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RESEARCH ARTICLE

EFFECTS OF SAND ON CBR FOR SWELLING CLAYS OF THE FAR-NORTH REGION CAMEROON

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ABSTRACT

The CBR index is a fundamental parameter used in the construction of the earth works or the bearing layers of roadways. The measurements carried out on the swelling clayey soils show that it is still very weak. CBR measurement tests carried out on the swelling clays and sand compounds in the Far North region of Cameroon indicate that with a 40% sand content and a compactive effort of 25 strokes, the CBR of the swelling clay of Maroua moves from 1.27 to 5.58 and that of Fotokol from 2.18 to 5.26. For a sand content of 30% (resp. 40%) and a compactive effort of 55 strokes, the swelling clay from Maroua moves from 4.3 to 5.31 (resp. 4.3 to 7.9) and that of Fotokol from 3.54 to 5.69 (resp. 3.4 to 7.59) for water content values ranging between 12.11% and 19.79%.

INTRODUCTION

Situated between the 10th and the 13th parallel, the Far North Region of Cameroon has a lot of soil mainly made up of swelling clays. This region, where this type of material is predominant, is prone to consequences due to infrastructures built on them, namely roads. The life span of these projects is reduced due to the low mechanical features, namely the CBR index of this type of soil, especially when it is near to saturation. Roadway platforms generally include swelling clay, usually referred to in that region as 'karal'. Road infrastructures built in this region suffer degradations due to the traffic of heavy-duty vehicles, climatic conditions and more especially the nature of the soil underneath. This soil is exposed to more or less wide volume variations, high increases in volume (swelling phenomenon) when the water content increases, and conversely, contraction (shrinkage phenomenon) during periods of severe drop in rainfall (French Ministry of the ecology, 2007). Studies carried out by *et al.* (2015) on sand litho-stabilized karal shrinkages using samples taken from this region show a sharp reduction in the shrinkage level when the sand content increases. Similarly, studies carried out by A. Hachichi *et al.* (2009) on soil shrinkage swelling phenomena reveal that for a 40% proportion of sea and quarry sand, swelling is substantially reduced.

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Infrastructure built on this type of soil; especially roads suffer severe degradations such as potholes, cracks and various distortions. The use of this material as supporting soil has to be generally avoided when there is a risk of saturation due to the swelling potential of this clay which increases as compacting is longer (General Report - EDF, Study on economic roadways in Africa, European Economic Community, 1967). This situation prompted Government authorities to adopt various methods in order to improve the carrying capacity of the supporting soil. Techniques used deal mainly with stabilization with binding agents (cement, lime, etc.) and hydrophobic materials (ISTED, 1988), or the use of geo-membranes that entail high costs. In spite of the fact that these investments are supported by the local Government or sponsors such as the European Development Fund (EDF), road infrastructures are still suffering very rapid degradations. It is within this context that this article was drafted in order to study the behaviour of the CBR of swelling clay litho-stabilized with sand.

METHODOLOGY

MATERIALS

Soil that was studied come from two boreholes carried out in the Far-North Region of Cameroon: one in the near outskirts of Maroua at a point whose geographical coordinates are found at 10°38'20'' North latitude and 14°24'53'' East longitude. The other at Fotokol at a point with geographical coordinates 12°22'20'' North latitude Nord and 14°14'25'' East longitude.

Figure 1. Location of sites in the Far-North Region of Cameroon from where samples were taken. (www.editions2015.com)

Table 1. Parameters for the identification of karal samples from Maroua and Fotokol

Sample	Clayey portion in %	Plasticity threshold Wp(%)	Plasticity threshold Wp(%)	Plasticity index IP(%)
Maroua swelling clay (K1)	45	31.64	56.84	25.2
Fotokol swelling clay (K 2)	35	27.06	53.49	26.43

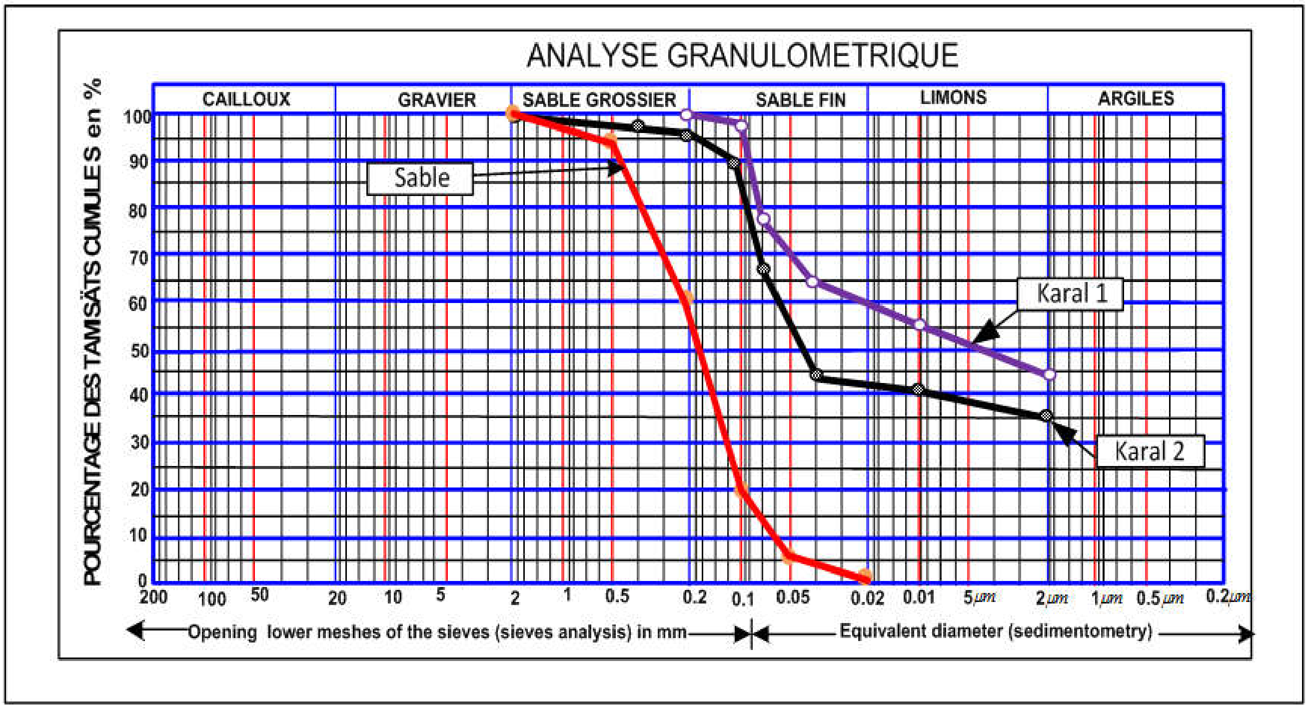

Figure 2. Results of the granulometric test

Table 2. Values of dry densities, and optimum water contents, for various compounds of K1 and K2 at Modified Proctor Optimum

	Sand (S) and K1 compound				
	0%	10%	20%	30%	40%
w_{opt}(%)	8,4	10	8,2	9	7,96
Υ_{opt} (t/m^3)	1,97	2,07	2,1	2,115	1,98
	Sand (S) and K2 compound				
w_{opt}(%)	10,6	9,98	9,95	9,2	10
Υ_{opt} (t/m^3)	1,99	2,01	2,105	2,075	2,06

Table 1. CBR Evolution, according to sand content

	0%			10%			20%			30%			40%		
	Number of strokes			Number of strokes			Number of strokes			Number of strokes			Number of strokes		
	10	25	55	10	25	55	10	25	55	10	25	55	10	25	55
Maroua	0,76	1,27	4,3	2,05	2,81	4,18	2,34	3,02	4,02	3,19	3,57	5,31	3,87	5,58	7,9
Fotokol	1,85	2,18	3,54	1,52	2,58	3,49	1,97	2,96	4,18	2,51	3,49	5,69	3,26	5,26	7,59

Table 2. CBR Evolution, according to sand content for 10 strokes

Sand content	0%	10%	20%	30%	40%
Maroua	0,76	2,05	2,34	3,19	3,87
Fotokol	1,85	1,52	1,97	2,51	3,26

The sand used comes from the Sanaga River. It was chosen because it has the same texture as the sand used in the northern part of the country. Maroua and Fotokol swelling clay samples belong to the soil category with a high swelling potential as per Holtz *et al* (1973).

The material

The material used is in conformity with the NF P 94-078 Standard. The material used for producing test tubes includes:

- The CBR mould
- The modified Proctor compacting beetle
- Accessories (riser block, spacing ringwave, strike-off screed, etc.)
- Common usage equipment (scales, driers, tanks, etc.)

The stamping equipment includes a press equipped with:

- A cylinder-shaped steel punch of 49.6mm diameter.
- A mechanism to drive in the punch into the material at a speed of 1.27mm/min.
- A mechanism to measure the depth at which the stamp has gone into the material.
- A mechanism to measure the piercing force.

The submersion material includes several tanks of sufficient height to ensure the full submersion of the test tubes.

Tests carried out

The granulometric, sedimentation, Proctor and CBR tests were carried out on samples of swelling clay mixed with sand.

Granulometric and sedimentation analysis tests

Granulometric and sedimentation tests carried out on sand and swelling clay samples from Maroua and Fotokol were done in accordance with the process envisaged by the ASTM D 422-63 Standard.

Modified Proctor and CBR tests

Modified Proctor and CBR tests were carried out using the procedure envisaged by the NF P94-093 and NF P 94-078 standards. These tests were done on swelling clay samples coming from Maroua (Karal 1), Fotokol (Karal 2), and on mixtures of these clay samples mixed with 0%, 10%, 20%, 30% and 40% of Sanaga sand. Submersion is done so that the test tube is covered with about 20 mm of water and that a 10 mm water strip is present under the mould. After four days of submersion, the mould and the test tube are taken from the water and after draining the stamping is carried out. To calculate the CBR index, the test involves measuring the force (pressure) to exert on a cylinder-shaped stamp to make it drive into a test tube containing the material at a constant speed (1.27mm/min). Values of forces corresponding to penetrations at 2.5mm and 5mm are taken down. These values are compared to those obtained on a reference material to deduce the desired carrying index. Reference pressures are of 7 and 10.5Mpa for penetrations of 2.5mm and 5mm respectively.

The following characteristic values are then defined:

I_1= (Penetration Effort at 2.5mmx100)/7 and I_2= (Penetration Effort at 5mm)x100)/10,5. The desired CBR index is theoretically the highest of these two values: max (I_1 ;I_2). Below, we shall refer to letters « K1 (resp. K2) » samples of swelling clay from Maroua (resp.de Fotokol) and to letter « S » Sanaga sand samples.

RESULTS AND DISCUSSION

Granulometric analysis

Results of the granulometric test summarized by Figure 2 and Table 1 indicate that karals 1 and 2 have a 45% and 35% content of clayey materials respectively. These clay contents are confirmed by works carried out by Gwet H. (1992) showing that karals taken on the Maroua-Yagoua road, in the town of Moulvoudaye in the Far-North of Cameroon, contain more than 30% of clayey materials.

Dry densities at Proctor Optimum

Dry densities at Modified Proctor Optimum for sand (S) and karal (K) compounds from the towns of Maroua « K1 »and Fotokol « K2 » according to the water content are given in Table 2. Table 2 and figure 3 indicate that for K1 clay from Maroua, the maximum dry density at Modified Proctor Optimum is obtained when 30% of sand is mixed with 70% of clay. The density value obtained is thus of 2.115t/m^3 with a maximum water content of 9% and for K2 clay from Fotokol, the maximum dry density at Modified Proctor Optimum is obtained when 20% of sand is mixed with 80% of clay. The density value obtained is thus of 2.105t/m^3 with an optimum water content of 9.95%.

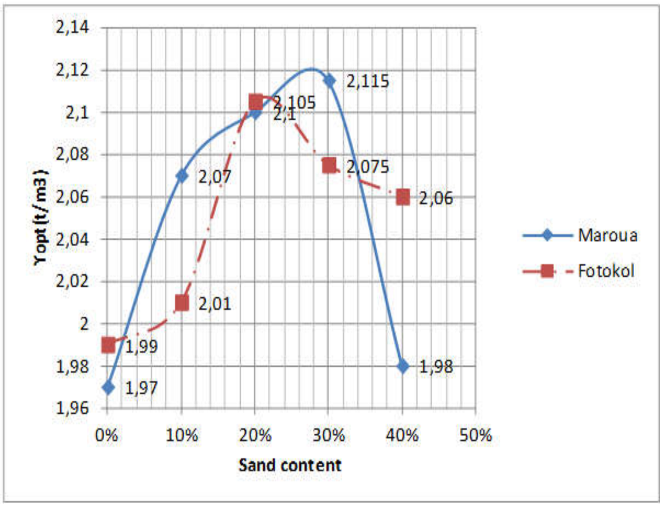

Figure 3. Dry density at Modified Proctor Optimum of compounds according to the quantity of sand added

CBR indexe

CBR indexes according to the number of strokes

Results giving CBR index values after submersion are summarized in table 3 and figures 4 to 6. It is noted that CBR indexes increase according to the number of strokes (compactive effort).

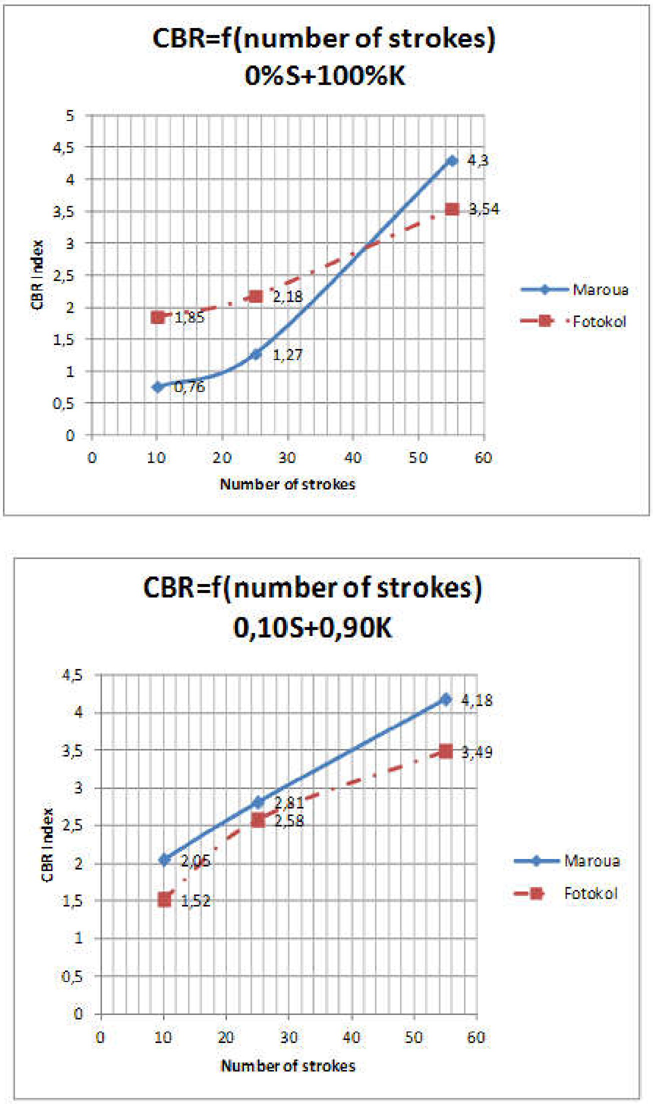

Figure 4. CBR Indexes according to the number of strokes for compounds 0%S+100% (K1 and K2), 10%S+90%(K1 and K2).

CBR indexes according to sand content

Tables 4 to 6 and figures 7 to 9 summarize results giving CBR indexes for sand (S) and karal (K) compounds from Maroua « K1 » and Fotokol « K2 » according to sand content and number of strokes. Results obtained as summarized by Tables 4 to 6 and Figures 7 to 9 help us to get the following information:

- Variation is minimal between Maroua and Fotokol CBR for sand contents higher or equal to 30% and a compactive effort higher or equal to 25 strokes.
- CBR indexes increase from a 30% sand content irrespective of the compactive effort.
- The highest values of CBR indexes are attained with a 40% sand content and a compactive effort of 55 strokes ; the Maroua CBR index moves from 4.3 to 7.9 and that of Fotokol from 35.4 to 7.59, that is an increase of 83.72% and 114.41% as for clay alone.

The addition of sand greatly increases the bearing capacity of swelling clay. Figures 7 to 9 illustrate this assertion using as reference swelling clay CBR indexes without no addition of sand. It is noted that the CBR does not very much, irrespective of the compactive effort (number of strokes), for a sand content varying from 0 to 20%. Beyond 20% and up to 40% of sand content, the CBR increases significantly.

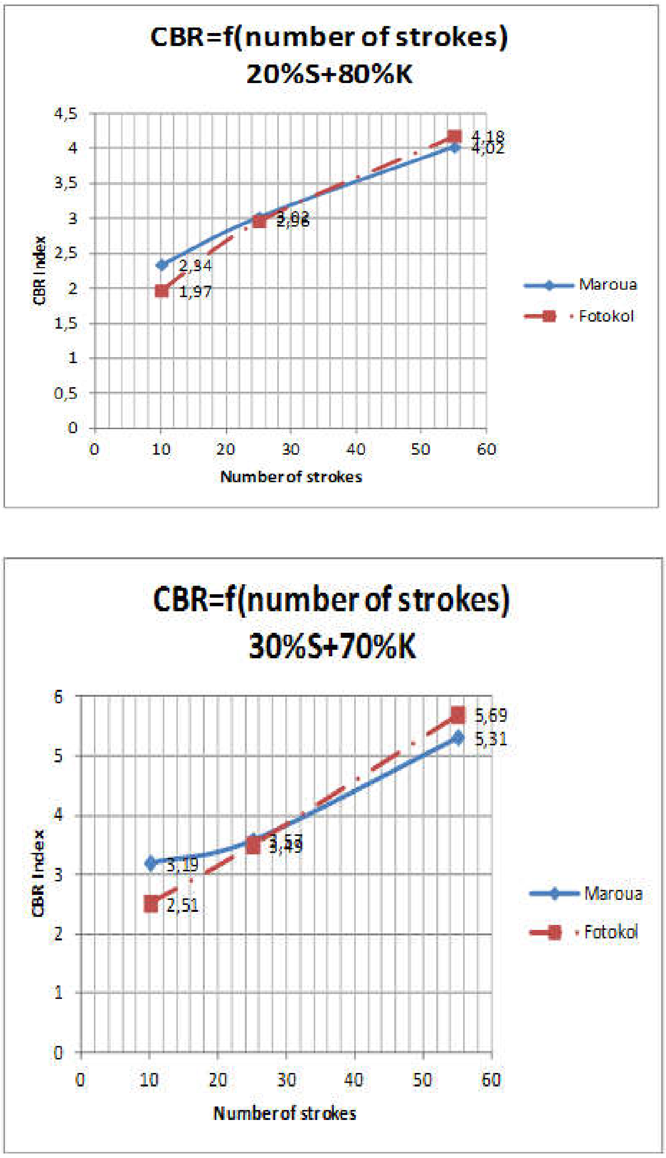

Figure 5. CBR Indexes according to the number of strokes for compounds 20%S+100% (K1 and K2), 30%S+90%(K1 and K2)

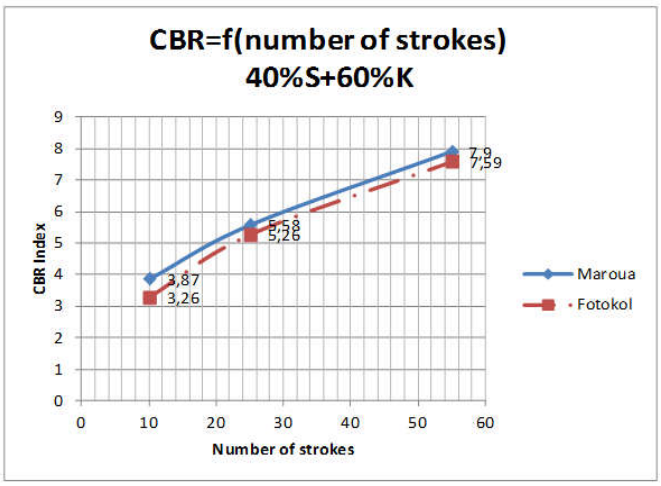

Figure 6. CBR Indexes according to the number of strokes for compound 40%S+60% (K1 and K2)

Table 5. CBR Evolution, according to sand content for 25 strokes.

Sand content	0%	10%	20%	30%	40%
Maroua	1,27	2,81	3,02	3,57	5,58
Fotokol	2,18	2,58	2,96	3,49	5,26

Table 6. CBR Evolution according to sand content for 55 strokes

Sand content	0%	10%	20%	30%	40%
Maroua	4,3	4,18	4,02	5,31	7,9
Fotokol	3,54	3,49	4,18	5,69	7,59

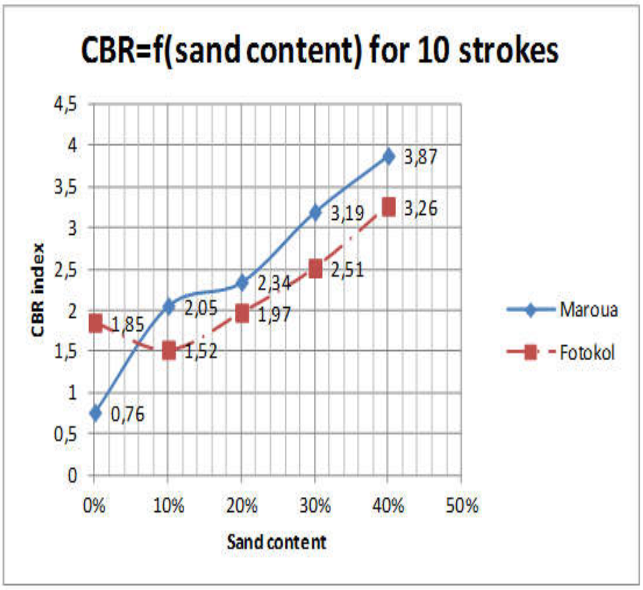

Figure 7. CBR index according to sand content for 10 strokes (K1 or K2)

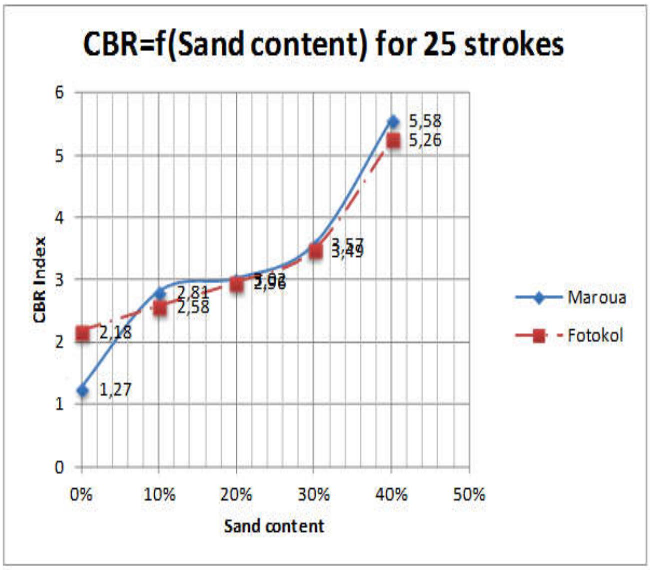

Figure 8. CBR index according to sand content for 25 strokes (K1 and K2)

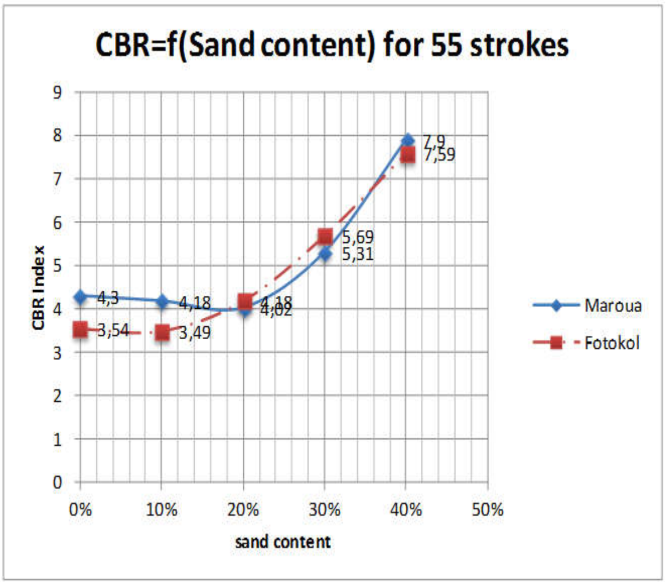

Figure 9. CBR Evolution according to sand content for 55 strokes (K1 and K2)

This phenomenon could be explained by the fact that the compound's texture, with a reduction of fine particles and the addition of a quantity of sand (from 20% to 40%), contributes to reduce the swelling and shrinkage of the mixture (Baana *et al*, 2015) whose behaviour is not flexible enough. This texture provides better resistance to litho-stabilized clay.

Conclusion

The mechanical characteristics of swelling clay are improved when a certain quantity of sand is added to the initial material. Thus, Optimum dry densities at Modified Proctor Test of swelling clay increase when sand is added. With a percentage of 20% for the Maroua sample, the resulting maximum dry density is of 2.105t/m^3 and with a percentage of 30% for that of Fotokol, it is 2.115t/m^3. The higher value of the CBR index is obtained for a sand content of 40% and a compactive effort of 55 strokes; it moves from 4.3 to 7.9 for the Maroua sample, and from 3.54 to 7.59 for that of Fotokol, for a water content of 12.11% and 17.56% respectively.

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