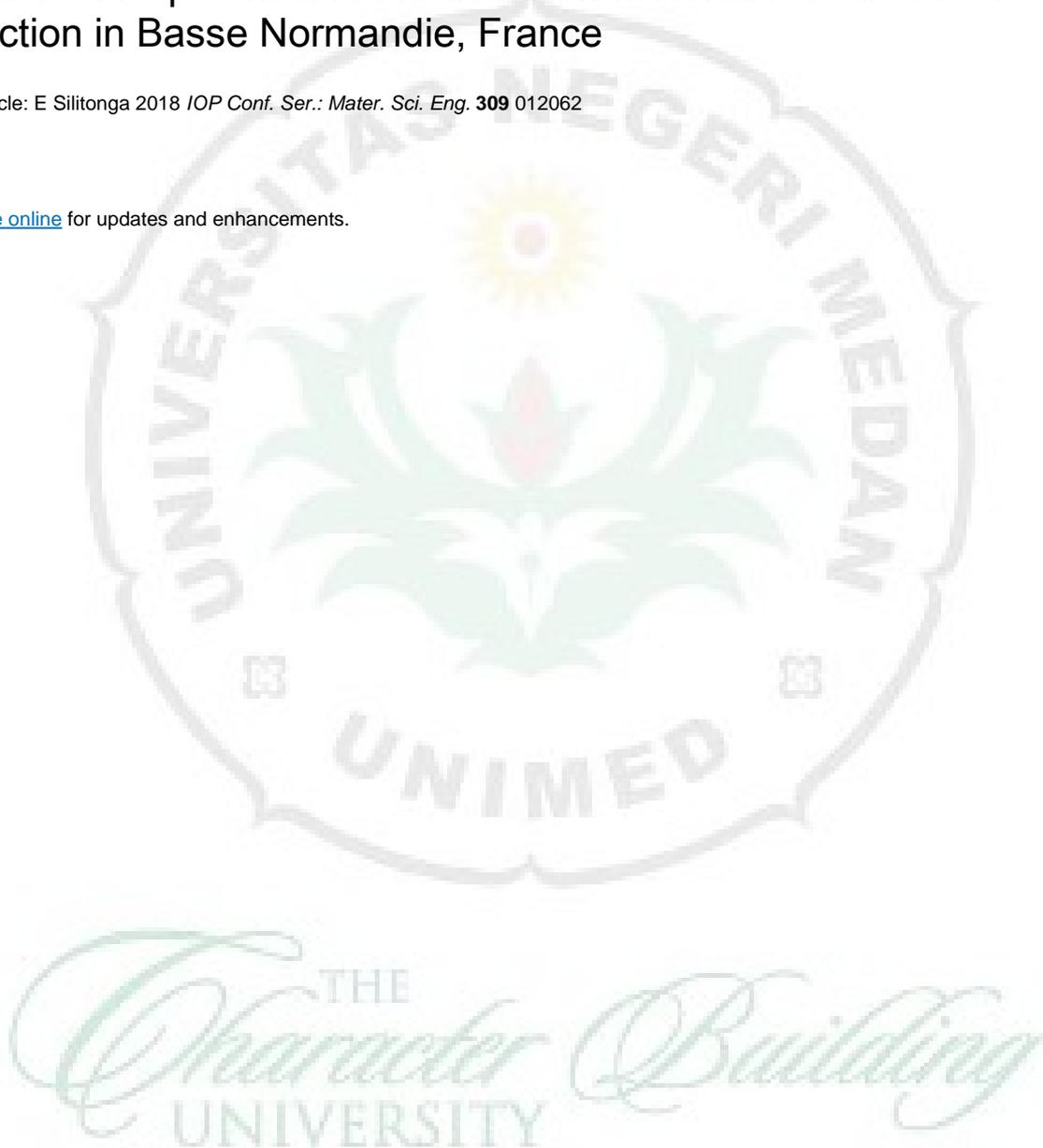


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Impact of pozzolanic binder addition on stabilization of polluted dredged sediments on its potential reuse as a new material resource for road construction in Basse Normandie, France

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Abstract. Due to the increase of the amount of marine dredged sediments (MDS) and the cost of managing the disposal site is very high, a reutilization of dredged sediment is urgently needed in France. The primary goal of this research is to find a domain for reuse of MDS materials as a new material regarding the environmental issues, and other requirement needed. In this study, the MDS was used as replacement material in road construction. Hence, various tests need to be realized to identify if MDS could achieve the requirement needed in this domain. The secondary objective is to enhance the geotechnical characteristic and to reduce the pollution content of the MDS, by incorporating binders and sediments, and revealed the geotechnical characteristic. The geotechnical test result shows that the stabilization by hydraulics binders improve the geotechnical characteristic and could fulfil the requirement needed. The present of Fly Ash and Silica Fume in this study is aimed to reduce the pollution level, especially the heavy metal content. After the geotechnical study in laboratory results shows as expected then the study to identify the chemical characteristic was realized. In order to evaluate the environmental impacts, leaching test was performed. The Leaching test result shows that with 7% of Silica Fume and 10% of Fly Ash capable to fulfil the criteria needed, hence, the use of MDS is consider safe in term of geotechnical and environmental impact, as a new material in road construction

1. Introduction

In 2003 the European Council established a regulation stated that operation of rejecting the contaminated dredged sediment into the sea is not allowed. This decision is taken regarding to the environmental issues. Available or attainable, there are many constraints on policy implementation need to be designed. To decide if the dredged material is acceptable for a beneficial use, it is recommended to realize a study to evaluate the capability of marine dredged sediment in its each utilization domain. This goal of this study is to determine the type and composition of binder to stabilize marine dredged sediments to enhance the geotechnical characteristic and reduce the pollutants content in the MDS. Previous studies with different alternative treatment method, to find the domain application for the reuse of marine dredged sediments have been investigated in Europe. Colin [1] treated Marine dredged sediment with hydraulic binders and the result show an improvement of Physical characteristic. Silitonga [2] stated that the ideal amount of hydraulic binder



needed to stabilize dredged sediment was between 7%-9%, this percentage was able to enhance the Geotechnical characteristic but could not reduce the amount of pollutant content in the MDS. A study by D Zhibo [3] show that to enhance the Geotechnical characteristic of MDS of Port Cherbourg, the amount of hydraulic binder utilized was 10%. E Silitonga [4] [5] utilized Fly Ash to enhance the geotechnical characteristic of MDS of Port de Cherbourg. The percentage of Fly Ash need to stabilize MDS is around 11%. In this study, A serial test were realized to identify the potential reuse of MDS of Port en Bessin as replacement material in road construction. To meet the requirements needed in road construction (geotechnical and environmental) pozzolanic binders such as Silica Fume and Fly Ash were utilized in this study.

2. Material and Methods

2.1. Dredged Sediment and Silica Fume

The MDS used in this study was collected from Port en Bessin. The harbour Port-en-Bessin (PEB) is located in the West of France. The sediments dredged from four different, Bassin no.1 (A, see figure 1), Bassin no.2. (B), Avant Port 1 (C) and Avant Port 2 (D).



Figure 1. Location of material sampling (Port en Bessin)

The hydraulic binder utilized in this study is Cement and Lime that normally used in road construction. The Silica Fumes utilized are not commercialized yet. In fact, the Silica Fumes used in this study are a prototype of low-cost Silica Fume (SF). The SF utilized in this study has a coarser particle size and less Silica content than normal SF commercialized. Three different types of SF were utilized in this study. Two types of Fly Ash utilized in the mixture (Sodeline and Soproline). Sodeline and Soproline are Fly Ash that produced especially for stabilization work.

2.1.1. Particle size distribution

Due to its particle size distribution, a laser diffractometer Coulter LS200 was used to identify the particle size of marine sediments utilized. The results as shown in Table 1, confirm that the particle distribution of marine dredged sediments taken from four different locations (PeB-1, PeB-2, PeB-3 and PeB-4) is almost similar, this result shows the homogeneity of the marine sediment of Port en Bessin. The result shows that MDS constituted of a large amount particle with the size between 66,7-78,4 μm . The Silica Fume type 2 (SF2) has a finer diameter of particle compared to Silica Fume type 2 (SF2) and Silica Fume type 1 (SF1). The particle size distribution of Sodeline and Soproline does not show an important difference. The two types of Fly Ash and Silica Fume constituted a large amount of particle size between 2-63 μm .

Table 1. Particle size distribution of MDS, Fly Ash and Silica Fume.

	A	B	C	D	Sodeline	Soproline	SF1	SF2
<2 μm (%)	10.7	10.6	13.8	9	3.7	5.4	2.3	13.8
2 - 63 μm (%)	77.2	78.8	74.8	78.8	61.3	58.7	78.8	68
> 63 μm (%)	12.6	10.6	11.5	12.2	35	35.8	18.9	18.2

2.1.2. Chemical Characteristics (dredged sediments and Silica Fume)

The level of pollution was identified using Leaching Test. The results of chemical characteristics are shown in Table 2. The samples were taken from 4 different locations (A, B, C and D) in Port en Bessin area. In order to identify the level of pollution of the marine sediment, the researcher used the reference established by European Council 2003/33/EC (Table 2).

Table 2. Leaching test of dredged MDS of Port en Bessin

Pollutants	A	B	C	D	European Council Reference (2003//33/EC)		
					Inert Waste	Non-Hazardous Waste	Hazardous Waste
As (mg/kg)	14	8.9	8.9	4.9	0.5	2	25
Cd (mg/kg)	1.33	1.59	1.6	1.18	0.04	1	5
Cr (mg/kg)	77	58	63	70.4	2	50	100
Cu (mg/kg)	0.63	1.41	0.94	0.7	0.01	0.2	2
Hg (mg/kg)	0.63	0.73	0.3	0.58	0.01	0.2	2
Pb (mg/kg)	20.2	17.9	22	17.3	0.5	10	50
Ni (mg/kg)	29.4	30.2	26.9	19.8	0.4	10	40
Zn (mg/kg)	137	148	109	77.5	4	50	200

Table 3. Chemical characteristic of Silica Fume utilized

Parameters	SiO ₂ (%)	Fe ₂ O ₃ (%)	Al ₂ O ₃ (%)	CaO (%)	MgO (%)	Na ₂ O (%)	C (%)	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	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	1-1.5	<0.4	<1	<1
Sodeline	40-45	10-12	20-22	8-10	2	2	5-5.5	>1	>1	<1
Soproline	23-25	23-25	23-25	5-7	5	3	7-9	>1	>1	<1

This reference values relate to the elements contained in the leachate and not in the raw material. According to the European Reference, all MDS considered as a waste material thus it must be disposed in a special area to measure the pollution level, if the MDS categorized as Inert Waste, the MDS can directly be reused. On the other hand, if the pollution level of MDS categorized as Non-Hazardous or Hazardous Waste, it needs to be stabilized until a number of pollutants reach Inert Waste level. From the leaching test, we can observe that the amount of micro pollutants from four different locations (A, B, C and D) categorized as non-hazardous waste. The chemical characteristic of Pozzolanic binders utilized in this study is shown in Table 3.

2.2. Preparation of samples

After being dredged, physical characteristics of marine sediment were measured. The measured initial water content is about 169%. The dewatering process was realized, the marine sediment, oven-dried

for 5 days at 60°C was pulverized to 2mm sieve size, it was initially mixed with determined quantities of Silica Fume, lime and cement as a binder, in a dry state and subsequently mixed with water by a mechanical mix. The sample was realized by using cylindrical specimens ($\phi = 40\text{mm}$, $h = 80\text{mm}$). Samples with SF1, SF2, Sodeline and Soproline addition were set in order to investigate the influence of the Silica Fume on the strength gained, the mixtures were realized with various percentage of Silica Fume content. The mixture without any Silica Fume and Fly Ash content (LIM-CEM) was realized as a reference to identify the effect of Pozzolanic binder (Fly Ash and Silica Fume) addition.

3. Results and Analysis

3.1. Tensile Strength

In order to identify the capability of MDS as replacement material in road construction work, the Tensile Strength test needs to be realized. The results of the tensile test are presented in figure 2.

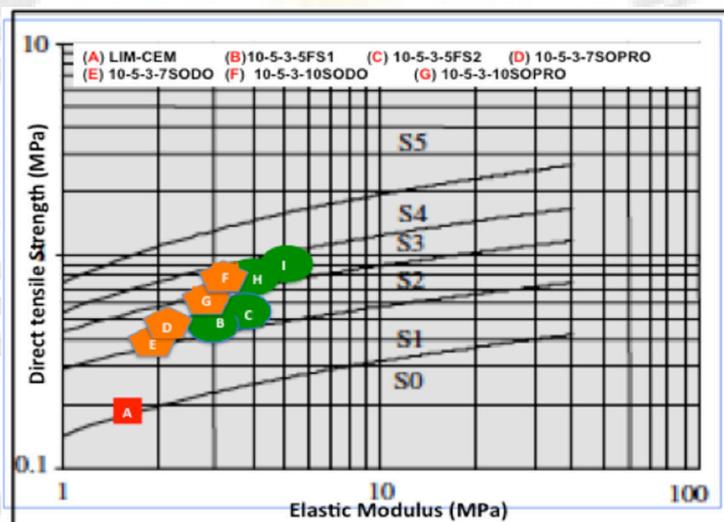


Figure 2. Tensile test result for treated Marine Dredged Sediment (MDS)

As shown in the Figure 1, only the samples with 10% Fly Ash (Sodeline and Soproline) and with 7% of Silica Fume located in class S3 (F, G, H and I). According to the Scheme of road section and recommended engineering characteristics, the samples with 10% of Fly Ash (Sodeline) is consider safe to be utilized as material as material on sub base and Foundation. The result showed that the sample with Silica Fume addition, produces a higher Elastic Modulus and higher Tensile strength value than sample without Silica fume (LIM-CEM). The sample without Silica fume LIM-CEM (A) located within the limit of S0 and S1 classes, it means the reuse for sub base need to be considered. On the other hand the samples with 5% Silica fume (B and C) and 7% of Fly Ash (D and E) located in the same class (S2), yet the Elastic Modulus values of sample with 5% of Silica Fume (B and C) is higher than samples with 5% Silica Fume. The presents of Silica Fume with its filler 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 5% of Silica fume (B and C) and 7% of Fly Ash (D and E) could be used as material only in sub base. On the other hand, the samples with 7% of Silica fume (H and G) and 10% of Fly Ash (G and F) could be reused in sub base and foundation.

3.2. Leaching Test

The main objective of using Pozzolanic binder (such as Silica Fume and Fly Ash) is to fulfil the road regulation criteria and is consider harmless to the environment. However, due to drying and oxidation process of polluted marine dredged sediment may affect mobility and bioavailability of the land utilized.

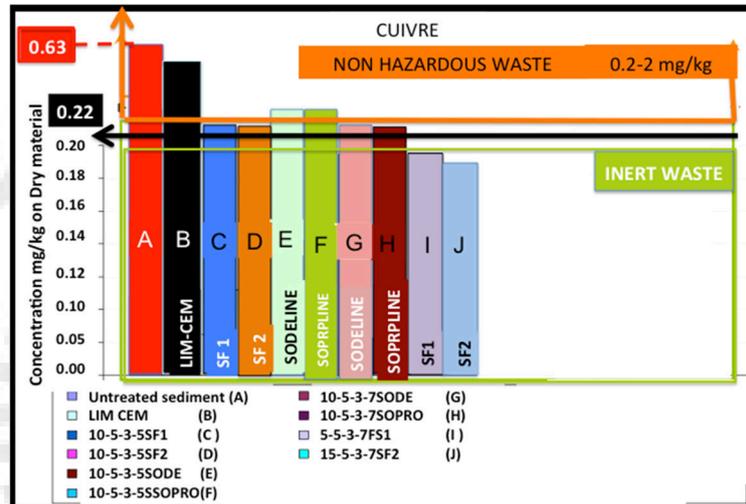


Figure 3. Leaching Test result for Copper (Cu)

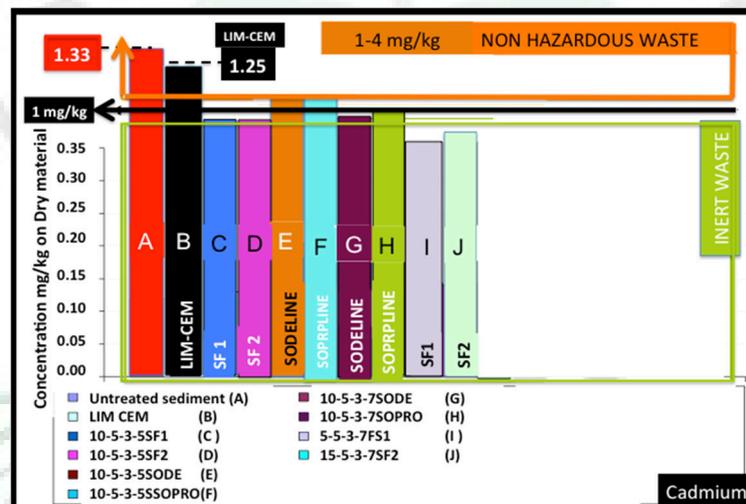


Figure 4. Leaching Test result for Cadmium (Cd)

Lixiviation Test was realized to identify the strength 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 solubilized elements during the test, which are performed on the analytical characterization. According to the result, the amount of Cadmium (Figure 4) in MDS of Port en Bessin is 1.33 mg/kg, and for Copper is 0.633 mg/kg. In order to help to classify the pollution level, the reference values established by European Council No. 2003/33 / EC are utilized. According to European reference; the quantity of Cadmium and Copper are categorized as non-hazardous waste. According to European Council, the non-hazardous waste should be stabilized and after categorized in to inert waste, than the material could be reused as new material. The result of leaching 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 (B in Figure 4), show a slight reduction of 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 level). All the samples mixed with Silica fume established a major reduction on amount of Cadmium; all the samples are situated in Inert Waste. The samples with 5% percentage of Silica fume (C and D) show minimal reduction of Cadmium content compared to samples with 5% (E and F) and 7% Silica Fume (I and J). 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 advantage of using 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 space between sand grains. After the pozzolan reaction, Silica Fume is capable 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 samples with Fly Ash show a reduction of Cadmium as well, although after stabilization with 7% of Fly Ash the Cadmium content are still located in level Non-Hazardous Waste. On the other hand samples with 10% Fly Ash established to reduce the Copper content (Figure 3) and located in border between (Inert waste and Non Hazardous Waste). From this study we can observe that, the addition of Silica Fume (5% to 7%) has greater impact on reduction the pollutant content than Fly Ash. This result due to the filler effect of Silica Fume and the content of Silica thus produces more dense material, that capable to trap the pollutant in the matrix. According to European reference value for dredged sediment, from the environment point of view, after stabilization process with 7% of Silica fume and 10 % of Fly Ash, the MDS of Port en Bessin categorized as inert waste, hence harmless to environment and could be reused as a material in road construction

4. Conclusion

The objective of this research is to fulfil the criteria (geotechnical and environment impact point of view) for the reutilization of polluted dredged sediment as material in Road construction. The granulometric test shows that 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 content amount of pollutants is categorized as non-hazardous waste (according to European Reference). Test on tensile strength confirmed that with the sample with addition 7% Silica fume and 10% of Fly Ash could be used as material in sub base and foundation. In the other hand, sample with 5% Silica fume and 7% of Fly Ash only can be used as material in sub base. Leaching test determine that the present of 7% Silica Fume and 10% of Fly Ash in the specimens, remarkably capable to reduce the amount of pollutant (Cadmium and Copper) and passed from level non-hazardous waste to categorize as inert waste. Hence the MDS stabilized with 7% Silica fume and 10% of Fly Ash can be used in road construction and is consider harmless to the environment.

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