Organic dredged sediments treated with Portland Cement: compaction characteristics

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ABSTRACT In France, there is a large number volume of sediments dredged each year to maintain navigation in waterways and access to ports, but traditional solutions such as land deposit and ocean dumping are restricted due to environmental regulations. Solidification/stabilization (S/S) of sediments is popularly accepted as a well-established disposal technique. Portland cement is used as the binder for solidification/stabilization (S/S) of sediments in this study. Firstly, the physical characteristics of the dredged sediments were studied. Secondly, Portland cement was mixed with sediments to explore the effect of cement on compaction property and the Californian Bearing Ratio (CBR), to explore the potential of solidified sediments as road construction material.

Key words Dredged sediment, Portland cement, solidification, Proctor, CBR.

I. INTRODUCTION

In France, the Hauts-de-France region dredges about 4 million m³ sediment each year, a volume that represents 8 % of materials dredged at the national level. Therefore the management of so much sediments is an interesting issue. On the other hand, in France, the civil engineering project's annual need for granular materials is close to 400 million tons, 96% of which are of natural origin (Hamouche and Zentar, 2020). However, the use of sediments in the field of construction can not only solve problems related to sediments, but also provide a new source of construction materials. Some research on the valorization of sediments in the road construction has been published (Wang et al, 2012; 2013; 2013; 2018; Dubois et al, 2011; Zri et al, 2011; Saussaye et al, 2017; Le Guern et al, 2017). In this study, the marine sediment from Dunkirk Port, France is studied for potential use as a material in the road. Portland cement is used as the binder for solidification/stabilization (S/S) of the marine sediments. Firstly, the physical characteristics of raw sediments were studied. Secondly, different contents of Portland cement were tested to improve the compaction properties and California bearing ratio (CBR) of cement-solidified sediments.

II. MATERIALS AND METHODS

2.1 Materials

The sediments (SD) were dredged from Dunkirk Harbour in France, and Portland cement (OPC) with CEM I 52.5 R from LafargeHolcim Saint-Pierre-La-Cour company was used in this study.

2.2 Methods

The physical characteristics of the Dunkirk dredged sediments were studied according to the French standards, including water content (NF P 94-050), specific gravity (NF EN ISO 17892-3), Atterberg limits (NF EN ISO 17892-12), organic matter content (XP P 94-047), and particle size distribution (NF EN ISO 8130-13). Then, the modified Proctor and CBR tests were carried out according to NF P94-093 and NF EN 13286-47, to determine the feasibility of the cement-solidified sediment to be used as a filling material in the road.

III. RESULTS AND DISCUSSION

3.1 Physical characteristics of the studied sediment

The physical characteristics of Dunkirk dredged sediments are shown in Table 1. The initial water content is about 5.20%, measured in the oven with 105°C. The Specific gravity is 2.58 g/cm^3, obtained by using a helium pycnometer. The liquid limit and the plastic limit is 39.5% and 28.0%, respectively. The organic matter content is 7.67%, determined by the ignition test at 450°C. The sediment is composed of 6.97% clay, 39.48% silt, and 53.55 % sand.

TABLE 1. Physical characterization of sediments

Exemple		Values
Initial water content (%)		5.20
Specific gravity		2.58
Liquid limit (%)		39.5
Plastic limit (%)		28.0
Plasticity index (%)		11.5
Organic contents (%)	450 ℃	7.67
Clay fraction	% < 2 μm	6.97
Silt fraction	2 μm < % < 63 μm	39.48
Sand fraction	% > 63 μm	53.55

3.2 Compaction properties

To explore the suitability of solidified sediments for road construction materials, the effect of cement treatment on compaction property and CBR values of sediments are shown in Figs. 1 and 2, respectively. The cement content was set to 0%, 2%, and 4% of the dry mass of the sediment. It can be observed that for the 0% cement-treated sediment (raw sediment), the maximum dry density is 1.642 g/cm^3, and the corresponding optimum water content is 21.1%. Then as the cement content increased to 2% and 4%, optimum water content increased to 22.5% and 23.4%, whereas the maximum dry unit weight decreased to 1.588 g/cm³ and 1.558 g/cm³.

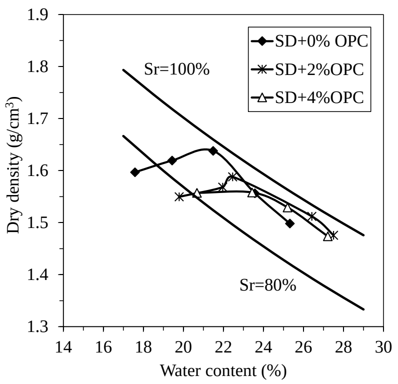

FIGURE 1. **Proctor compaction curves**

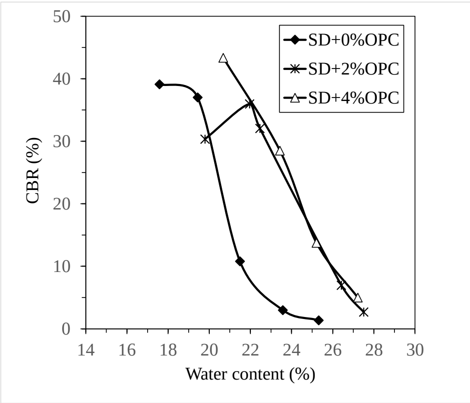

FIGURE 2. **CBR values curves**

The results of the CBR index of solidified sediment with cement are shown in Table 2. For the solidified sediment with 0%, 2%, and 4% cement, the CBR value was 15.0%, 32.1% and 35.8%, respectively. This result reflects the positive effect of cement contents on the CBR index of Dunkirk dredged sediments. According to the recommended characteristics for the different road layers as specified in French standards (assises de chausse´es: guide d'application des normes pour le re´seau routier national, 1998), the dredged sediments treated with 2% cement could be considered reused in a sub-layer (CBR ≥ 25) for road construction, and the sediments treated with 4% cement could be used as a road foundations (CBR ≥ 35) material.

TABLE 2. **The CBR index of cement-treated sediments**

Samples	CBR index (%)
SD+0%OPC	15.0
SD+2%OPC	32.1
SD+4%OPC	35.8

IV CONCLUSION

The physical properties and the compaction characteristics throughout the CBR index of treated Dunkirk dredged sediments with OPC were studied to evaluate the potential use of this material in road construction. The maximum dry density decreases from1.642 g/cm3 to 1.558 g/cm3 with the increase in cement content from 0% to 4%, while the optimum water content increases from 21.1% to 23.4%, and CBR value increases from 15.0% to 35.8%, respectively. The Dunkirk dredged marine sediments treated with cement can be reused successfully as a new material for the construction of the sub-layer and the foundation of the road. However complementary studies are necessary to confirm these results by the measurement of tensile strength and Young Modulus on cylindrical samples.

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