MINERALOGICAL AND GEOTECHNICAL CHARACTERIZATION OF DREDGED SEDIMENTS FROM THE CANAL BOIS-DE-CHÊNE (PORT-AU-PRINCE, HAITI)

CARACTERIZACIÓN MINERALÓGICA Y GEOTÉCNICA DE LOS SEDIMENTOS DE DRAGADO RESULTANTES DEL CANAL BOIS-DE-CHÊNE (PORT-AU-PRINCE, HAITÍ)

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Abstract

The management of sediments raises more and more important technological, economic and environmental challenges. These sediments are especially constituted by fragment of calcareous and detrital rocks accumulated in the canal. They also contain waste resulting from industries, from the draining of engines etc., susceptible to have fatal consequences on the environment and the health of the local residents. The realized mineralogical, geotechnical tests and chemical analyses report their essentially carbonated nature and they are poor in physical and mechanical quality. However, this work can make a considerable contribution to the reduction of the environmental impacts due to the existence of sediments polluted in the urban community of Port-au-Prince, strengthens the idea to envisage the use of sediments of the canal Bois-de-Chêne as building materials for common usages.
Keywords: sediments, mineralogy and chemistry, geotechnical, construction, environment.

Resumen

La gestión de los sedimentos levanta retos tecnológicos, económicos y medioambientales cada vez más importantes. Aquellos sedimentos están constituidos sobre todo por ruinas de rocas calcáreas y detríticas acumuladas en el canal. Contienen también residuos procedente de las industrias, del drenaje de los motores etc., susceptibles de tener consecuencias dañinas sobre el medio ambiente y la salud de los residentes. Los análisis mineralógicos, las pruebas geotécnicas y los análisis químicos dan cuenta de su carácter esencialmente carbonatado y ellos son pobres en la calidad física y mecánica. Sin embargo, este trabajo puede aportar una contribución considerable a la reducción de los impactos medioambientales debidos a la existencia de sedimentos contaminados en la comunidad urbana de Port-au-Prince, refuerza la idea de prever la utilización de los sedimentos del canal Bois-de-Chêne como materiales de construcción para usos corrientes.
Palabras clave: Sedimentos, mineralogía y química, geotécnica, construcción, medio ambiente.

INTRODUCTION

The sediments in gullies, for several decades, became a concern for many countries which made studies in order to characterize them and be able to effectively manage them (Environment Canada, 2002). Number of these works is dedicated to the mineralogical, geotechnical, physical and chemical and ecotoxical characterization of the sediments (Bonnet, 2000; Perrodin and *al.*, 2004) which can be made of natural contaminant receivers (Wen and *al.*, 1998). The existence of these pollutants in sediments can entail ecological and human damages (US EPA, 1997), such as the decrease of the variety of communities, invertebrates in particular, with indirect consequences on the population of fishes or shells. The presence of pollutants also causes the loss of edibility of certain species; they can affect or make impossible entertaining activities and even create supplementary costs linked to the management of contaminated materials during dredging or cleaning out operations. When the volume of these sediments increases, the risk of flood is raised (Imbert and *al.*, 1998).

The management of sediments raises more and more important technological, economic and environmental challenges. Their phase of characterization allows to choose the adequate technology and to estimate the cost to be possibly used (Projet européen LIFE, 1992). The studies of characterization of sediments aim besides at supplying answers to the concerns of the speakers in protection of the integrity and the health of the ecosystems (Environment Canada, 2002).

The sediments found in Haiti are materials especially from the drop pipes. They arise from the erosion accelerated by hillsides. They constitute a source of exploitation which could decrease the misuse and anarchy of the sandpits and aggregates, real challenges to the environment. The exploitations of these

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quarries have a fatal effect on the environment which is characterized by: a disastrous visual impact, an erosion accelerated by hillsides, a subterranean decrease of water reserves, insecurity of the workers, road danger, evacuation of materials, nuisances to the local residents and the absence of rehabilitation (ADISH, 1996).

These problems settle at the world level and lead to the same risks. That is why, in Haiti, following the example of the developed countries, it takes there place to envisage the valuation of materials. It turns out necessary, in the case of this study, to value sediments of dredging of the canal Bois-de-Chêne (Port-au-Prince) to integrate them into the industry of the construction, as rolled and crushed materials.

MATERIALS AND METHODS

Experimental Site

The canal Bois-de-Chêne, one of the biggest collectors of sediments of dredging of the urban community of Port-au-Prince, turns from East to West to the bay of Port-au-Prince and winds the administrative space of the metropolitan region of Port-au-Prince, that is mainly the Communes of Pétion-Ville and Port-au-Prince (Léger, 2002). This canal 10 km in length approximately, originates in the Morne l'Hôpital in more than 400 m of altitude from the heights of Pétion-Ville. During the 80s, a section 2 km was fitted out in concrete, going of the corridor Bois-de-Chêne (of coordinates 18°30'10" of latitude North and 72°20'35" of longitude East) in the intersection of streets Harry Truman and Oswald Durand (of 18°30'10" of latitude North and 72°21'35" of longitude East). The canal Bois-de-Chêne is fed by a certain number of ponds hillsides constituted by calcareous and basalt materials. By erosion, transport and deposit, the detrital materials or alluvial deposits settled in the canal.

About twenty gullies train the network of drainage of the Morne l'Hôpital. Nine more important cross this one in the part East and constitute the tributaries of the canal Bois-de-Chêne. They are: the gully of Juvénat, the gully in the Chat, the gully Bois Patate or Canapé Vert, the gully of Mont Joli, the gully of Turgeau, the gully Debussy, the gully Saint Rome (constituted by gullies Bois Caïman and Fond Diable), the gully Malthèque, the gully Bourgot (constituted by gullies Bois Cochon and Fond Diable).

The geologic formations met in the zone of study begin with massive limestones of Eocene. These formations level widely not far from the police station of Pétion-Ville, on the road of Laboule, just as in Morne Calvaire, locality located at the South of the sector of study.

The Miocene puts back on these formations and is represented by limestones more or less chalky, particularly visible on the road of Canapé-Vert.

Lower Pliocene is the last term of the series. It consists of an alternation of silts and of calcareous stonewares, observable during the canal Bois-de-Chêne.

On two (2) upstream banks of this canal, towards Bourdon, levels conglomerates polygenic containing pebbles of basalt of tholeiite natural are also observed. They are accompanied with diverse pebbles and with some pebbles of flint, stemming from the dismantling of the relief of the Massif de la Selle.

Study data

Two campaigns of sample have been realized on the Ravine Bois-de-Chêne site. The sampling has been made according to the standard AFNOR, 1990. A first series of three samples by selected point was taken manually, during period from 17 till 18 March 2005, and another series of three samples, from 12 till 14 March 2006 in dry weather. Three points all in all were selected to take samples to be analyzed, they are noted P_1, P_2, P_3 (figure 1). The first sample mentioned P_1 was taken at the top of the bridge Saint Géraud in the avenue Christophe and two others, P_2 and P_3, were collected in the locality of Djobèl (street Charlevoix), towards Bourdon. Samples taken in March, 2005 were used without physical transformation (non-crushed materials) for the tests of laboratory. Those of March, 2006 were crushed before the tests of laboratory.

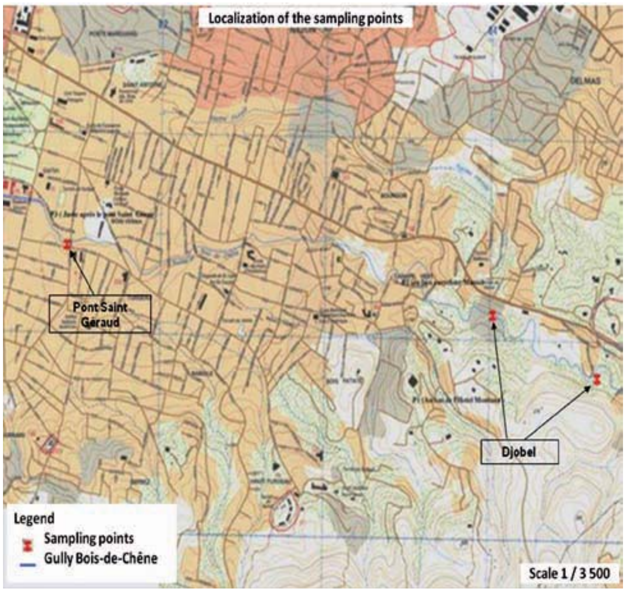

Figure 1. Sampling points

Analysis and characterization methods

Mineralogical and chemical analysis

First of all, a sieve of 50 µm and a washbasin profoundly black covered were used for the wash of sediments. For the determination of the physical, chemical and mineralogical properties, a binocular magnifying glass was used.

The method of volumetric dosage in the EDTA (Ethylene Diamine Tetra Acetic) was used for the determination of the percentage of lime. For the determination of the percentage of silica, the gravimetric method weighed was used.

Grain size analysis and fineness modulus

The grain size analysis is realized according to the standard P 18-560, 1990. The more or less fine character of sand can be quantified by the calculation of the fineness modulus (MF). This parameter is used in particular in the calculations of composition of concretes.

Physical and mechanical tests

The tests are realized according to the European Standards and AFNOR (FRENCH NATIONAL ORGANIZATION FOR STANDARDIZATION). The standard P 18-553, 1990, has been used for the preparation of the samples for the tests.

Sand equivalent tests

This test describes by the standard P 18-598,1991, used in a common way to estimate the cleanliness of sands entering the composition of concretes, is it also for grounds but, in that case, its importance is lesser.

Mass density

This test realized by the standard NF P 94-054, 1991, aims at allowing to know the mass of a granular fraction when for example we elaborate a concrete composition. This parameter allows, in particular, determining the mass of the various granular classes to mix for the obtaining of a concrete the characteristics of which are imposed.

Los Angeles test

It is the resistance in the fragmentation by shocks. This test is described by the standard P 18-573, 1990.

Micro-Deval test

This test allows to measure the flat broke wear resistance of rocks or in the presence of water by mutual frictions in a cylinder in rotation. The standard P 18-572 allows to realize this test.

Proctor-CBR tests (Standards: NF P 94-093, 1999, and NF P 94-078, 1997)

The tests Proctor normal and modified Proctor allows to define the relation between the moisture content of a mixture granular and its density dries for a given energy of compaction. The indication CBR is generally included between 0 and 100. The material is mediocre below 12, bad below 6 (Coquand, 1970).

Compression tests

This test allows to control the quality of the hardened concrete. It is about the most current tests. It is carried out according to standard NF EN 1354, 2006.

RESULTS AND DISCUSSION

The mineralogical and chemical analysis reveal that sediments of the canal Bois-de-Chêne are of limestone nature with percentages of carbonate of calcium (CaCO3) varying between 90 and 95 %. Furthermore, they have on average a percentage of 51.24 % lime and 3.24 % silica (Table 1).

These sediments are of whitish or yellowish color. Samples are altogether heterogeneous. They contain grains especially round. More than 90 % of them are clear minerals, sedimentary origin whereas 7 in 8 % represent dark and clear minerals of volcanic nature. Clear minerals have a gleaming aspect whereas those of dark tint are masts. Tracks of fossils (micro foraminiferous: milioles and globigerina) are observed.

The presence of pebbles of volcanic rocks in three studied samples is attributable to the dismantling of the heart of the Massif de la Selle, as give evidence of it basalts tholeiites appearing upstream to the sector of study and the contents in major elements revealed by the chemical analysis.

The dark grains crushed do not make excitement for the hydrochloric acid (HCl) diluted in 12 %. On the other hand, those of clear tint of carbonated nature, beforehand washed, react to the HCl by presenting a characteristic bubbling. Are present also in the dark elements of minerals silicates as the olivine (dark grains) and the calcic plagioclase (clear grains). The chemical analysis reveals the presence of major elements: SiO_2, Al_2O_3, Na_2O and K_2O.

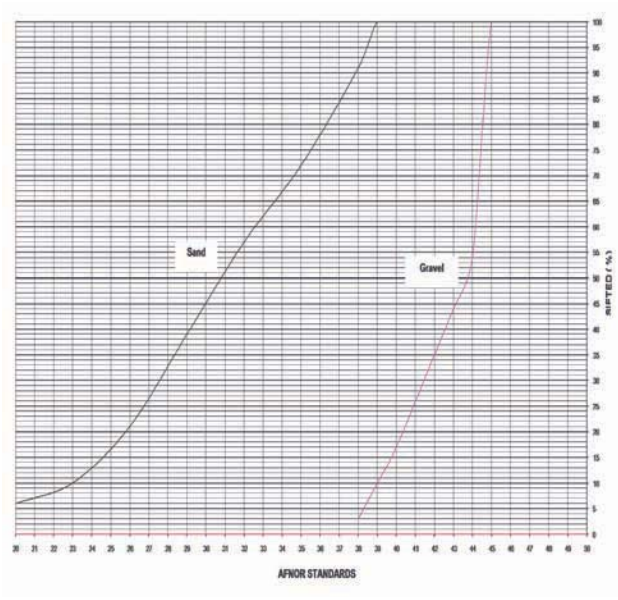

Figure 2. Grading curve corresponding to sands and gravels at bridge Saint Géraud (March 2005, non-crushed materials)

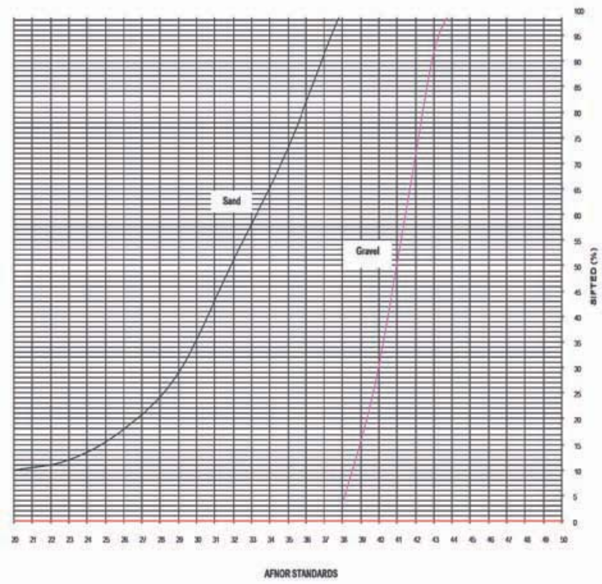

Figure 3. Grading curve corresponding to sands and gravels at bridge Saint Géraud (March 2006, crushed materials)

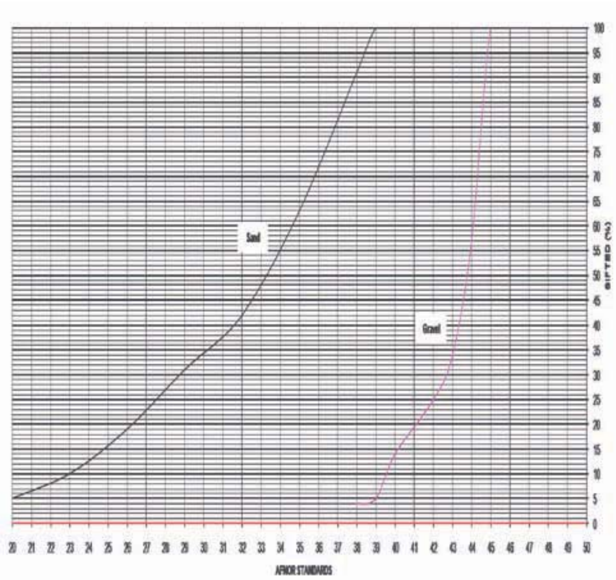

Figure 4. Grading curve corresponding to sands and gravels at Djobèl (March 2005, non-crushed materials)

According to the standard XP 18-540 the samples of materials (Mars 2005, non-crushed materials) figures 2 and 4 contain too much fine to be used as bits of gravel in hydraulic concretes, it is necessary to sieve them from 0,63d in (d + D)/2.

The fraction 0/4 mm (sand) represented in figures 2 and 4 cannot be used in hydraulic concretes because the content in fine is too low. Furthermore, the obtained grading curves and the fineness modulus show clearly that these materials are poor in fine elements.

The results of the grain size analysis of crushed materials (figures 3 and 5) taken in March, 2006, can be so interpreted:

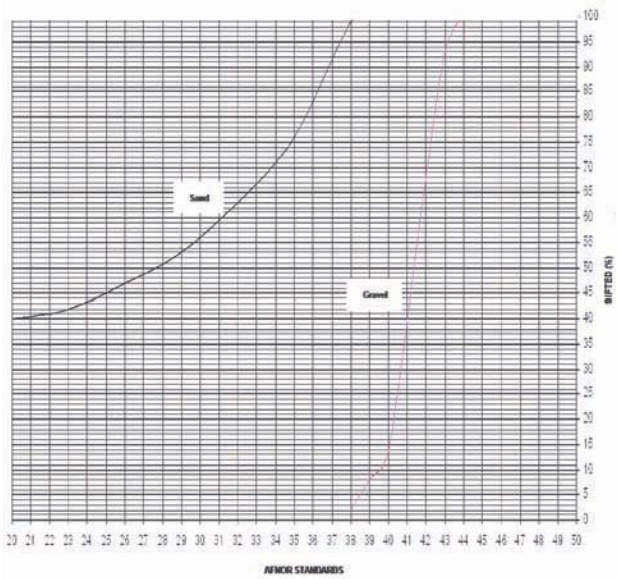

Figure 5. Grading curve corresponding to sands and gravels at Djobèl (March 2006, crushed materials)

- The samples of materials do not contain fine in 0,63d and little in d, what lets believe that they can be used in hydraulic concrete;
- The fraction 0/4 mm (sand) of these samples contains a percentage (%) of respective fine of 10 % and 40 %. They can be consequently used in hydraulic concrete.

Sample P_1, P_2, P_3 of the table 2 (March 2005, non-crushed materials) has the following respective values of Los Angeles: 23; 20; 19, of equivalent of sand: 58, 69, 81 and of cleanliness: 2.68; 2.33; 1.22. Compared with the thresholds values of the standard XP 18-540, they are convenient for the sub-base and base course. On the other hand, according to the standard XP 18-540, the test Micro-Deval gives values too much raised for the use of these bits of gravel in the first two categories of aggregates retained by the standard.

The values of the sand equivalent tests found for three samples P_1, P_2 and P_3 (crushed materials, in

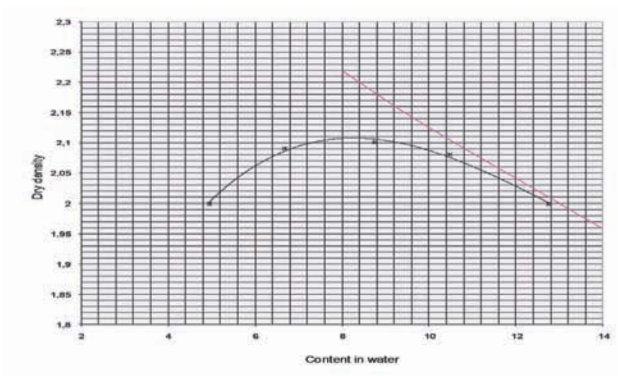

Figure 6. Proctor curve at bridge Saint Géraud (March 2005, non-crushed materials)

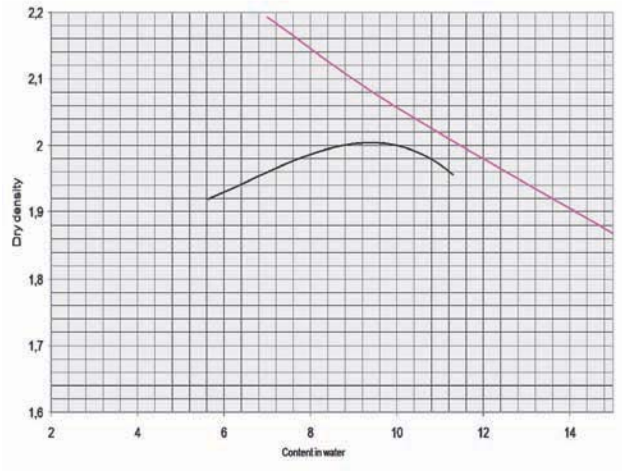

Figure 7. Proctor curve at bridge Saint Géraud (March 2006, crushed materials)

March, 2006), following the table 3, allows to assert that P_1 offers a better sand equivalent compared with two other samples (P_2 and P_3). It suits perfectly to the standard (NF P 18-598).

The percentages of wear obtained from the tests Los Angeles and Micro-Deval compared with the values fixed by the standards (NF P 18-573) prove that three

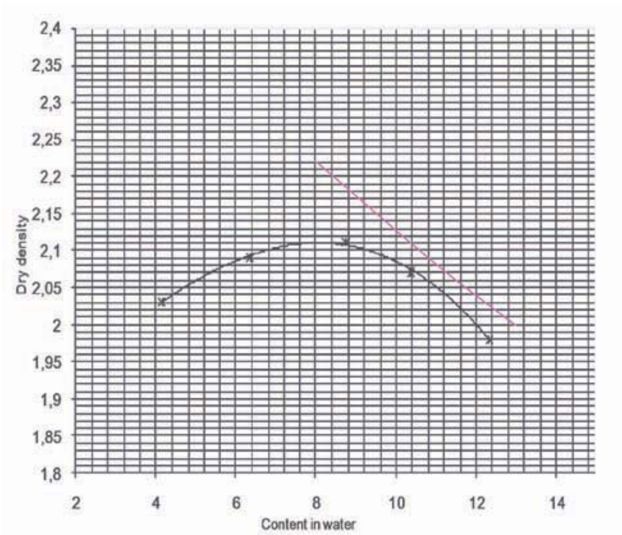

Figure 8. Proctor curve at Djobèl (March 2005, non-crushed materials)

sample P_1, P_2 and P_3 can be used sub-base, because of their weak impact resistance and in the friction.

Figures 6, 8, 10 and 12 summarize the results of curves Proctor and CBR on samples studied in March, 2005 (non-crushed materials):

The value of lift required by the National Laboratory of the Building and the Public Works in Haïti (LNBTP, 1982) for the use of a material in the sub-base is: CBR in 95 % of the OPM > 30.

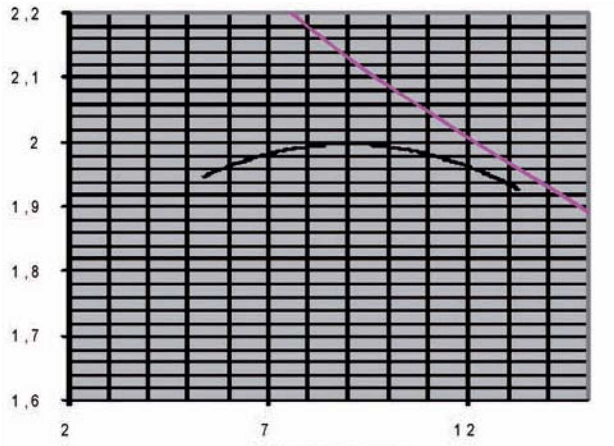

Figure 9. Proctor curve at Djobèl (March 2006, crushed materials)

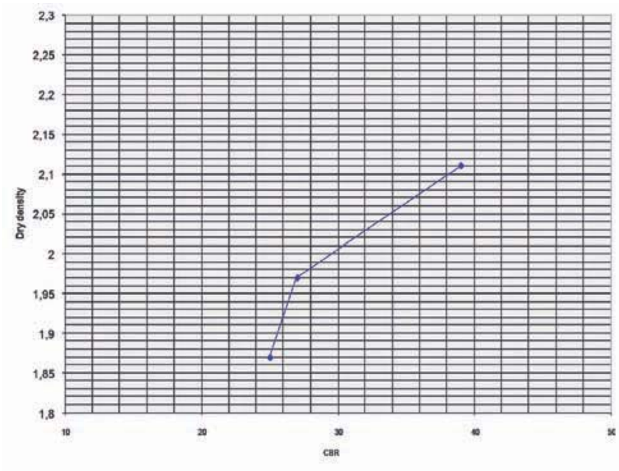

Figure 10. CBR curve at bridge Saint Géraud (March 2005, non-crushed materials)

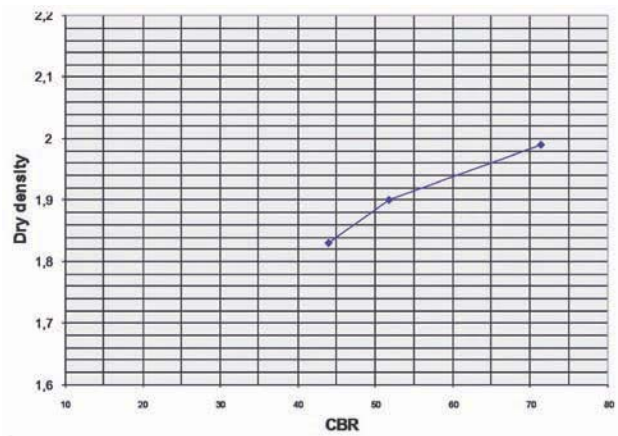

Figure 11. CBR curve at bridge Saint Géraud (March 2006, crushed materials)

The value of C.B.R. obtained for the sample P_1 (non-crushed materials) requires an improvement of the material that is the increase of its compactness before being used in the sub-base. By increasing the percentage of the modified optimum Proctor, the material becomes much more compact, thus this last one will present a CBR much bigger. On the other hand, sample P_2 and P_3 agrees very well for the sub-base.

Furthermore, the curve of the figure 6 accuses an modified optimum Proctor by 8.4 % for a maximal density of 2.11, what characterizes an excellent material (Coquand, 1970) and present an indication CBR from 30 at 95 % of the modified optimum Proctor (figure 10).

The curve of the figure 9 which presents an optimum Proctor of 8.2 % for a maximal density of 2.11, characterizes an excellent material. They present besides a CBR from 66 at 95 % of the modified optimum Proctor (figure 12).

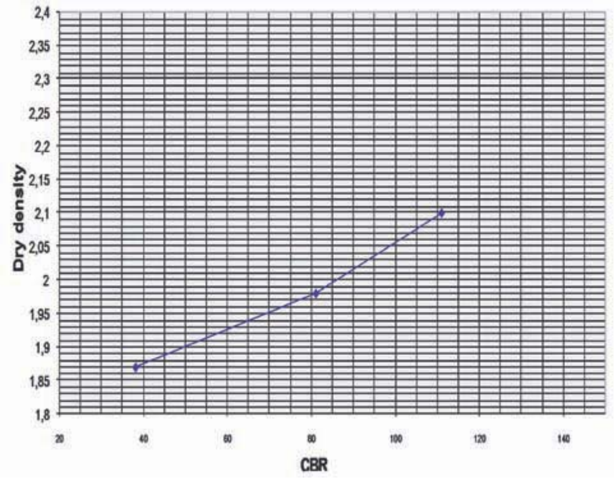

Figure 12. CBR curve at Djobèl (March 2005, non-crushed materials)

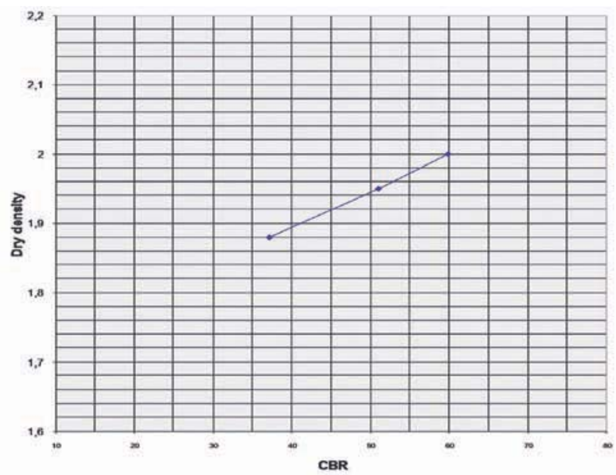

Figure 13. CBR curve at Djobèl (March 2006, crushed materials)

The obtained indication CBR by realizing the tests of Proctor-CBR on crushed materials (March 2006) accuses values respectively of 53, 53 and 42 for three samples P_1, P_2 and P_3 (Table 3). These results show that they can serve as sub-base. The capacity of lift is of as much better than the indication CBR is more raised. On the other hand, we can use materials (P_2 and P_3) non-crushed in base course according to the result of the previous study.

The resistance in traction (Table 4), obtained for the sample P_1 (crushed materials), is equal to 2.46 MPa. It corresponds to the class of resistance 4, intended for the wearing course for traffic T3 i.e. from 50 to 150 heavy goods vehicles a day (NF EN 12390-6, 2001). The resistance in compression is equal to 27.86 MPa for the same sample P_1. Its utility depends on the choice of the foreman (NF EN 1354, 2006).

CONCLUSION AND PERSPECTIVES

Sediments of the canal Bois-de-Chêne analyzed by whitish, yellowish and beige color are sedimentary detrital rocks resulting from volcanic rocks of the Massif de la Selle. Tracks of micro foraminiferous were met in sifted as well as some grains of zeolite.

The analysis of the grading curves reflects a dimensional continuous distribution and a grain size analysis spread. It is also advisable to make the sieving from the finest elements on bits of gravel before they can be used for the hydraulics concrete and as sub-base and base course.

The tests of dynamic fragmentation or Los Angeles give acceptable values for aggregates to concrete and sub-base and base course. On the other hand, the values found for the test Micro-Deval show that analyzed sediments cannot be used for the traffics of heavy goods vehicles. The values obtained for the density show that studied sediments are common materials. Furthermore, their degree of cleanliness gives values too much raised to be directly used. It is necessary to wash them beforehand.

This work on sediments of the canal Bois-de-Chêne shows the possibility of valuing these sediments and constitutes a first stage. The step must be pursued by the other analysis, the tests and the treatments to use them to reduce the exploitation of the quarries of the Morne l'Hôpital. Besides, considering the variety of the rejection in the canal, it would be good to proceed to the physical and chemical characterization of these sediments to understand the phenomena of sedimentation and transport of sediments, as well as the adsorption of contaminants and also their fate on aquatic ecosystems.

This work contributes on the one hand to explain the origin of the sediments and on the other hand, the determination of their physical and mechanical quality. It approaches also the problems of the management of the sediments under a scientific angle in order to contribute to solve the environmental problems of this country.

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TABLES

Table 1. Results of the chemical analysis (March 2005)

Samples	CaO %	SiO_2 %
P_1	50.94	3.23
P_2	50.98	2.76
P_3	51.79	3.72
Average (P_1, P_2, P_3)	51.24	3.24

Samples	CaO %	SiO_2 %
P_1	50.94	3.23
P_2	50.98	2.76
P_3	51.79	3.72
Average (P_1, P_2, P_3)	51.24	3.24

Table 2. Results of the physical and mechanical tests of materials non-crushed (March 2005)

Samples / Parameters	P_1	P_2	P_3
Grain size distribution (mm)	0 – 50	0 - 63	0 - 63
Silt content < 0,08 mm (%)	5	6	10
Fineness modulus (Fraction 0 – 5 mm)	3,43	3,43	3,19
Sand equivalent tests (%)	57	65	79
Cleanliness	2,68	2,33	1,22
Buk density on gravel	2,47	2,52	2,49
Bulk density on sand	2,50	2,64	2,69
Los Angeles	23	20	19
Micro-Deval	25	27	22
CBR	30	86	66

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Los Angeles	23	20	19
Micro-Deval	25	27	22
CBR	30	86	66

Table 3. Results of the physical and mechanical tests of materials crushed (March 2006)

Samples / Parameters	P_1	P_2	P_3
Grain size distribution (mm)	0 – 20	0 – 20	0 – 20
Silt content < 0,08 mm (%)	6,17	9,77	12
Fraction modulus (Fraction 0 - 5 mm)	3,18	2,52	2,19
Sand equivalent tests (%)	64,05	41,58	32,20
Cleanliness	0,75	2,54	1,77
Bulk density on gravel	2,57	2,56	2,58
Bulk density on sand	2,59	2,61	2,64
Los Angeles	25	25	25
Micro-Deval	18,25	19,33	19,33
CBR	53	53	42

Table 4. Tensile strength and compression of samples (March 2006, crushed materials)

Sample	Cement mass (kg/m^3)	Water masse (kg/m^3)	Concrete age (day)	Slump (cm)	Fracture stress in tensile (MPa)	Fracture stress in Compression (MPa)
P_1	350	248	7	7	2.34	10.62
P_1	350	248	28	7	2.46	27.86