Treatment of dredged marine sediments for their Reuse in road construction.

Traitement des sédiments de dragage marins en vue de leur réutilisation en techniques routières.

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Abstract-A great quantity of marine sand and sediments are dredged each year in Europe. Dredged sediments were considered as a waste product of the dredging operations and were a serious problem for the harbour managers. Recently, sediments are seen as a natural resource that could provides opportunities for a number of beneficial uses. However, these raw material can't be used in road construction without a specific treatment process. Sediments suitablity tests has shown that most of studied sediments are not suitable to be used in road construction. In order to improve theircompacity and their mechanical performance, addition of a granular material is recommended.The use of a dredged sand, to improve the granular mixture containing sediments, allows a better management of the two types of dredge materials (sand and sediment). In this study, a new road material containing dredged marine sediments and dredged sand is formulated and treated by adding various binders. Mechanical performance investigation of different mixtures by measuring Proctor-IPI values and simple compressive strengths is realized.

Résumé- Une grande quantité de sable et de sédiments marins sont dragués chaque année en Europe. Les sédiments de dragage ont été considérés comme des déchets des opérations de dragage et ont consitutés un sérieux problème pour les gestionnaires des ports. Récemment, ces sédiments sont vus comme une ressources naturelle qui peut donner des opportunités pour de nouvelles utilisations. Mais, ces matériaux sont inutilisables en techniques routières à leur état brut sans l'ajout d'un processus de traitement spécifique. Les essais d'aptitude au traitement ont montrés que la majorité des sédiments étudiés ne sont pas aptes pour une réutilisation en techniques routières. Afin d'améliorer leur compacité et leur performance mécanique, l'ajout d'un sable de dragage s'avère nécessaire. Dans cette étude un nouveau matériau routier contenant du sable de dragage et des sédiments de dragage é été formulé en ajoutant des liants hydrauliques. Les performances mécaniques des différents mélanges par suivis des valeurs des IPI et la résistance à la compression simple ont été réalisées.

Key-Words*:* dredged sediments, suitability tests, road construction, hydraulic binder.

1. INTRODUCTION

Nowadays, more than 90% of the economic exchanges are performed by sea channels.In order to improve harbor infrastructures, dredging and clearing out operations are organized and generate a large quantity of sediments, around 600 m^3/year [1]. These important volumes of sediments must be managed according to the new environmental rules.Given that civil engineering material resourcesbecome rarely, one of the innovative solutions for dredged sediments management is their valorization as a reused material in road construction.Dredged sediments are characterized by their high initial water content and high organic matter content, which causes difficulties for their reuse at their raw state in road construction.

Recent studies were realized on treated sediments with hydraulic binders (1 to lime 4%) to evaluate the modification of their behavior according to the hydraulic binder[2,3,4].Chauvel and al. [5] show that a clay soil treatment will only modify the Proctor optimum parameters (water content; density) from (27%;1620kg/m^3) to (31%; 1470 kg/m^3) and will increase the bearing pressure of the ground from 10% to 54%.The influence of lime on dredged sediments (sampled from Le Havre port, in France)was studied by [6]. Obtained results show that a treatment with only 4 % of lime increases the optimal water content by 1% (from 38 to 39%).The density, whereas, decreases from 1210 to 1140kg/m^3. The bearing pressure increases from 8% to 10%. By using a mixed treatment composedof 2% of lime and 6 % of cement (CEMI), the author notes that the water content reaches a value of 37%, the dry density reaches a value of 1190kg/m^3 and the bearing pressure is 12%.The author concludes that treatment with only lime does not improve the bearing pressure of sediments. This is due to the important organic matter content of the studied sediments which consumes a part of the pesticides and could resist tohydration reaction[7].

In this order,a mixed material containing marine sediments and dredged sand treated with two types of road hydraulic binders with different mineralogical compositions is formulated. Mechanical performance of different formulations is investigated.

2. MATERIALS AND METHODS

2.1 Sampled sediment

The studied sediment is sampled from the Brest port located at the West of France. Physical and geotechnical characteristics of the sample are listed in Table 1.Using these results and according to the GTR French guide [8], the studied sediment is considered as a fine material and classified in F_{11}subclass with high organic content. With such GTR classification, this sediment can't be used in road construction and hydraulic binders must be used to improve its mechanical performance.Applying the suitability test procedure for the sediment we obtain swelling results (Gv) summarized in Table 2. These results show that sample sedimentwith volumetric swelling value of 1 % is able for treatment according to the GTS French guide [9].

Table 1.Physical and geotechnical characteristics of the sampled sediment

Sediment parameter	Value (%)
Organic matter (O.M)	5.4
Argilosity fraction (0/2 µm)	19.6
Silt fraction (2/63µm)	31.4
Sand fraction (63µm/2mm)	49.0

Fine fraction (0/80µm)	77.0
Absolute density ($\rho_s$mg/m^3)	2.5
Liquid limit (LL)	57.0
Plasticity index (PI)	20.0
Methylen Blue Value VBs (g/100 g dry)	1.4
GTR classification (LCPC-SETRA)	F_{11}

Table 2. Suitablity test results of the sampled sediment

Gv value	Gv judgment	judgment
1 %	Gv < 5 %: able for treatment 5 < Gv < 10%: doubtful Gv > 10 %: not able	Able for treatment

2.2.The granulometric correctors

In this experimental work two types of granulometric correctors were used to study their influence onsediments compacity and treatment efficacity. As shown by Fig. 1, the first one is constituted by adredged sand (class 0/2 mm) (SD) and the second is apitsand (SC)composed of 98% of particles having a diameter higher than 63x10^{-6} m(63µm).

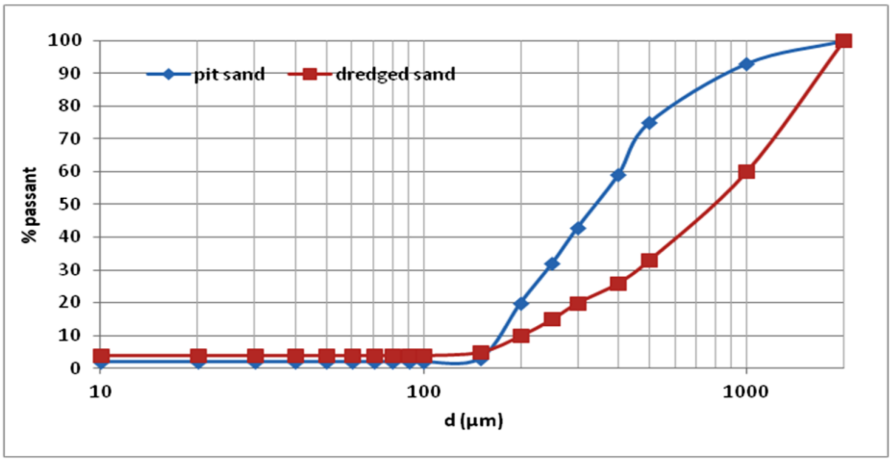

Figure 1.Grain size distribution curves for granulometric correctors.

2.3.Hydraulic binders

In this study two types of road hydraulic binders were used, Ligex FPL1 (composed of 66 % C3S) andRolacPi LH (62 % C3S). The characteristics of the two used binders are summarized in Table 3.

Table 3. Characteristics of the two used hydraulic binders.

Element	Value (%)	
	Cement 1	Cement 2
C3S	66	62
C2S	11	12
C3A	7	12
C4AF	10	6

Obtained treated sediments were prepared according to the following steps (see Figure2): the sediments are humidified 24 hours before pesticides addition; than quicklime addition; after a period of1 h, which is the needed time for lime action, the hydraulic binder is incorporated; and finally the unit is mixed during 3 minutes before compaction test.

Mechanical performance of treated samples is investigated through simple compression and diametrical compression tests. The compressive strength test was carried out on 2 test tubes (5×10 cm) and the diametrical compression tests were carried out on 1 test-tube (5×5) (see Figure 3). After specimen preparation, the test-tubes are preserved at a constant water content in hermetic membranes. The cure period is 7 and 28 days.

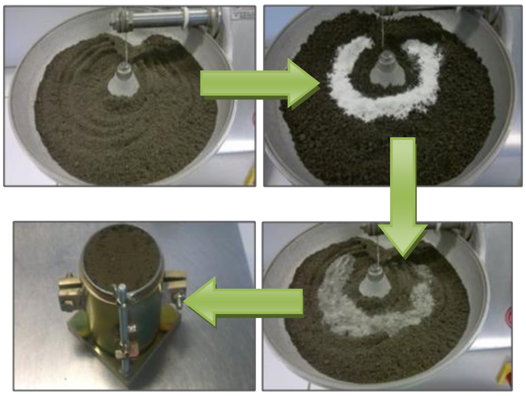

Figure2.Preparation of treated mixtures.

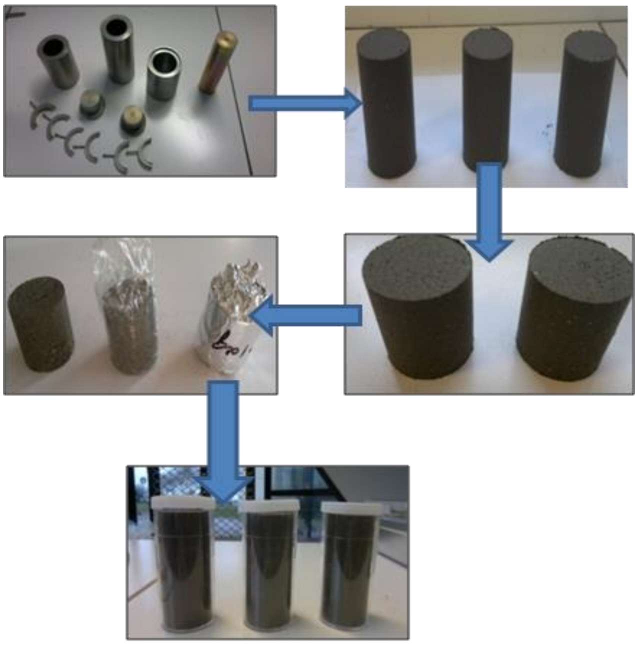

Figure3.Specimen preparation for mechanical tests.

3. RESULTS AND DISCUSSION

3.1. Proctor test results

Obtained results forthe optimum Proctor Normal test and IPI the treated formulations with lime and hydraulic binders are summarized in Table 4.For mixtures treated with HB2, dry densities vary between 1.52 and 1.70t/m^3, for water contents between 14.4 and 20.5%.Corresponding IPI values are between 21.0 and 29.1%.It can be seen from these results that IPI values are improved by various treated mixtures. For mixtures treated with the LIGEX, dry densities are between 1.49 and 1.66t/m^3, for water contents ranging between 17.1 and 23.1%. Corresponding IPI values are between 19.8 and 26.8%.In comparison with obtained results for mixtures with 100% of raw sediment and 70% sediment+ 30%SD, a treatment with lime and with road hydraulic binders could improve the IPI values.

Figure 4 shows obtained IPI values for all treated formulations. It can be seen that most studied formulations respond to the criterion of a minimal bearing pressure (for A1 Class, IPI min = 20 %) for a use in subgrade layer [9] and for all formulations we could improve IPI values (in comparison to untreated sediments).

Table 4.Proctor-IPI results forthe mixtures treated with cement.

Formulation	W_{OPN} (%)	ρd_{OPN} (kg/m^3)	IPI (%)
Untreated sediments	21.5	1510	10.5
Sediment +DS30	15.0	1730	17.5
Sediment +PS30	16.0	1760	19.0
Sediment +Lig6	23.0	1490	19.8

Sediment +Lig15	23.1	1510	22.1
Sediment +PS+Lig6	17.1	1650	19.8
Sediment +DS+Lig6	18.3	1640	23.3
Sediment +PS+Lig15	17.7	1650	26.8
Sediment +DS+Lig15	18.0	1660	26.8
Sediment +RoL6	20.5	1520	24.5
Sediment +RoL15	18.7	1540	25.6
Sediment +PS+RoL6	15.7	1660	24.5
Sediment +DS+RoL6	16.1	1640	21.0
Sediment +PS+RoL5	14.4	1700	26.1
Sediment +DS+RoL15	16.5	1660	29.1

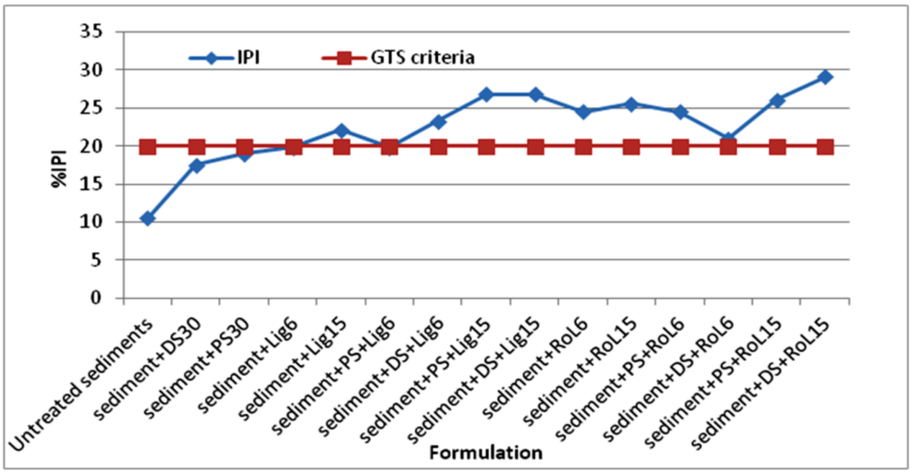

Figure4. IPI values for all treated formulations and IPI criteria (according to the GTS).

3.2. Mechanical performance results

Results of the simple compressive strength (R_C) (or the unconfined compressive strength) are an average of three values.The standard deviation of measurements varies between 0.01 and 0.09 MPa.Figures5 and6show the evolution of the simple compressive strength of the treated mixtures at a constant water content. These figures show that the Rc increases between 7 and 28 days of cure for all formulations. Values obtained with the LHR are higher than those with the sediment treated with CEMII for mixture with 6% of Ligex. A needed Rc value of 1 Mpa for the circulation of machines [9] was obtained for all formulations treated with 15 % of Ligex after 28 days of cure. Also it was the case for the formulations containing a granular corrector treated with 6% of Ligex. Mechanical performance results are better using Rolac hydraulic binder with higher obtained Rc values for 7 and 28 days.

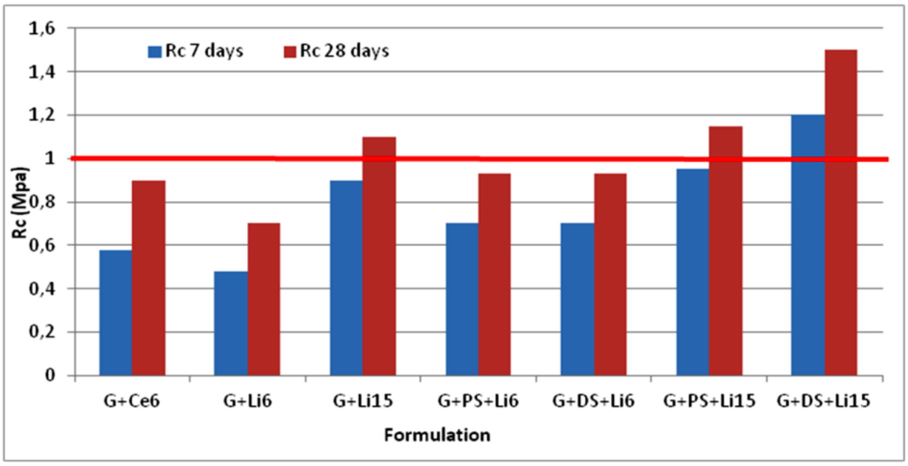

Figure 5. Results of simple compressive strength for mixtures treated with lime and Ligex at 7 and 28 days.

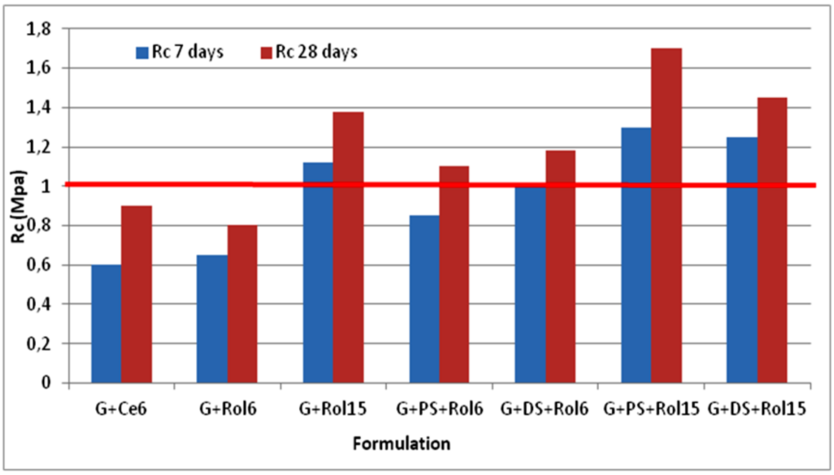

Figure 6. Results of simple compressive strength for mixtures treated with lime and Rolac at 7 and 28 days.

4. CONCLUSION

The main objective of this study is to formulate a new road material based on dredged marine sediment, sand and hydraulic binder.Obtained results highlight the use of treated mixtures containing sand and dredged marine sediments for their reuse in road construction. From this study, we can conclude that addition of sand todredged sediments can increase the compacity of mixtures. This can have a significant influencein the exchange process between treated materials and their environment.Also, mixtures containing dredged sediments, sand and hydraulic binders with high lime contentcan increase the mechanical performances,particularly the compressive strengths.Finally, using differentcorrector granulometry is interesting in order to evaluate their influence on the compacity of obtained mixtures.

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