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RESEARCH ARTICLE

CORRELATIVE STUDY OF YOUNG'S MODULUS AND THE CBR OF RUN-OF-MINE SHELLS FROM MAURITANIAN QUARRIES

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ABSTRACT

Like the countries of the sub-region, the Mauritanian context is characterized by the absence of a local road design guide. Thus, classic methods developed elsewhere and based on parameters whose relevance is debatable, given the climatic context, are used. This research, a pioneer in geotechnical engineeringin Mauritania, aims to determine the correlation between the CBR and the Young's modulus of the two most commonly used shell quarries, PK23 NDB and PK35 AKJT, in order to determine objective geotechnical characteristics for road design. The geotechnical characteristics of the materials studied were determined in the laboratory after a cement treatment with a dosage of 3 to 3.5%. Thereafter statistical analysis of the experimental results via computer tools like Python, Numpy, Pandas, Matplotlib, Scipy and Sklearn, showed that the widely used equation "E= 5*CBR" relation is not always appropriate in the local context and it varies between quarries. For the PK23 NDB quarry, the correlative relationship is established as follows: E = 3,55*CBR while for the PK35 AKJT quarry it is given by this equation: E = 3,76*CBR. The results obtained in this study are an important step towards the development of a pavement design guide that is appropriate to the local context, and they reinforce the idea of using these materials in pavement base layers.

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INTRODUCTION

Run-of-mine shell quarries are abundantly available in Mauritania, especially in the areas surrounding the Capital city Nouakchott. The national road network is made up of about 12,253 km of roads, a large part of which is experiencing advanced levels of deterioration. The annual motor vehicle fatality rates are very high compared to many African countries despite the significant funds devoted to road maintenance, which raises some legitimate questions about the quality of road infrastructure (World Bank Database). Indeed, it has been established that most of the degradation originates from: poor characterization of the materials, implementation shortcomings, and the use of sizing methods not appropriate to the local context. The CBR and Young's Modulus are important parameters for determining the thickness a pavement and their overvaluation leads to pavement under-dimensioning, hence a reduction in its thickness, which leads to early degradation.

MATERIALS AND METHOD

The origin of the study materials: The materials of the study are raw shells often used in Nouakchott given their quantity and strategic locations. They come from two sampling sites which are the PK23 on the RN3 national road linking Nouakchott to Nouadhibou and the PK35 quarry on the Nouakchott – Akjoujt road. These two quarries are currently used in the largest road projects already completed or in progress. Several investigation campaigns have made it possible to collect the quantity of materials necessary for the experimental phase of this research work. The materials were then transported to Senegal and more precisely to the Geotechnical Laboratory at the Polytechnic School of Thiès, to be subjected to an experimental program.

Methodology

The samples were made in split CBR molds with materials enhanced with cement with a CBR exceeding 160. Then, they were tested in simple compression with a loading speed of 1.27 mm/min using a CBR press after three days of curing in air and four days of soaking in water. The experimental results were used to plot all the stress-strain curves of the series of samples and then determine the different values of the Young's modulus which represents the slope of the elastic part of the stress-strain curve (Figures 1 and 2). Subsequently, a statistical treatment of the different values of CBR and Young's modulus made it possible to establish the relative correlates between these two variables. A linear approximation of trend lines and linear regression coefficients was then performed using the ordinary least squares method (Blanchelle, 2013; Matloff, 2020). Statistical analysis and modeling were performed in Python and R software using *Scipy, sklearn, Matplotlib, Pandas libraries* and the *lm function of the R stats package* (UNPINGCO, 2016).

Determination of the CBR of materials treated with Cement: The CBR of a material is influenced by several parameters, which is why its correlations with other physico-mechanical parameters have been the subject of numerous studies (Fall, Usluogullari, 2007; Ybpbcbm). This research is mainly concerned with determining the correlative relationships between CBR and Young's modulus. The results obtained are summarized in Table 1 below.

Table 1. Summary of CBRs of cement-enhanced material

PK 23 NDB	CBR	Medium CBR	PK35 AKJT	CBR	Medium CBR
Series N°1	171		Series N°1	205	
Series N°2	200	163	Series N°2	189	
Series N°3	124		Series N°3	119	
Series N°4	174				
Series N°5	185				
Series N°6	154				171
Series N°7	157				
Series N°8	165				
Series N°9	142				
Series N°10	157				
Series N°11	163				

Determination of Young's modulus: Young's modulus is determined from a simple compression test using a press with the same speed as the CBR test. The samples tested were compacted with the optimum water content of the Modified Proctor test with the same compaction energy. The experimental results made it possible to plot the stress-strain curves shown in Figures 1 and 2.

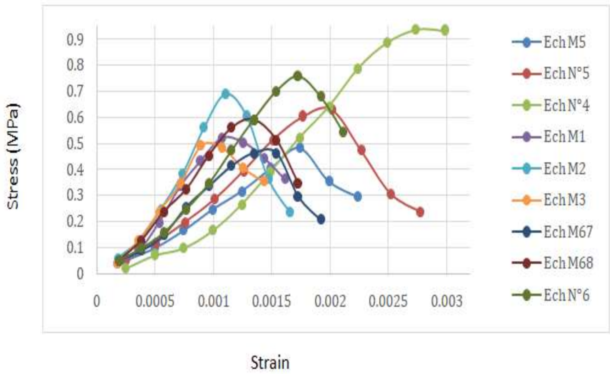

Figure 1. PK23 NDB Stress-Strain Curves

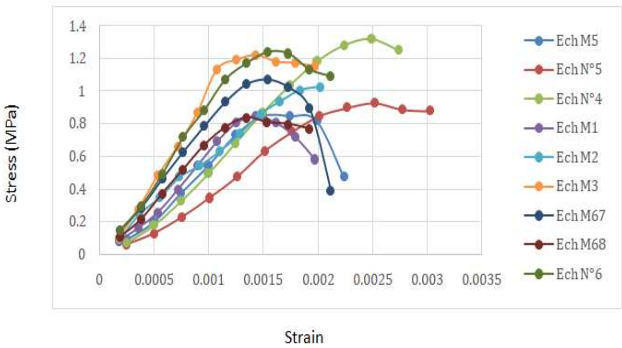

Figure 2. PK35 AKJT Stress-Strain Curves

After plotting the stress-strain curves, we subject the first portions, where the behavior is considered to be elastic, to statistical processing through linear regression as illustrated in Figures 3 and 4. The trend curves obtained by linear regression made it possible to determine the Young's moduli presented in Table 2 below.

Correlative study between Young's modulus and CBR: We sought to determine the correlative relationship between the lift expressed by the CBR and the modulus of elasticity E of a natural material treated with cement.

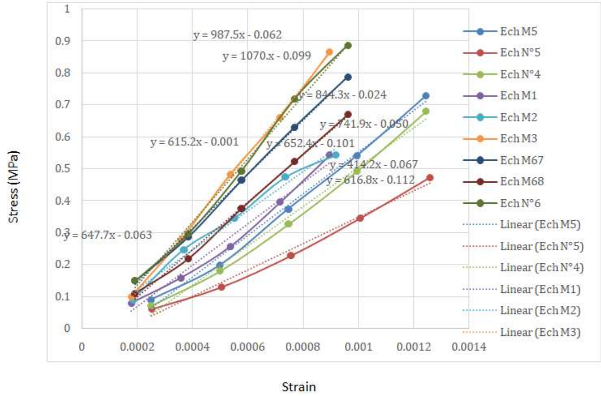

Figure 3. PK35 AKJT trend curves

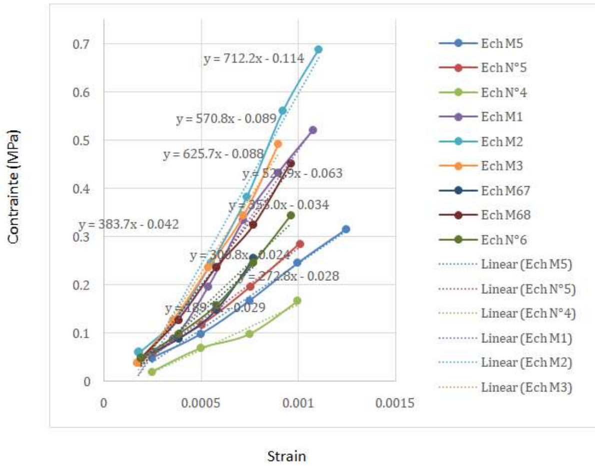

Figure 4. PK23 NDB trend curves

Table 2. Summary of Young's Modulus of Cement-Enhanced Material

Young's moduli of the PK23 NDB quarry	Young's moduli of the PK35 AKJT quarry
712.26	987.58
570.87	1070.4
625.76	844.31
521.94	741.97
383.78	652.42
353.07	414.2
300.88	616.83
272.83	615.21
189.79	647.72

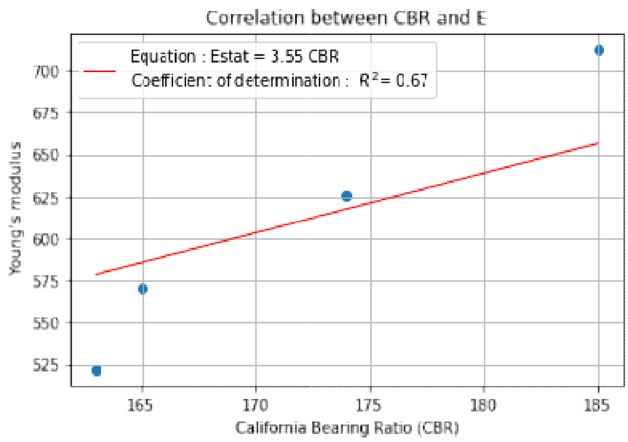

Figure 5. Correlation between Young's modulus and CBR for the PK23 NDB quarry

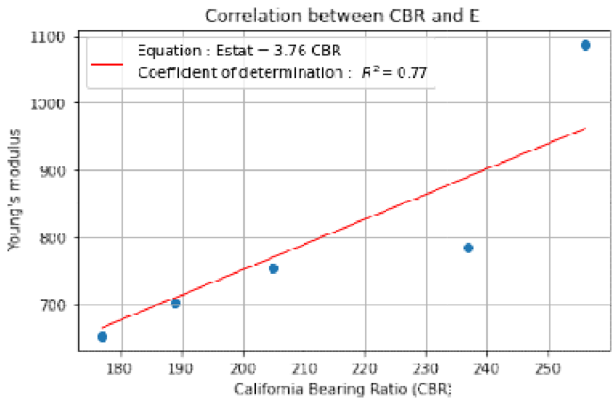

Figure 6. Correlation between Young's modulus and CBR of the PK35 AKJT quarry

Thus, from the CBR of a soil, which is a parameter that can quite easily be determined in the laboratory, we can estimate its Young's modulus with acceptable precision. Data analysis and modeling were performed with Python programming language and R software. The libraries (libraries) of Python-Numpy made it possible to do numerical calculations, mathematical operations and matrix products. Pandas software was used to export, collect and manipulate the data, and Matplotlib was used for their visualization. Finally, the computer tools Scipy and Sklearn allowed the statistical modeling of the data and more precisely the Differential Statistics. The value of the correlation coefficient provides information on the functional relationship between the parameters studied. A coefficient close to 1 reflects a strong correlation between the parameters studied. For the PK23 NDB quarry, the regression line is shown in Figure 5 below. The correlation coefficient is equal to 0.82 which means that there is good relationship between CBR and Young's modulus. Thus, for the quarry PK23 NDB, we conclude that the equation E = 3,55*CBR gives a good correlation between the modulus of elasticity and the CBR. For the quarry PK35 AKJT, the regression line is represented in the following figure 6. The correlation coefficient is equal to 0.88 which means that there is good relationship between CBR and Young's modulus. Thus, for the quarry PK35 AKJT, we conclude that the equation E = 3,76*CBR gives a good correlation between the modulus of elasticity and the CBR.

CONCLUSION

Throughout this study, we tried to find a correlation between the Young's modulus and the CBR of run-of-mine shells coming from Mauritanian quarries. The formulas obtained are similar to those used in practice but differ from one quarry to another. The correlation coefficients obtained confirm that there is a good functional relationship between the Young's modulus and the CBR, and the formulas that we established can, thus, be used with confidence. In addition to the time saved in the determination of the Young's modulus, these new correlations make it possible to refine Road Design guides due to a better precision in the estimation of the parameters. Furthermore, as demonstrated by previous studies on laterites, it is also important to consider each quarry separately and to avoid the use and generalization of a single correlation on multiple quarries.

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