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POISSON'S RATIO IN THE CHOICE OF THICKNESSES OF LAYERS OF A PAVEMENT STRUCTURE IN LATERITIC NATURAL GRAVE

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Abstract - ***This study is part of optimizing quality and cost of the design of a pavement structure in Lateritic Natural Grave (LNG). It focuses on the problem of taking into account the influence of Poisson's ratio assigned to the material constitution of a roadway, especially for rational methods of design, in the elastic range. In order to initiate the development of a local standard for this parameter, we carry out an experimental characterization of Poisson's ratio of LNG from the unconfined compression test on the materials used in the construction project of a 7km stretch of road Bafoussam in Cameroon. Depending on the extreme values (0.25 and 0.50) can take Poisson's ratio for different materials, we notice a change in thickness of the layer of pavement that LNG is about 3cm. Knowing the value of Poisson's ratio of the LNG will prevent a bad design can be an oversized (to earnings) or a undersizing (very rapid onset of degradation). In the case of our project, this is an under-sizing of 7cm of foundation's layer.***

Keywords— Roadway, Natural Gravely Laterite, Poisson's ratio, unconfined compression, design.

I. INTRODUCTION

In the pavement design by the method Alize 3 [1], the parameters that influence the choice of a structure from another is the deflection (vertical strain), the tensile and compression, the transverse strains and longitudinal in the different layers. Thus for an optimal design, we fix a maximum deflection, we calculate the stresses and strains do not exceed allowable (stresses and strains which obviously depend on the nature of the material used in the different layers), then we vary the number layers and the thicknesses of these layers until we have the optimal structure in cost and safety searched.

However the choice of some parameters (particularly Poisson's ratio) is not unanimous in all geotechnical laboratories of Cameroon. Indeed, studies of experimental determination of this parameter has not yet been made for local materials, design offices are generally based on the values given in pavement design guide (values generally vary between 0, 25 and 0.5). Thus, the dimensioning of the same pavement, we get very often a multitude of variations by different design offices (variants that differ because of the value of Poisson's ratio assigned materials).

In Cameroon, as indeed in all countries of the tropical zone, the material for road construction reference remains the laterite ([2], [3]). An impressive work has been performed on this material. Most of the results consist of simple physical characterizations. Only those characteristics help define the identity cards of lateritic gravel for applications in the road. This is the case of semi-empirical design methods (CBR method, for example). However, with regard to the rational design, the determination of the mechanical characteristics of materials, including elastic parameters is necessary.

Due to the complexity and variety of materials used, the study and design of flexible pavements have long kept an empirical character. More sophisticated methods have been developed, which improve the inclusion of more realistic mechanical behavior of these materials, obtained in laboratory tests.

II. METHODOLOGY

In this study, we study two samples of the LNG project to build the stretch of highway (crossroads auberge-military camp) in the city of Bafoussam in Cameroon [4]. This project is a 5km long and 7m wide.

* Sample 1: Grave reddish lateritic clay taken from platform at KP 25 + 780 at depth from 0.00 to 1.05 m

* Sample 2: Grave reddish lateritic clay loan at KP 47 + 320 collected at depth from 0.15 to 1.50 m

We firstly present the procedure to determine experimentally the Poisson's ratio of LNG and then see its influence in the design of a pavement structure.

The tests for determining the mechanical properties of LNG (granulometric analysis, the Proctor, the CBR) were made following the French standards ([5], [6], [7]).

Laboratory tests simulating traffic loading are introduced to characterize the response behaviour of the GLN and the subgrade. These are the cyclic triaxial tests, torsion tests on hollow cylinder and simple compression tests.

We present in this study only the simple compression test since it is one that was used for determining the mechanical properties of materials studied.

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This test involves subjecting a test tube of cylindrical shape with two opposite axial forces by placing it between the plates of a press (Figure 1).

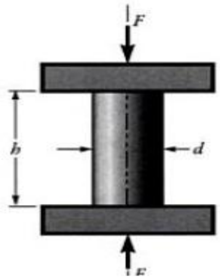
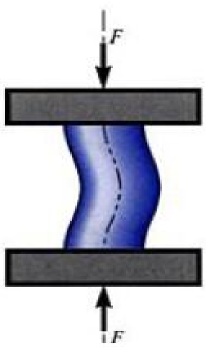
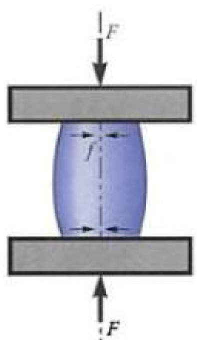


Fig. 1 Simple compression of a cylindrical specimen

Although the test seems fairly simple, its realization has no less than two problems that limit its use and operation of experimental results. If the specimen is too high compared to its diameter, there's risk of developing an elastic instability: the buckling (Figure 2a). In material strength, we show that the buckling load is a function only of the specimen geometry and Young's modulus of the material used. To avoid this problem, the ratio h/d is maintained substantially equal to 2.

The second difficulty comes from the friction that occurs between the bearing faces of the specimen and the plates of the testing machine. This friction is opposed to the increase in diameter of the test piece when its height decreases. This results in heterogeneous strains which give the tube a barrel-shaped (Figure 2b).





a) Buckling **b) Form of roll**

Fig. 2 Difficulties encountered in the simple compression test

The specimens tested are cylindrical (80mm diameter, 160mm in height for a mass of about 1900g). The ideal would be to collect samples of material directly on site by coring, but this technique is difficult to use for unbound, which are unconsolidated material. The gravel material being very compact and the specimen extracted from the core barrel can not be easily cut to a length determined so as to have a flat surface finish.

Making and implementation of test operations are important to the quality of test results. They are made using molds Duriez and press concrete. They are compacted in a static manner for 5min under a pressure of about 60 KN.

They are made with a density and water content similar to that of OMP (Optimum Modified Proctor). The figure below shows the system of sample preparation (Figure 3). For both samples, eleven samples were made.

a) Compression of the sample **b) Extraction of the sample**

c) Specimens of GLN

Fig. 3 Specimen preparation at "SOIL AND WATER"

The determination of Poisson's ratio is doing in the elastic domain, it is indispensable to determine the field for samples that are the subject of our study. Remember, this is the linear part of the stress-strain curve of the sample.

This test conducted at the National Laboratory of Civil Engineering (LABOGENIE), required the use of triaxial apparatus under a lateral pressure $\sigma_2 = \sigma_3 = 1$bar. The specimens of slenderness substantially equal to 2 had the following dimensions: 70mm for diameter and 149.3mm of height.

Fig. 4 Realization of the triaxial test at LABOGENIE

In this apparatus, two comparators one giving the variation in height of the specimen and the other vertical σ1 pressure associated with this height variation allowed us to collect data to plot the stress-strain curve of the sample of LNG.

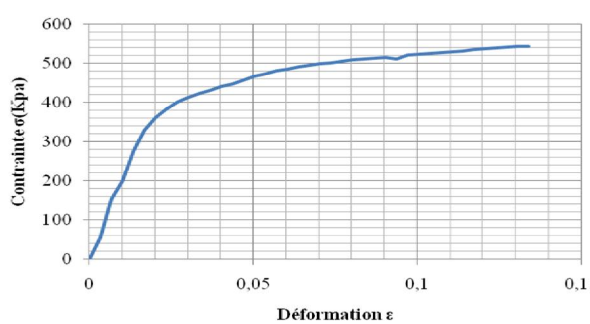


Fig. 5 Law stress-strain behavior of the GLN

Thus, we conclude that the elastic range for this sample ranges from $\varepsilon = 0$ to $\varepsilon = 0.02$. It is in this area that we will perform simple compression specimens LNG of our two samples.

However, given the fact that the unconfined compression test is no lateral pressure, we can not reach the strain $\varepsilon = 0.02$. Indeed, our samples will be destroyed long before.

Once known the elastic range in which we work, we perform the compression test specimens to the press for concrete electronic speed 1mm/min. During this compression, for variations in height (Δh) of 0.05 mm, we note the change in diameter (ΔD) of the samples. To do this, we go on magnetic three comparators precision 0.01 mm which allow us to have the desired values. The first comparator gives us the height variation, the second and third give the swelling of the sample (confer Figure 6).

Fig. 6: of the unconfined compression test to "SOIL AND WATER"

Poisson's ratio of a material is defined experimentally as the linear radial strains curves and axial strains of the material for small strains.

Data from the unconfined compression test done, we deduce the axial and radial strain of each specimen, then we draw the curves of the two strains and the right corresponding to the linear portion of this curve for small strains. And calculating the slope of this line, we obtain the value of Poisson's ratio of each specimen.

The fact that specimens are not made up homogeneously (same granulometry and same compactness), Poisson's ratio which we will retain will be the average Poisson's ratios of these samples.

III.RESULTS

The determination of Poisson's ratio of GLN is based on the results obtained in simple compression specimens of the materials concerned.

Thus, for samples 1 and 2, we draw the curve εx ($\Delta D/D0$) as a function of εz ($\Delta h/h0$) and we deduce the Poisson ratio presented in the tables I and II.

Sample 1

TABLE I VALUES OF POISSON'S RATIO FOR SAMPLES 1

N° Specimen	Poisson's Ratio
1. (H0=162,60mm; D0=80,67mm; γ_H = 2.205T/m^3)	0.399
2. (H0=162,98mm; D0=81,08mm ; γ_H=2.192T/m^3)	0.45
3. (H0=161,55mm; D0=80,78mm γ_H =2.205T/m^3)	0.30
4. (H0=160,81mm; D0=80,45mm ; γ_H =2.209T/m^3)	0.24
5. (H0=161,19mm; D0=80,88mm γ_H =2.216T/m^3)	0.25
6. (H0=162,99mm; D0=81,22mm ; γ_H =2.192T/m^3)	0.22
7. (H0=161,80mm; D0=80,13mm ; γ_H =2.196T/m^3)	0.35
8. (H0=162,59mm; D0=81,05mm ; γ_H =2.185T/m^3)	0.23
9. (H0=160,97mm; D0=80,36mm ; γ_H =2.219T/m^3)	0.35
10. (H0=162,75mm; D0=80,11mm ; γ_H =2.195T/m^3)	0.4
11. (H0=160,60mm; D0=80,24mm ; γ_H =2.146T/m^3)	0.4

Thus, for sample 1, the average Poisson's ratios is :

$$\overline{\nu}_1 = \frac{\sum_i^{11} \nu_i}{11} = 0.326$$

The variance of this sample is :

$$Var(\nu) = \frac{\sum^{11} (\nu_i - \overline{\nu}_1)^2}{11} = 0.0061$$

Its standard deviation is :

$$\sigma(\overline{\nu}) = \sqrt{Var(\nu)} = 0.0781$$

We take as the confidence interval range

$$\overline{\nu}_1 - \sigma(\overline{\nu}) \leq \nu_i \leq \overline{\nu}_1 + \sigma(\overline{\nu})$$

Then $0.248 \leq \nu_i \leq 0.404$.

Then removing all values of ν_1 that are not in this interval and by averaging the rest of values, we finally find $\nu_1 = 0.35$

Sample 2

TABLE III VALUES OF POISSON'S RATIO FOR SAMPLES 2

N° Specimen	Poisson's Ratio
1. (H0=161,00mm; D0=80,56mm ; γ_H =2.33T/m^3)	0.2
2. (H0=162,12mm; D0=80,89mm ; γ_H =2.338T/m^3)	0.17
3. (H0=161,47mm; D0=80,4mm ; γ_H =2.33T/m^3)	0.4
4. (H0=160,64mm; D0=80,2mm ; γ_H =2.354T/m^3)	0.4
5. (H0=160,67mm; D0=80,78mm ; γ_H =2.347T/m^3)	0.366
6. (H0=158,25mm; D0=80,47mm ; γ_H =2.384T/m^3)	0.42
7. (H0=162,60mm; D0=80,89mm ; γ_H =2.32T/m^3)	0.33
8. (H0=159,84mm; D0=80,78mm ; γ_H =2.39T/m^3)	0.4
9. (H0=159,40mm; D0=80,24mm ; γ_H =2.373T/m^3)	0.44
10. (H0=162,34mm; D0=80,47mm ; γ_H =2.336T/m^3)	0.43
11. (H0=160,63mm; D0=80,76mm ; γ_H =2.348T/m^3)	0.45

Thus, for sample 2, the average Poisson's ratios is :

$$\bar{\nu}_2 = \frac{\sum_i^{11} \nu_i}{11} = 0.364$$

The variance of this sample is :

$$Var(\nu) = \frac{\sum^{11} (\nu_i - \bar{\nu}_2)^2}{11} = 0.0082$$

Its standard deviation is :

$$\sigma(\bar{\nu}) = \sqrt{Var(\nu)} = 0.09$$

We take as the confidence interval range

$$\bar{\nu}_2 - \sigma(\bar{\nu}) \le \nu_i \le \bar{\nu}_2 + \sigma(\bar{\nu})$$

Then $0.274 \le \nu_i \le 0.454$

Then removing all values of ν_i that are not in this interval and by averaging the rest of values, we finally find $\nu_2 = 0.4$

These results show that these samples, although both of LNG, do not have the same Poisson's ratio. This can be explained by the fact that both samples were not collected in one place and have not necessarily received the same compaction energy. There is however a difference of 0.28 between the extreme values of Poisson's ratio. Reflecting the random behavior of untreated materials and justifies the clip we did. We also note that the Poisson ratio of the platform (sample 1; $\nu = 0.35$) is smaller than that of the loan (sample 2, $\nu = 0.4$).

However, the values obtained and proposed are higher than those currently used and recommended by the LABOGENIE in Cameroon which is 0.25 whatever the sampling site.

In the following we will consider a pavement structure that has been a project carried out by the laboratory "SOIL AND WATER", in the case study on the building of roads Bafoussam (crossroads auberge-military camp), structure to which we vary only the Poisson's ratio of foundation's layer, from 0.25 to 0.5. Then we will see any value between these extreme values of ν is varied the thickness of this layer to obtain almost the same as that imposed deflection.

In this project, the traffic study conducted by the Design Office "CERBAT" resulted in the adoption of traffic T3 for a lifetime of 15 years. Either in a cumulative traffic axle of 13 tonnes during the lifetime calculated by adding two-way traffic between $1.5\ 10^6 - 4\ 10^6$, which allows us to calculate the allowable strain of the subgrade.

Let :

$\varepsilon_{z,ad} = 0.012\ (NE)^{-0,222} = 0.012(4.10^6)^{-0,222} = \varepsilon_{z,ad} = 4\ 10^{-4}$ mm

The final permissible deflection imposed, measured on the pavement, for a traffic T3 is 60 mm / 100

The basic solution proposed by SOIL AND WATER is :

* Scarification of 35 cm, and then recycling the current layer (coating + base layer) layer of foundation in concrete soil or LNG of 25cm

* 12cm of Bitumen Grave (BG) in base layer

* 5cm of Bituminous Concrete (BC) surfacing

BC : H_1 = 5cm ; E_1 = 25000bars ; $\nu_1 = 0.45$
BG : H_2 = 12cm ; E_2 = 40000bars ; $\nu_2 = 0.45$
LNG : H_3 = 25cm ; E_3 = 1500bars ; $\nu_3 = 0.25$
LNG : $H_4 = \infty$; E_4 = 750bars ; $\nu_4 = 0.25$

Fig. 7 Pavement structure of roads proposed by "SOIL AND WATER" (crossroads auberge-military camp)

To vary the Poisson ratio, we proceed layer by layer of LNG and we consider all the other parameters mentioned in Figure 7 as unchanged.

Thus, we have the following results for the deflection of 60mm/100 shown in Figure below:

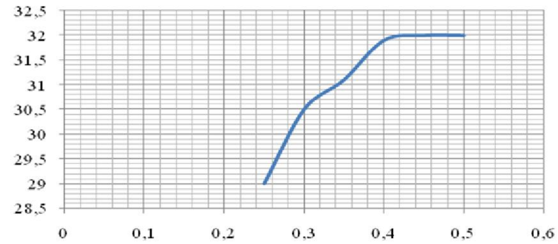


Fig. 8 Height of the layer of GLN according to the Poisson's ratio

Note that the thickness of the pavement layer increases with Poisson's ratio. So we leave 29cm for $\nu = 0.25$ to 32cm for $\nu = 0.5$, a variation in height of 3cm. This corresponds to a volume of $1050m^3$.

Considering the LNG for the value of Poisson's ratio obtained above ($\nu = 0.4$), we should have a layer thickness of LNG substantially equal to 32cm instead of 25cm implemented. This difference of 7cm and less for this project (under-sizing of the structure) greatly reduces the life of the road. This has several consequences:

- The maximum deflection of 60mm/100 will not be respected;

- The rapid degradation in this case the ruts;

- Safety and user comfort are threatened;

- Short-term reinvestment

IV. CONCLUSION

In this study, there was talk of seeing the influence of the random choice of Poisson's ratio of the constituent materials of a pavement structure on the design of that structure in order to attract attention of policy makers on the importance of established experimentally for a standard local materials.

Then we presented the characterization and implementation of the unconfined compression test for two samples of lateritic Grave to derive the experimental values of Poisson's ratio. Finally, we showed the influence of the variation of Poisson's ratio in the choice of layer thicknesses and therefore the cost of conducting a pavement structure.

It is therefore apparent from this study that the Poisson ratio of materials in the elastic range is a constant for each material generally between 0.25 and 0.5. However, although the range of variation does not seem quite significant overestimation or underestimation of Poisson's ratio would lead to oversizing or undersizing of a pavement structure that would not go unnoticed on the quality and cost the realization of this pavement structure. Note that for the lateritic Grave, after tests at “SOIL AND WATER”, we obtained as Poisson's ratio $\nu = 0.35$ for the sample in platform and $\nu = 0.4$ for the borrowing.

The borrow material being foundation layer of roadway was undervalued by about 7cm which is not negligible and significantly reduce the life of the road.

This study has still a limit as the unconfined compression test does not reflect the actual operating conditions of a pavement structure. It would be interesting to verify the results obtained from the triaxial test.

Perspective, will be discussed to study the effect of varying the water content of the Poisson's ratio and to consider not only the deflection as a reference but also stresses and strains allowable to choose the net thickness for better optimization in quality and cost of the pavement structure.

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