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Valorisation of Coal Mine Tailings in Roads Construction

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ABSTRACT/RESUME

Abstract: *In this paper, a real scale road was realized and investigated in Kenadsa using coal mine tailings with the cooperation of socio-economic partners (OPGI, private enterprise and municipality of Kenadsa), the optimal dosage of coal mine tailings was determined in laboratory, which lead to acceptable geotechnical characteristics, also leaching tests were realized. In field long time investigation, shows some cracks in the pavement. That cracks was due to local swell at base layer, due to schist particles, which presents a high rate of swelling. The proposed solution is that coal mine tailings must be pre-treated before using as base layer road material, but can be used as it in sub-base or capping layer. Leaching tests results show that the tuff don´t absorbs all pollutants, thus a treatment by hydraulic binders and/or addition of anti-contaminant layer are necessary.*

I. Introduction

Coal was discovered in Bechar in 1907 by the geologist G. B. M. Flamand, and exploitation start in 1918 at Kenadsa. The deposit was given in concession to Algerian Ray Ways Company "C.F.A" (Algerian Railways) which supplies the extremity of the metric rail way line Oran-Bechar. The first exploitation was open-cast mine, and after the exploitation was underground until 600 m vertically. After first World Ware, there was a necessity of locale energy resources, then Bechar-Djedid mine was prospected in 1941 and equipped in 1942, and the thermal central was installed and the normal rail way line Mediterranean-Niger was prolonged to Kenadsa. The coal veins were thin (from 35 to 50 cm), but the production tenfold from 1800 in 1939 tons per month to 20000 in 1946 [1,2]. That exploitation produced a huge quantity of waste were abandoned in the nature.
Nowadays, Bechar, Bechar-Djedid and Kenadsa grow speedily, and Bechar and Bechar-Djedid are connected. The coal mine tailings which were abandoned in nature are now surrounded by neighborhoods and suburbs, and they occupy 20 and 70% of the urbanizable area of Bechar and Kenadsa respectively, their total volume is about 3,7 million cubic meters. That wastes are in form of Heaps, of two types: huge conical heaps and surficial heaps, conical heaps present the majority in volume because of theirs important high and, the conical heaps are still active and burners when it's raining, which produce contaminated air. That wastes present an ecological problem and it has negative consequences for the population health.
Coal mine tailings are a common problem around the world, the policy to face this problem is varying from developed countries [3] to developing countries [4,5].
In early two thousand, to resolve this problem direction of energy and mines of Bechar lunched a big investigation realized by the National Office of Geology and Mining Research, which results in four consistent documents [6-9], this research proposes five solutions: 1) Burying: cover heaps with clay is the first suggestion. 2) The second is to put them back into the original extraction galleries. 3) Displacement: repel these heaps and drop them away from the city into target sites. 4) Development: these heaps represent a local heritage, thus deserving a lot of care. Some heaps

are proposed for a development and integrated into the tourist circuits. 5) Reuse: as materials in the field of civil engineering. Some of these solutions are expensive as reinjection in mine or displacement, the others can be achieved and are practical and realistic as development sites or reuse in civil engineering field.

In 2008, development of surface heaps as playground and football stadium, directed by direction of energy and mine, sponsored by Sonatrac and Sonelgaz. In 2009, using coal mine tailings as granulates for bituminous concrete, experimental road section of 7m x 1000m with a thickness of 6 cm was sponsored by direction of public work, the results were acceptable [10].

In this research, the possibility of the use of coal mine tailings as materials for road base layer was investigated, an experimental road section of 7m x 60m and a thickness of 20cm.

II.2. Road test section description

The Road Test Section (RTS) is part of the development of a housing project in east of Kenadsa, which is located 20 km west of Bechar, the project is near a big coal mine tailings heap (fig 1), RTS is characterized by a low traffic, 7 m large, 60 m long and 20 cm thickness. RTS is edged by two sidewalks and covered by concrete bitumen layer of 6 cm thickness.

Fig. 2, 3, 4 and 5, show the different operations for the realization of the RTS, first the soil was stripped, in order to level the ground, following by spreading the materials in the determined dosage (Fig. 2), after that, water was sprayed in the determined content, humidified materials were mixed (Fig. 3), and finally humidified materials were compacted (Fig. 4). Fig. 5, presents the Finished RTS.

Figure 1. *Satellite of the Coal Mine Tailings Heaps and the Road Section.*

II. Materials and methods

II.1. Materials

Coal mine tailings used is near the RTS job site (Figure 1), the chemical average composition of coal mine tailings wastes is given in table 1.

Used tuff is from SARL PRODAG200 Company, its mineral nature is silico-calcareous, and it is largely used in pavement base layer and embankments in Bechar.

Table 1. CHEMICAL AVERAGE COMPOSITION OF COAL MINE TAILINGS WASTES

	Si	Fe	Ca	Al	Mg	K	Na	Mn	V	Ba	Ti	Others
% interval	17.72 18.84	19.84 20.63	0.83 0.90	8.75 9.12	0.72 0.90	5.16 5.31	0.65	0.17 0.26	0.03 0.05	0.04 0.05	0.05	0,15

II.3. Methods

Fist, on lab geotechnical characterization was done, in order to determine the optimal mixture coal mine tailings (CMT) and tuff, several mixtures soils were studied: 100%Tuff, (Tuff) 100%CMT (CMT), 50% of CMT and 50% of Tuff (CMT50), 75% of CMT and 25% of Tuff (CMT75) and 25% of CMT and 75% of Tuff (CMT25).

A *B*

Figure 2. *A: Soil stripping, B: materials spreading.*

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A B

Figure 3. *A: Water Spraying, B: Mixing.*

The geotechnical identification was divided on three parts: physical, chemical and mechanical characterization. In the physical parts, particles size analysis and Atterberg Limit tests were done. In the chemical analysis, chemical components were identified, such as: sulfate, chloride and carbonate. And in the mechanical experiments, Proctor and CBR test tests were done.

Soil pollution was studied by a lixiviation (leaching) tests of the different soils, then, leaching tests were done on two compacted soils: Tuff and TMC 25. For each soil 3 specimens are prepared using cylindrical rigid plastic molds 11 cm diameter and 22 cm high, approx. 3 kg of the soil is filled on 3 layers compacted using standard Proctor rammer, each layer received 30 blows of a 2.5 kg falling hammer from 0.305 m height, with a flat circular face of 50 mm diameter. Leaching tests were done according to protocol proposed by previous research [11] inspired from standard (CEN/TS 16637-2) [12], each specimen was immersed in a recipient/reactor of leaching, the surface of specimen was immersed in the leacher which was distilled water, with a ratio L/S (Liquid to Solid) equal to 10.

Figure 4. *Compacting of RTS.*

Figure 5. *Finished RTS.*

For each studied soil 3 specimens were placed in a recipient (bucket with lid) separately containing 30 l of distilled water, so as to leave at least 5 cm of the edges, and specimens was immersed in at least 5 cm of distilled water, time t_0 is when the specimen is immersed in distilled water, after 6 hours a volume (for chemical analysis) of water was sampled and equal volume of distilled water was replaced in the recipient, in order to have the ratio L/S equal to 10, the same procedure was conducted for each sample, according to standard (CEN/TS 16637-2) [12] leaching period. Leached water was subjected to different tests, an EXECH Exstik EC500 meter (Extech Instruments Corporation, Nashua, New Hampshire, U.S.A.) was used to measure pH, conductivity, TDS (Total Dissolved Solids) and salinity. And Chloride, sulfate and Carbonates tests were done also for the leachate water at the time steps.

After in lab investigation, using the optimum Soils mixture the RTS was realized. And checked by using Gamma densimeter (Troxler3430) which is a nuclear moisture density gauges, according to ASTM standards D6938, D2950, and C1040.

After one year, an investigation was done in order to determine possible defects.

III. Results and discussion

III.1.Geotechnical characterisation

Materials used for the realization of road base layers in the Sahara must have its particle size distribution curve between the ranges of Beni Abbes curves [13].

Fig. 6 and 7 show particle size distributions of CMT 75 and CMT 50, which are classified as family III following Beni Abbes Range specification [13], then they are not acceptable as road base material.

Fig. 8 shows particle size distribution of CMT 25, this curve is classified as family II according to Beni Abbes Range specification [13], then it is acceptable as road base material.

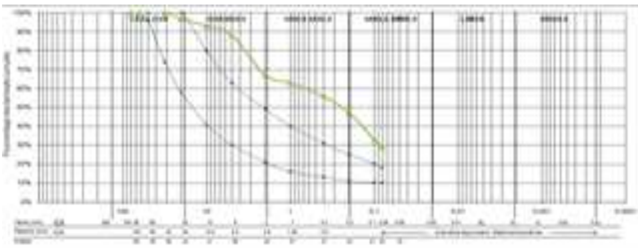

Figure 6. *Particle size distribution of CMT 75.*

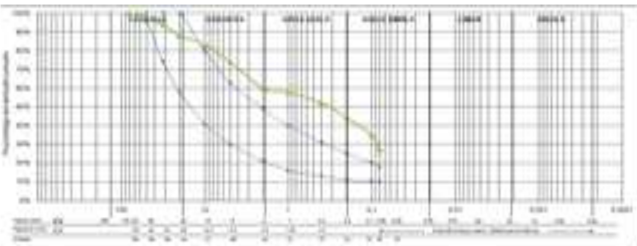

Figure 7. *Particle size distribution of CMT 50.*

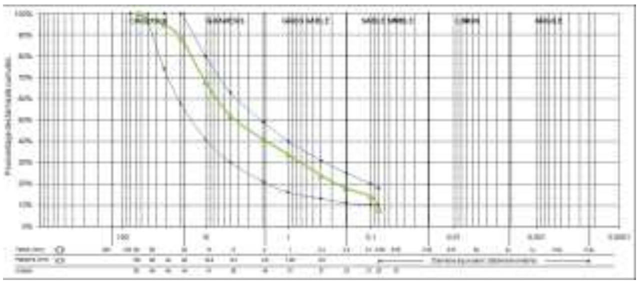

Figure 8. *Particle size distribution of CMT 25.*

Table 2 shows Atterberg limits and plasticity index, from the results it can be state that: tuff and CMT25 are low plasticity soil and can be used as road base materials, and theirs PI is below the recommended limit 13% [13]. For the other soils the measurement of Atterberg limits are impossible.

Table 2. *Atterberg limits and Plasticity Index*

	Liquid Limit %	Plastic Limit %	Plasticity Index I%
Tuff	21.76	11.20	9.86
CMT	IMP	IMP	IMP
CMT75	IMP	IMP	IMP
CMT50	IMP	IMP	IMP
CMT25	36.4	25.95	10.45

Methylene Bleu Value and chemical analysis are presented in table 3, the results show that all soils are clean (MBV≤1,5%) according to GTR standard [14], and not aggressive for the bitumen pavement, as sulfate contents is bellow recommended limit of some researcher [15], Carbonate contents of tuff and CMT25 are a little below 45% the minimum limit recommended by CTTP [16],

Table 3. *Methylene Blue Value / chemical analyses*

%	MBV	CO3	Unsolvable	Cl2	SO4
Tuff	0,3	29.50	70.36	0.14	Trace
CMT	0,45	6,3	92,78	Trace	4,92
CMT75	0,42	15	85	Trace	0.24
CMT50	0,4	36,4	63.42	Trace	0.18
CMT25	0.33	40	59.84	Trace	0.16

Proctor tests results for all soils are presented in fig. 9, the optimal water content for all soils is 8 %, the highest dry density is belonging to tuff by value of 1,98, CMT25 present a dry density equal to 1,86 which is acceptable to realize road base layers, the limit is 1,7 [13], the other soils present a dry density below to 1,70 which is not acceptable to realize road base layer.

Table 4 presents CBR tests results of the different soils, according to used specification [13] the minimum CBR required in Sahara road is 40, then, all soils are acceptable expect CMT, CMT 50, which has CBR equal to 14, it can be seen that CMT 25 has better CBR ratio then Tuff.

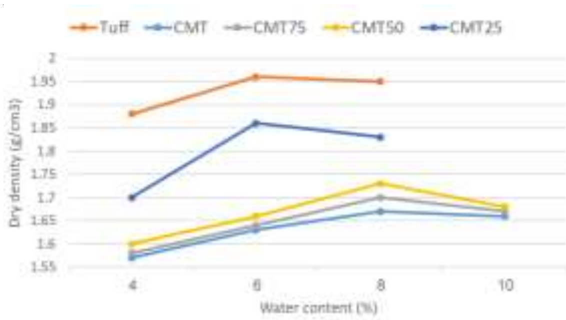

Figure 9. *Proctor tests results*

III.2. Leaching tests

Figure 10 shows pH development in time, Average pH values of Tuff is 8,4 and CMT 25 is 7,9, which is acceptable according to Algerian standard [16] and World Health Organization (WHO) standard [17] don't give guide value but an optimum between 6.5 and 9,5.

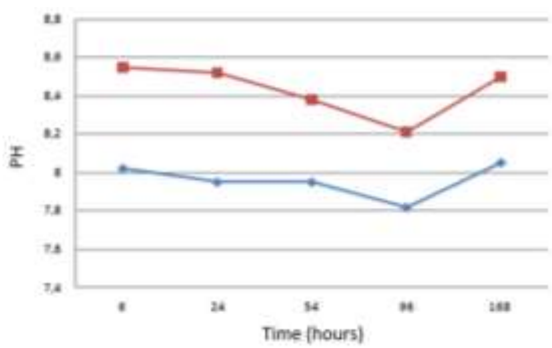

Figure 10. *PH development of lixiviant, time in hours, Tuff in red and CMT25 in blue.*

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Table 4. *Summary of CBR test results*

Soils	Characteristics	Compaction (Blows/Layer)		
		10	25	55
Tuff	Water Content (%)	6,00	6,00	8,00
	Dry Density (g/cm3)	1,42	1,64	1,98
	CBR Indice	-	34	68
CMT	Water Content (%)	-	-	-
	Dry Density (g/cm3)	-	-	-
	CBR Indice	-	-	-
CMT75	Water Content (%)	6,00	6,00	8,00
	Dry Density (g/cm3)	1,4	1.65	1.8
	CBR Indice	6,00	8.00	14,00
CMT50	Water Content (%)	6,00	6,00	8,00
	Dry Density (g/cm3)	1,72	1.96	2.02
	CBR Indice	15,00	24.00	36,00
CMT25	Water Content (%)	6,00	6,00	8,00
	Dry Density (g/cm3)	1,66	1,72	1.86
	CBR Indice	26,00	57,00	108,0

Figure 11 shows conductivity development of leachate solutions for Tuff and CMT25 in time, used unite is micro siemens per cm, first all values of leachate solutions are below limit value (2800 µS/cm) of Algerian standard [17], Tuff soil presents the lowest conductivity with a variation from 270 to 640 µS/cm, followed by CMT25 with conductivity variation from 550 to 1200 µs/cm.

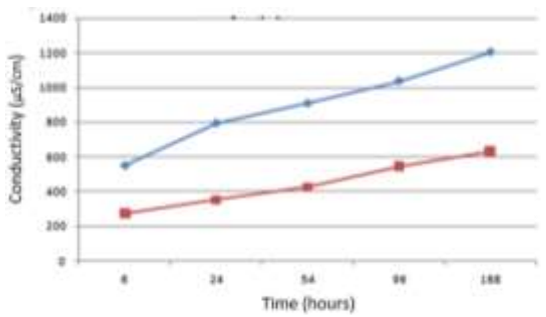

Figure 11. *Conductivity of Lixiviate (µs/cm), time in hours, Tuff in red and CMT25 in blue.*

Figures 12 and 13 show development of salinity and TDS (total dissolved solid), theirs curves shapes are similar to conductivity curve because they both are calculated from conductivity. Both TDS curves are below 1000 ppm the standard limit [18]. For salinity research [19] recommend also 1000 ppm as limit.

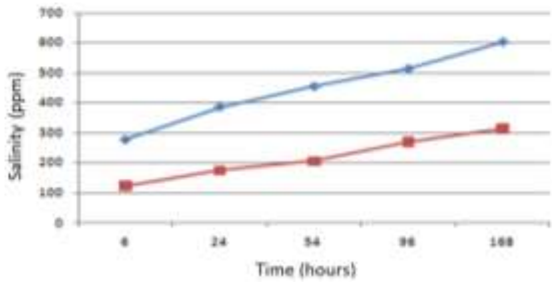

Figure 12. *Salinity of Lixiviant (ppm), Tuff in red and CMT25 in blue.*

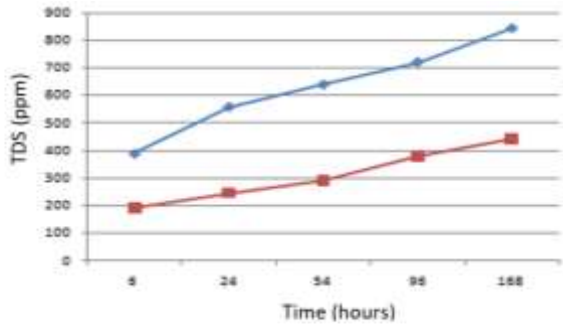

Figure 13. *TDS of Lixiviant (ppm), time in hours, Tuff in red and CMT25 in blue.*

Figure 14 show the development of sulphate of lixiviate solution in time, the maximum value is 4,5% for CMT25, which is equal to 45000mg/l Algerian standard [17] gives a limit of 400 mg/l, that is due to the high sulphate content of CMT, then CMT25 is very pollutable and contaminant for soil and surface and ground water. For tuff soil is in the limit.

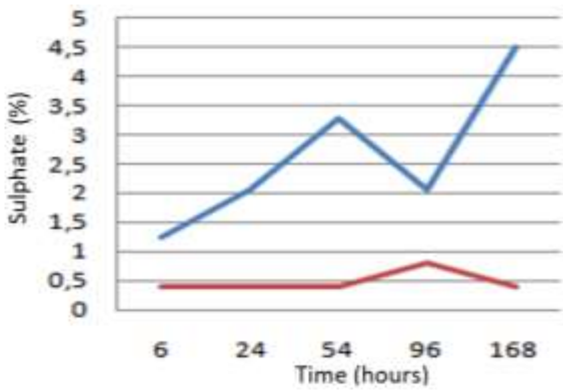

Figure 14. *Sulfate Content of lixiviant (%), time in hours, Tuff in red and CMT25 in blue.*

Chloride content of leached water in time is presented in fig. 15, CMT25 shows the maximum value equal to 1,1% which is 11000mg/l, the use CMT25 is pollutant for surface and ground water that is higher than the maximum of Algerian standard [16], tuff shows maximum of 800mg/l.

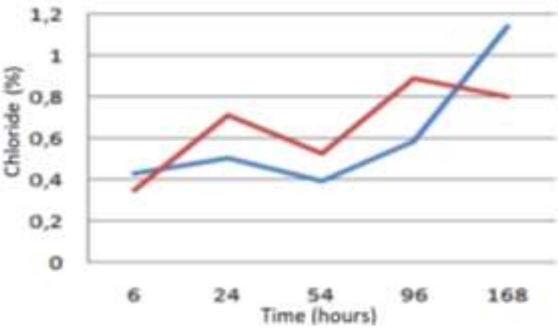

Figure 15. *Chloride Content of lixiviant (%), time in hours, Tuff in red and CMT25 in blue.*

Leaching tests show that the tuff don´t absorbs all pollutants, thus a treatment by hydraulic binders, or use anti contaminants layer is necessary.

III.3. In field tests

Road Section Test was realized using the optimum soil composition which is CMT25, the realization was controlled using gamma densimeter (Troxler3430), the results are presented in table 5, results show the repeatability of the in-lab results, but only results in the last point (which is in the end left) has a low density, which was due to failure in mixing the soils.

Table 5. *Gamma densimeter results test (in field).*

	Dry Density	Humid Density	Water Content	Compacity
Start Right	1.82	1.99	9.1	98.2
Middle Centre	1.86	1.91	6.4	100
End Left	1.69	1.69	11.2	90.8

After one year of the realization of RTS, some cracks were founded, the cracks are in X form (fig. 16), which was due to local swilling in hump shape. The max length of the cracks was 40 cm, the max width was 5mm and the max deep was 3cm, the max height difference was 15mm.

Figure 16. *Cracks after one year.*

Two biggest humps were expertise by the coring the bitumen concrete layer, by a concrete curing of a diameter of 30 cm (Fig. 17).

Figure 17. *Coring concrete pavement layer.*

After coring, the soils below the pavement cracked hump shape, contented a big particle of schist of an average of 3 to 5 cm (fig 18), this can be the cause of the local swilling. Schist are stratified clay, which can swill. Coal mine tailings must be pre-treated before using as base layer road material, or can be used as it in sub-base or capping layer, but in field tests are necessary.

Figure 18. *Soil under cracked hump shape pavement layer.*

IV. Conclusions

Following conclusions can be state:

- Coal Mine Tailings can be used as road base material with a percentage of 25 % completed by local tuff, experimental geotechnical study demonstrates the acceptability characteristics according to used specifications.
- The use of Coal mine tailings as road base layer material can be contaminant for surface and ground water the use anti-contamination layer is suitable or the stabilisation with binder materials.
- After one year of the realisation of a Road Test Section, some cracks were observed, in field investigation find that is due to local swilling of big schist particles. Coal mine tailings must be pre-treated before using as base layer road material, or can be used as it in sub-base or capping layer, but in field tests are necessary.

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