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Research Article

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Improving Geotechnical Characteristics of Low Bearing Materials for use in a Base Layer

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Abstract Despite important fund invested in Mauritanian road construction and maintenance, significant road quality deterioration are observed in the early years of use, resulting in very high motor vehicle fatality rates.

In the absence of road design guides, conventional methods and norms, based on parameters not suitable to the local context, are used. The objective of this study is both to improve low bearing materials quality for their use in road construction and propose an appropriate Pavement Design guide. These low bearing capacity materials were traditionally limited to sub-base layers. Through this research work, we aim to study their use in a base layer. Three shell bank quarries were targeted and several samples were studied in Thies Polytechnic School laboratory in Senegal. Laboratory tests have shown that the raw materials maximum dry densities varied from 18.7 and 21.6 KN/m^3, the optimum water content from 4.8 to 11.8% and the California Bearing Ratio (CBR) from 16 to 51. Subsequently, the raw material was treated with cement with a percentage varying from 3 to 4%.

Interesting results were found, in particular a significant increase in the CBR as well as an improvement in other physico-mechanical characteristics. Thus, the CBR of the PK 23 NDB quarry, with a cement dosage of 3%, increased to 200. For the PK 35 AKJT quarry, a 3.5% cement treatment let to a CBR of 205. As for the PK 23 Rosso quarry, its CBR increased from 87 to 190 after a 4% cement treatment.

Keywords bank shells, low bearing capacity, improvement, base layer, sub-base layer

Introduction

The durability and resilience of a road depends on its design which in turn is dictated by the local environment. Soil heterogeneity, climate, road usage, and water are all an integral part of the specific environment of a pavement. The technical, financial and environmental aspects should be taken into consideration as a part of an all-encompassing approach to road design. Hence, an improvement in the materials making up road foundation will positively and significantly impact the national road network. In According the World Bank, the mortality rate linked to motor vehicle accidents in Mauritania currently stands at 26.69 deaths per 100,000 inhabitants. With an average of 1083 road deaths per year (2012 - 2019), road accidents in Mauritania constitute a serious issue [1]. Add to this the characteristics specific to the Mauritanian context: a centralized economic system, a vast network of road infrastructure managed under several institutional jurisdictions and large presence of soils with low bearing capacity. This results in major challenges to the development of an optimal road design in

Mauritania. Thus, it becomes critical to seek the application of new technologies allowing a response better adapted to the needs. Indeed, the use of inappropriate parameters for road design leads to premature degradation of the pavements while an overestimation of these parameters leads to low thicknesses which are, among other things, cause road quality degradation. Actually, in Mauritania there is no national road design guide. Instead, conventional methods are generally used in road construction projects, which are not appropriate for the local environment. Further complicating the matter is the scarcity of materials that meet conventional design requirements.

The general objective of our research is to improve low bearing shell sands from run-of-mines (currently only used in foundation layers) in order to be able to use them in base layers. The materials will be improved using cement at different dosages.

Materials and Methods

Geotechnical Studies Program

Investigation Campaign

Several investigation campaigns have been scheduled with a goal of extracting approximately one ton of materials from each of the three targeted quarries.

Core sampling carried out at the PK 23 Rosso quarry, as well as sub-surface sampling in the other two quarries, enabled us to collect a large amount of materials for the experimental phase of this research work.

The materials then were transported to Senegal and more precisely to the Thies Polytecnics Geotechnical Laboratory to be subjected to an experimental program.

Location of Materials

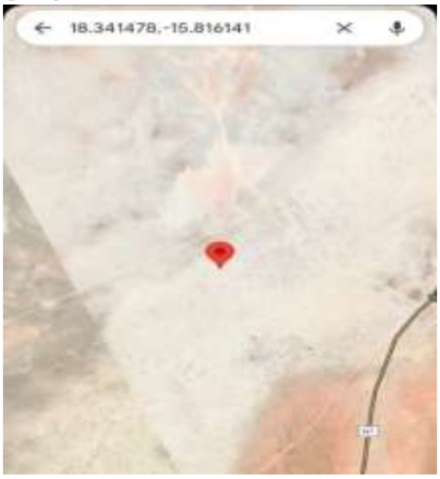
The materials used in this study come from three different localities, namely PK 23 between Nouakchott and Nouadhibou, PK 35 between Nouakchott and Akjoujt and PK23 between Nouakchott and Rosso which border Senegal.

Their latitude and longitude are:

- PK 23 NDB: latitude: 18.317984, longitude: -16.005569
- PK 35 AKJT: latitude: 18.341478, longitude: -15.816141
- PK23 ROSSO: latitude: 17.893838 , longitude: -15.982718

Collection of Study Materials

Below are images of one of the quarry sites, during the research and sampling works:



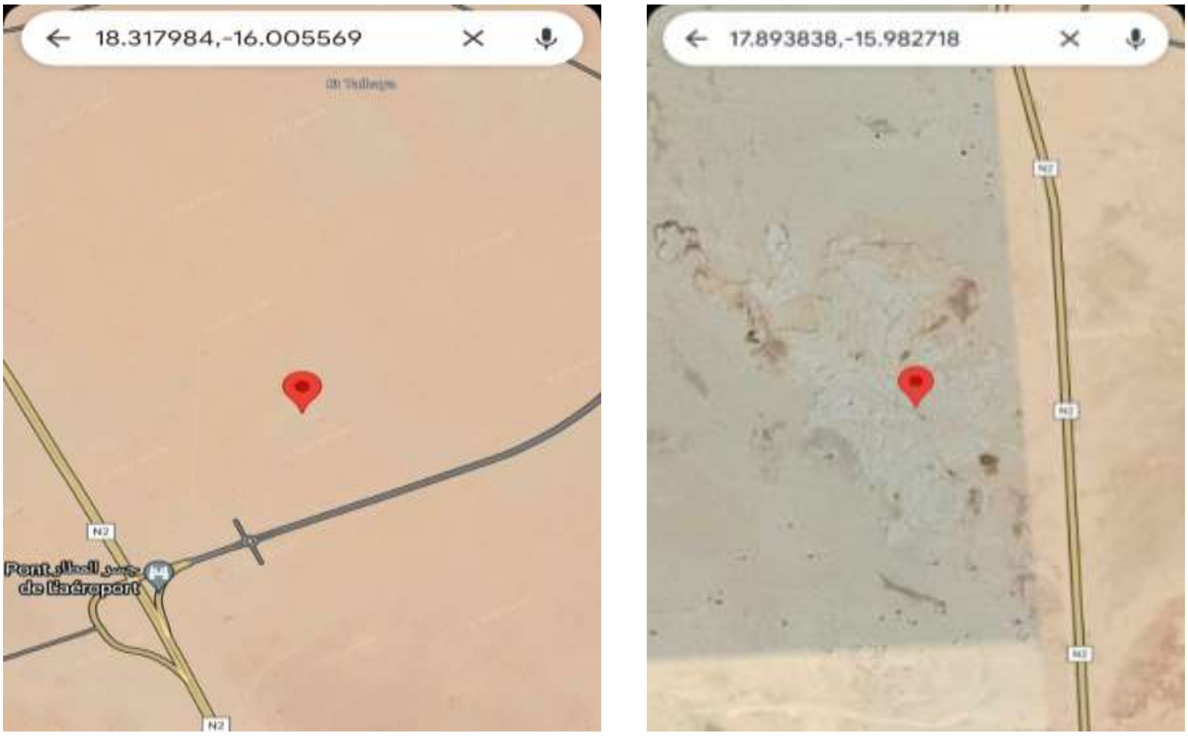


Figure 1: Material location & sampling images

Methodology

The samples taken were analyzed in the laboratory according to the following test program:

- Granulometric testing and analysis (by sieving);
- Modified Proctor Compaction Test;
- CBR test

Subsequently a series of samples was processed with different dosages of cement to determine which one will result in a CBR value greater than 160, which is the value required by the Technical Guide for the Construction of Embankments (TGCE), for the use of a material in a base layer.

Presentation and interpretation of results

The tests carried out at the Laboratory made it possible to classify the materials and to determine the percentages passing certain granulometric thresholds by sieving.

The results obtained are summarized in Table 1 below.

Table 1: Summary of laboratory tests

		PK 23 Rosso		PK 23 NDB		PK 35 AKJT	
	Mesh Sieve	**Minimal**	**Maximum**	**Minimal**	**Maximum**	**Minimal**	**Maximum**
Granulometric analysis	% < 20mm	97.53	99.93	98.94	100.0	97.15	100.00
	% < 2mm	73.66	80.10	76.30	83.32	58.79	83.28
	% < 0.400mm	64.37	75.35	71.99	79.14	20.17	63.43
	% < 0.080mm	0.62	5.71	1.42	11.28	1.05	43.20
Modified Proctor Compaction Test	γ_{max} (KN/ ^{m3})	19.8	21.6	18.7	20.3	18.7	21.1
	wopt (%)	11.8	7.4	4.8	9.8	6.6	10.2
	CBR at 95% OPM	18	51	20	39	16	44
Bearing	Swelling (%)	0	0	0	0	0	0

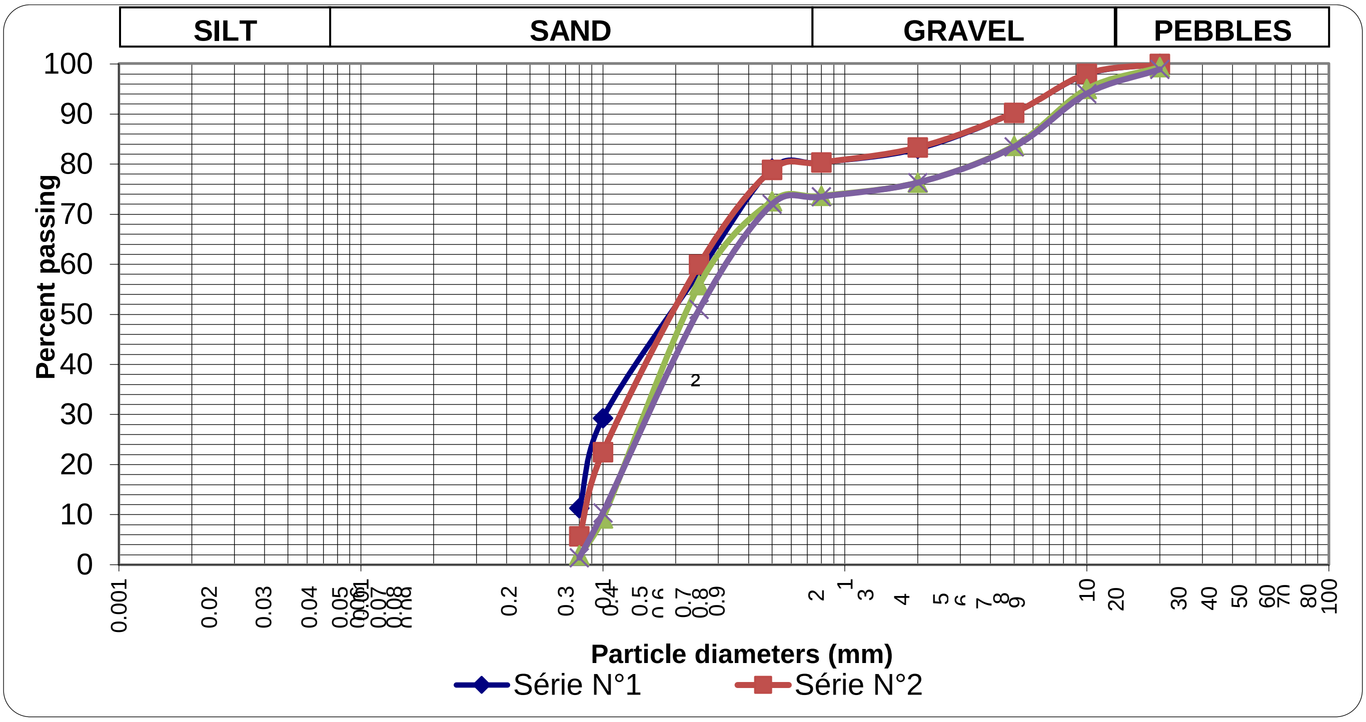


Figure 2: PK 23 NDB particle size

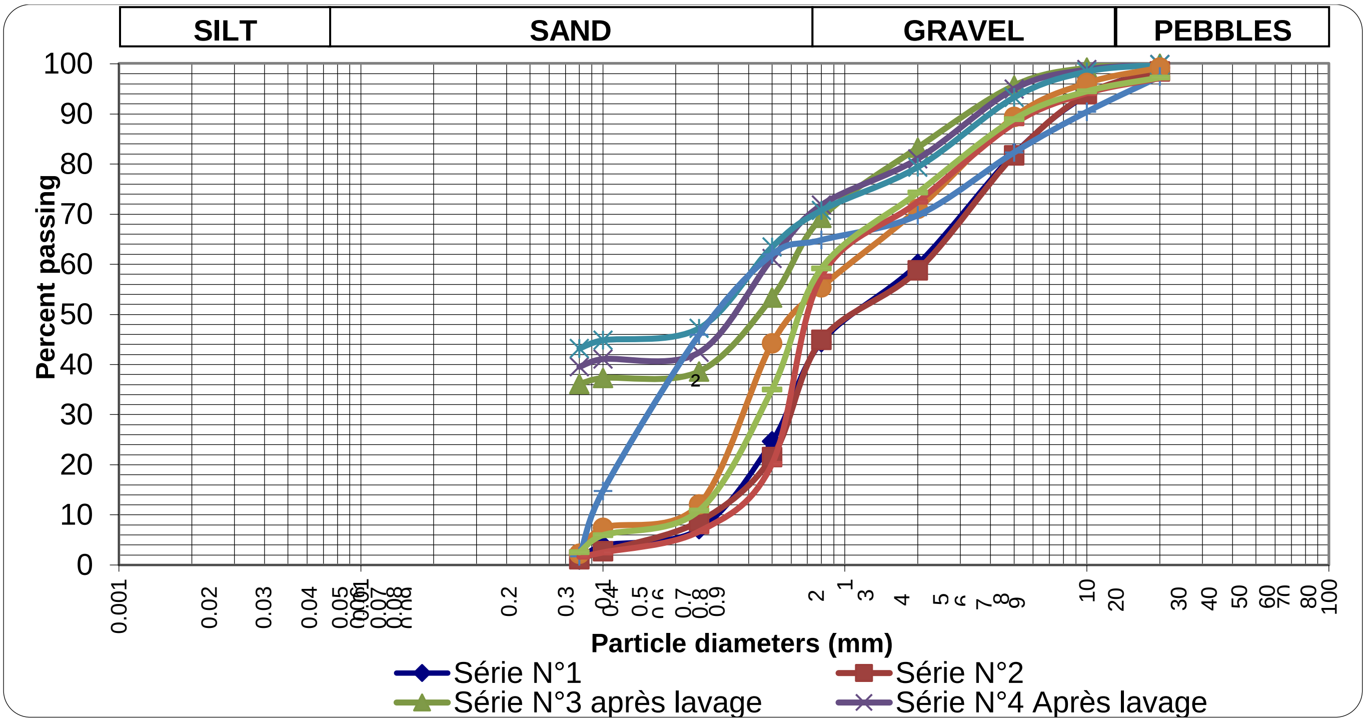


Figure 3: PK 35 AKJT grain size

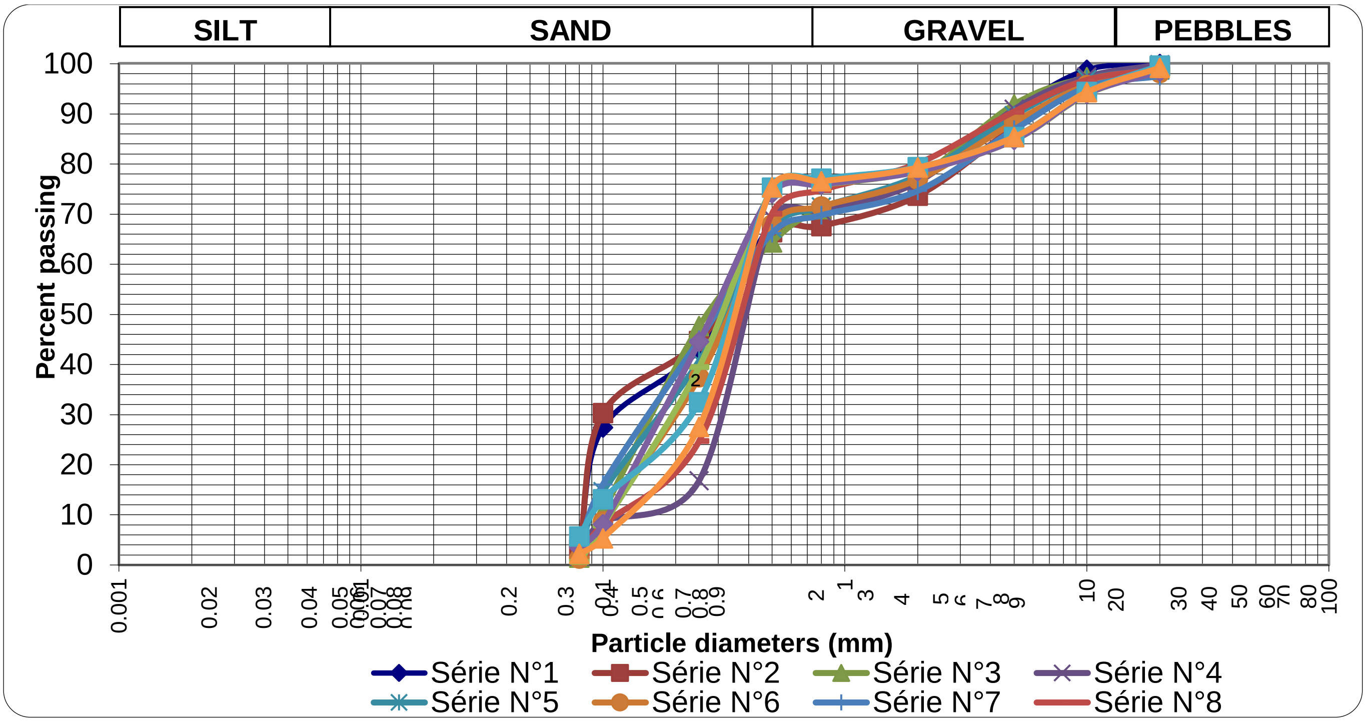


Figure 4: PK 23 Rosso grain size

Cement treatment of raw materials

The CBR test was carried out on the samples of raw materials to check their possible use in base layers without any treatment.

The results obtained are presented in Table 2 below:

Table 2: Results of Raw CBRs

PK 35 AKJT	CBR	PK 23 Rosso	CBR	PK 23 NDB	CBR
Series N°1	44	Series N°1	20	Series N°1	39
Series N°2	37	Series N°2	18	Series N°2	2 4
Series N°3	35	Series N°3	47	Series N°3	32
Series N°4	36	Series N°4	32	Series N°4	35
Series N°5	16	Series N°5	26	Series N°5	34
Series N°6	32	Series N°6	51	Series N°6	24
Series N°7	34	Series N°7	34	Series N°7	20
Series N°8	44	Series N°8	51	Series N°8	34
Series N°9	37	Series N°9	34	Series N°9	32

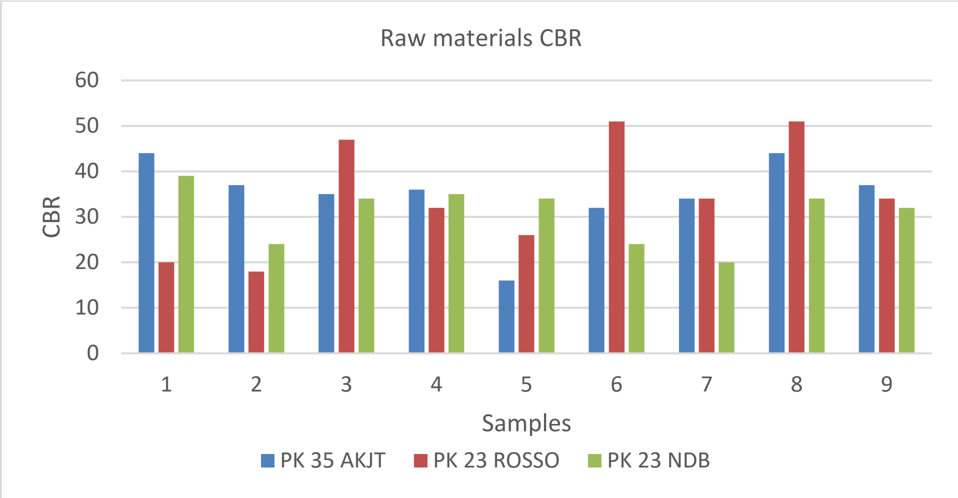


Figure 5: Values of raw materials CBR

Subsequently, the average CBR value for each quarry was compared to the Technical Guide for the Construction of Embankments (TGCE) requirements to check its suitability for use in a pavement structures.

According to the specifications of road construction standards, the studied materials are usable only in sub-base layer because their CBR is higher than 30 but lower than 60, minimum value required for a use in base layer if the CBR obtained, after treatment with cement, is higher or equal to 160.

Thus, we have tried to innovate by treating the materials studied with different percentages of cement, which goes against the prevailing standards and practices. The results obtained are surprising, very interesting and even seem to call into question the prevailing specifications and standards related to the CBR.

Indeed, with a 3% cement treatment, the average CBRs of the PK 35 AKJT and PK 23 NDB quarry samples reached 160 and 163 respectively, thus making it possible to consider their use in the base layer. This is when the current standards limit their use to the foundation layer due to their low bearing capacity.

With regard to the PK 23 Rosso quarry, the CBR obtained after treatment with 3% cement (139) always remained below 160, which limits its use to the foundation layer.

With the CBR value of the PK 35 AKJT quarry (160) being borderline, we increased the cement dosage to 3.5%. The result obtained was encouraging because the CBR increased to 171. An economic simulation would easily lead to the conclusion that the gain made on the thickness of the pavement is greater than the additional cost incurred from a (0.5%) increase in cement.

Table 3: CBR results of 3% Cement enhanced samples

PK 23 NDB	CBR	Medium CBR	PK 23 Rosso	CBR	Medium CBR	PK35 AKJT	CBR	Medium CBR
Series N°1	171	163	Series N°1	146	139	Series N°1	192	160
Series N°2	200		Series N°2	119		Series N°2	146	
Series N°3	124		Series N°3	241		Series N°3	148	
Series N°4	174		Series N°4	121		Series N°4	136	
Series N°5	185		Series N°5	66		Series N°5	176	
Series N°6	154							
Series N°7	157							
Series N°8	165							
Series N°9	142							
Series N° 10	157							
Series N° 11	163							

We thus observed that after treatment with 3% cement, the average CBRs of the PK 23 NDB and PK 23 Rosso quarries sample increased in relative value by 300%.
But it is the samples from the PK35 AKJT quarry that recorded the best improvement in lift, thus reaching a value of 400%.
The following histograms clearly show us the significant increase in CBR after the treatment of materials with cement.

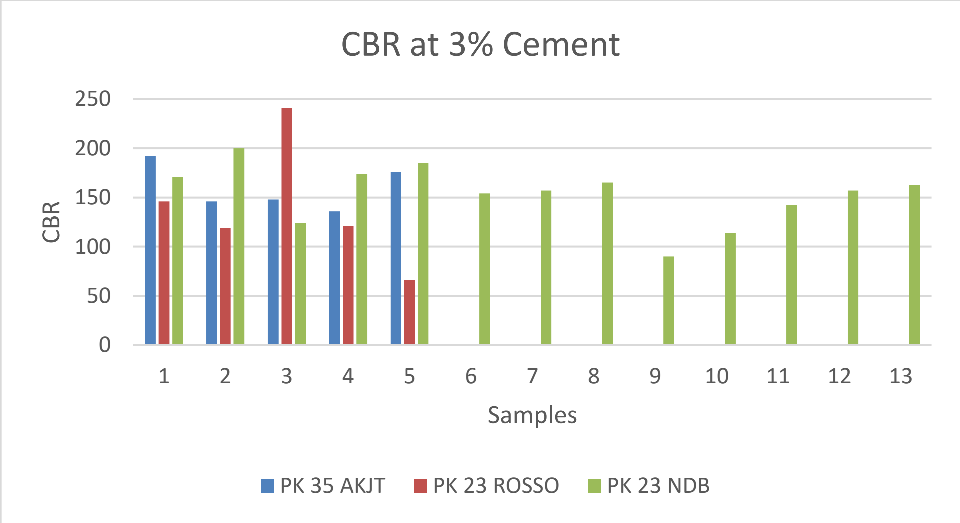


Figure 6: CBR values at 3% cement

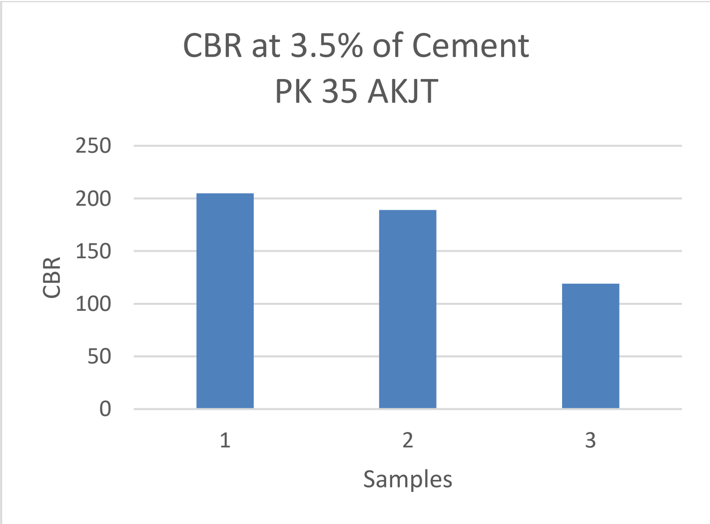


Figure 7: CBR values at 3.5% cement

Conclusion

The 3% cement treatment of materials from the PK 35 AKJT and PK 23 NDB samples has improved their low bearing capacity, with average CBRs reaching 160 and 163 respectively, thus making it possible to consider their use as a base layer whereas the prevailing standards limit them to the foundation layer only.
On the other hand, for the PK 23 Rosso quarry, its bearing capacity remains low despite treatment with a dosage of 3% cement (CBR obtained equal to 139) and thus its use under this treatment will be limited to the foundation layer.

An increase in the cement dosage (from 3% to 3.5%) has made it possible to further improve the bearing capacity of the material from the PK 35 AKJT quarry, bringing its CBR to 171, which could lead to a gain in the savings made on the thickness of the pavement. This is because an increase in CBR results in a decrease in the thickness of the pavement.

This study confirms that the low bearing materials reserved for the sub-base of road projects can be used in the base layer after a cement treatment with dosages to be determined experimentally to obtain a CBR in accordance with the requirements of the current prevailing standards.

In addition, this study also raises a question about the relevance of current standards and specifications which are largely imported from the Global North when used in the particular context of a country like Mauritania with very different climatic and economic conditions. Therefore, we would like to appeal to local geotechnicians to work on the development of standards better suited to the local environment and context.

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