Characterization of Dredged Marine Sediments for Road Construction

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Abstract: For the Small Island Developing States network, the management of dredged marine sediments and the pollution has to be an important issue as these materials could constitute important resources to build the infrastructures, to prevent the erosion of the shoreline and to maintain the economic activities.

In the world, several millions of tons of materials, ranging from rocks to clays and with different amount and types of contamination, are dredged each year in the harbors to maintain harbor activity and navigation. At present, the traditional solution to deal with the marine sediments is the dumping at sea, which is not strongly advocated.

The more and more environmental constraints and the increasing demand of the construction material bring on the good thought – considering the marine dredged sediment as a new source of construction material, in order to help to solve the environmental problem and the material need. For evaluating the potential of dredged marine sediment as the roadbed material, many tests in laboratory should be done. Therefore, a test program was conducted on the dredged marine sediment taken from the east zone of Dunkirk harbor in France.

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Firstly, a lot of physical characteristics are measured and discussed for a better identification of the sediment studied, for example, the initial water content, the density, the organic matter content are measured, the grain size distribution, the liquid limit and plastic limit. Secondly, the evolution of volumetric density and masse loss on ignition with the increase of temperature is researched, to explore the temperature sensibility of the two parameters. Finally, the general methodology of the recycle and reuse of marine sediment in road construction has been discussed, based on the physical properties of sediment and the previous relative research.

General Terms  
Environment, Technology & ICT

Keywords  
Dredged sediments, physical characteristics, methodology, road construction

Introduction  
As is well known, management of dredged marine sediment is a universally worldwide problem. Traditional methods such as dumping the polluted sediments into the deep sea are forbade gradually by more and more national and international legislations.

In Europe, huge amounts of sediments are dredged annually to maintain various navigation canals, rivers and harbors.
activities. The volume of dredged sediment amounts to about 50 million m³ in France (Alzieu et al, 1999).

According to the European and French directives, the dredged marine sediments are classified as waste (JOCE, 1975; Déchet N°2002-540, 2002).

According to the OSPAR Convention (1992), authorities and managers of harbors are encouraged to find an environmentally sound solution. In this context, several types of treatments of marine sediments, ranging from physical and chemical techniques to biologic techniques, were proposed recently for different uses in different fields.

These treatments methods range from physical and chemical techniques to biologic techniques, and could change the physical, chemical, mechanical and environmental characteristics in contrast with the untreated sediments.

But before reuse the dredged sediment, it requires a detailed research about diversified characteristics of natural dredged sediments. However, dredged marine sediment is a very complex material due to the presence of organic matter and pollution, especially heavy metals.

Growing environmental experts and engineers concern themselves with the research of dredged sediment and lots of theoretic and experimental results have been accumulated. Valorizations of treated sediments as a new material used in Civil Engineering (mainly as filling material) and industrial domain (as raw material of cement and brick production) has been widely investigated (Abriak, 2003; Zentar, 2008; Lafhaj Z. et al, 2008; Hamer K. et al, 2002). The proceedings are the records of the conference. ACM hopes to give these conference by-products a single, high-quality appearance. To do this, we ask that authors follow some simple guidelines. In essence, we ask you to make your paper look exactly like this document. The easiest way to do this is simply to down-load a template from [2], and replace the content with your own material.

**Characterization of Dredged Materials**

**Sampling**

The marine sediment used in this study was dredged from the Dunkirk harbor in June of 2008. This harbor, which is well known for its intensive industrial activities, is the largest seaport in the northern region and the third largest port in France.

The sediments have been stored immediately in hermetic containers of 0.054m³ in volume after being dredged from the harbor. It should be noted that, to a certain extent, the composition and its characteristics (physical, mechanical and environmental, etc) depend on the sampling time, sampling site, dredging mode, etc.

**Basal characteristics**

The physical properties provide a great basis for the classification and engineering attributes of marine sediments. Therefore, the physical characteristics of the marine sediment are very necessary to research.

The main physical characteristics are reported in Table.1. The initial water content is about 106% using the oven drying method at 40°C and 105°C. Normally, the initial water content of dredged marine sediment is bigger than 100% and bigger than the liquid limit.

**Table 1. Physical characteristics of marine sediment**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial water content (%)</td>
<td>40°C 106.5</td>
</tr>
<tr>
<td></td>
<td>105°C 106.8</td>
</tr>
<tr>
<td>Specific density (kg/m³)</td>
<td>2580</td>
</tr>
<tr>
<td>Methylene blue value (VBS)</td>
<td>2.2</td>
</tr>
<tr>
<td>Organic content (%)</td>
<td>450°C 4.4</td>
</tr>
<tr>
<td></td>
<td>550°C 7.6</td>
</tr>
<tr>
<td>Particle size distribution (%)</td>
<td>Grain size&lt; 2μm 14.6</td>
</tr>
<tr>
<td></td>
<td>2μm&lt; Grain size&lt; 63μm 57.5</td>
</tr>
<tr>
<td></td>
<td>Grain size&gt; 63μm 27.9</td>
</tr>
<tr>
<td>Liquid limit (%)</td>
<td>53.8</td>
</tr>
<tr>
<td>Plastic limit (%)</td>
<td>23.1</td>
</tr>
<tr>
<td>Liquidity index (%)</td>
<td>30.7</td>
</tr>
</tbody>
</table>

The methylene blue test is carried out to check the clay particle surface area and reflect the clay fraction activity, and the methylene blue value (VBS) of dredged sediment is about 2.2. Then the dredged sediment could be classified as silt soil according to the methylene blue value.

The specific density, which is measured on three samples by a helium pycnometer Micromeritics ACCUPYC 1330, is about 2580 kg/m³ on average.

According to these norms XP P 94-047 (1998) and NF EN 12879 (2000), the organic content which is measured respectively in an oven at 450°C at 550°C, is about 4.4% and 7.6% for this studied sediments.

With the help of laser technique, the grain size distribution is determined. Generally, the sediments are composed of three parts: silt, clay and sand. But the dredged marine materials are composed mainly of silt in this study (57.5%), and the clay fraction and the sand fraction is respectively 14.6% and 27.9%.

Through the percussion-cup method and the rolling test method, the liquid limit and plastic limit have been...
determined, and they respectively equal to 53.8% and 23.1%, according to the norm NF P 94-051 (1993) and NF P 94-052-1 (1995).

**Effect of Temperature on the Mass Loss on Ignition and Absolute Density**

**Evolution of mass loss on ignition**

The mass loss test was performed in an oven with adjustable temperature until constant weight, based on these samples dried at 105°C. For the determination of organic matter, the calcination temperature is fixed at 450°C and 550°C, according to French standard XP P94-047 (1998) and NF EN 12879 (2000). From the experimental results we can see, the measured organic content is 4.41% at 450°C and 7.59% at 550°C (Figure 1).

At the same time, the mass losses on ignition at 350°C, 750°C and 900°C were also measured to explore the thermal instability of dredged sediments (figure 1).

It should be noted that the mass loss is usually due to loss of bound water and loss of organic matter when the temperature is below 600°C. When the temperature exceeds 600°C, the decomposition of calcium carbonate could also contribute to the mass loss.

According to figure 1, we can find that the mass loss on ignition increase wholly with the raise of temperature, but the rate of increase slow a little while the temperature is bigger than 750°C.

**Evolution of absolute density**

The absolute density is a very important characteristic, which is determined by a helium pycnometer Micromeritics brand-ACCUPYC 1330.

First, the sample must first be crushed and calcined at the specified temperature until constant mass. Then we put the samples calcined in a desiccator for preventing the residue form the attack of water in air.

To study the influence of organic matter and decomposition of minerals (especially carbonates), the densities of residue samples calcined at 350°C, 450°C, 550°C, 750°C and 900°C for 3 hours were measured.

The absolute density increase on the whole with the increase of temperature, and it ranges approximately from 2.5g/cm3 to 2.7g/cm3. Obviously, with the increasing temperature, the absolute density amounts, mainly due to loss of organic matter and decomposition of carbonates.

For the dredged marine sediment, the general methodology of beneficial use in road engineering is reported in Figure 3. After an identification and evaluation of natural sediments, the potential as a raw material in road construction could be primarily defined. If the raw sediment can't meet the requirement of building materials, the additive such as granular materials (sand...) and binders (cement, lime...), should be chose to improve principally the mechanical and environmental properties.

The treated sediments could be utilized mainly as a sub-base material and a base-course material. In general, two types of additives: granular material (sand…) and binders
(cement, lime, fly ash, slag…), could be chose to improve the properties of raw sediments for the beneficial use in road engineering (Abriak and Damidot et al, 2008; Zentar, et al, 2008; Dubois, 2006; Weiguo et al, 2009; ).

These binders contribute not only to the improvement of mechanical properties, but also to the less environmental effect. Therefore, the treated materials, in our opinion, could be considered as and can be called “friendly environmental materials” to a certain extent.

Conclusions.
Before applying the dredged materials to the construction, an in-depth study about the physical properties have to be implemented to verify the feasibility of target material. In the study, some useful conclusions and data have been introduced with the help of lots of convincing tests.

Therefore, the initial water content, the absolute gravity, the organic matter content at different temperatures, the Atterberg limits and the grain size distribution have been measured. Normally, the initial water content of dredged marine sediment is bigger than 100%.

In addition, the sensibility analysis of two parameters (the absolute density and the mass loss on ignition) with the temperature has been carried out. It can be found that, the absolute density and the mass loss increase on the whole with the raise of temperature.

The absolute density of calcined sediments changes approximately from 2.5g/cm³ to 2.8g/cm³ according to the obtained results. Finally, the general methodology of the beneficial use of marine sediments has been discussed.

References.


