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Thickness Sensitivities for the Surface Course of Pavement based on the Variation of the Poisson Coefficient of Bituminous Concrete

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***Abstract*—The laboratory tests that allow to evaluate the Poisson coefficient of the pavement materials are costly in tropical countries. In the absence of these tests, a finite number of Poisson coefficient is often prescribed to design the pavements. This paper consists of studying the influence of these prescribed values in the structural design of the pavement, especially, on the thickness of the surface course. For this, we show that the values of Poisson coefficient taken between 0.25 and 0.45 are adapted for the flexible pavements because they do not affect the thickness of the surface course. The usefulness of the variation of the Poisson coefficient is illustrated with local data and the results show that the thickness of the bituminous and semi-rigid pavements can change when the prescribed values change.**

Keywords—Pavement structures; French method; Poisson coefficient; Bituminous concrete

I. INTRODUCTION

Several techniques ([1], [3], [5]) have been used to estimate the thickness of the road pavement and some relationship have been established between mechanical parameters and the quality of pavement layer material ([6], [7], [9]). Among these parameters, the Poisson coefficient has been characterized for the lateritic natural grave detailed in [13]. In this work, the behavior of the pavement was studied in laboratory to evaluate the influence of the Poisson coefficient in pavement design. But, this procedure is costly and not always practicable in tropical countries due to the absence of the appropriate infrastructures and the change of material properties.

In Cameroon, the values 0.25 and 0.35 are recommended in ([14], [15], [16], [17], [18]) and another work [26] had prescribed the value 0.45 while guaranteed values to be used for bituminous concrete has been determined by Messi et al. in [1]. It means that the Poisson coefficient can change for the same type of pavement and this paper consists of studying the thickness sensitivities of the surface course under the change of the prescribed Poisson coefficient of bituminous concrete.

In this work, we first present the approach which analyzes the thickness sensitivities by applying the French method ([9], [20], [26]) on the local data. By changing the prescribed Poisson coefficient, we then examine this sensitivity, in order to show that the thickness of the surface course remains constant for the flexible pavements while it varies for semi-rigid and bituminous pavements. We conclude our study with a short summary and discussion.

II. OUR APPROACH

A. *Input parameters*

For this study, we use the materials to achieve our goal, namely 6 prescribed values of the Poisson coefficient (υ_{BC}) of the bituminous concrete :

- 3 recommended values : 0.25, 0.35 and 0.45 ([14], [15], [16], [17], [18], [26]) ;
- 3 calculated values : 0.36, 0.42 and 0.43 [1].

In addition, 3 types of pavement structures are analyzed :

- Type 1 : flexible pavement (table I) ;
- Type 2 : bituminous pavement (table I) ;
- Type 3 : semi-rigid pavement (table I).

TABLE I. YOUNG MODULUS AND POISSON COEFFICIENT

Type of Pavement	*Surface course*	*Base course*	*Subbase*
	Material	Material	Material
1	BC [a]	CG/ Ci [d]	NLG [e]
2	BC [a]	BG [b]	-
3	BC [a]	CeG [c]	-

[a] BC.: Bituminous concrete.
[b] BG : Bitumen gravel
[c] CeG : Cement grave
[d] CG : Crushed grave 0/31.5 – Ci : Cinder
[e] NLG : Natural laterite gravel.

The design of these pavements is done with the help of the software ALIZE 3 [19] taking into account the recommended values E and υ of [26] as it is showed in the table II.

TABLE II. YOUNG MODULUS AND POISSON COEFFICIENT

Materials	*BC*	*BG*	*CeG*	*CG/Ci*	*NLG*
E (MPa)	2 450	3 500	23 000	400	150
υ	υ_{BC}	0.35	0.25	0.35	0.35

Other parameters used in the French method are important in the pavement design, namely, the traffic and the subgrade parameter. Having the materials defined in the table II above, the additional parameters are showed in the tables III and IV below.

TABLE III. MECHANICAL CHARACTERISTIC OF THE SUBGRADE [5]

Layer	Category	E (MPa)	υ
Subgrade	S2	50	0.35
	S3	75	0.35
	S4	150	0.35

In this table, we denote by S2, S3, S4 the subgrade material with given *E* and υ.

TABLE IV. TRAFFIC CLASSES DEFINED IN TROPICAL COUNTRIES [5]

EN [a]	Traffic class	Equivalent number of vehicle per day
< $5x10^5$	T1	< 300
From $5x10^5$ to $1.5x10^6$	T2	300 to 1 000
From $1.5x10^6$ to $4x10^6$	T3	1 000 to 3 000
From $4x10^6$ to 10^7	T4	3 000 to 6 000

a. EN: Equivalent number of axles.

B. States of stress and strain

In continuum mechanics, the states of stress and strain at a point in cylindrical coordinates are determined by :

- σ_r, σ_t, σ_z : normal stresses ;
- τ_{tz}, τ_{rz}, τ_{rt} : shear stresses ;
- ε_r, ε_t, ε_z : linear strains ;
- δ_{tz}, δ_{rz}, δ_{rt} : angular strains.

With known Young modulus and Poisson coefficient given by the formulas:

$$E_i = \mu_i.(3.\lambda_i + \mu_i)/(\lambda_i + \mu_i) \qquad (1)$$

And

$$\upsilon_i = \lambda_i/(2.(\lambda_i + \mu_i)) \qquad (2)$$

We determine the Lame coefficients μ and λ. According to the model prescribed by Burmister [19], we have the following graphic :

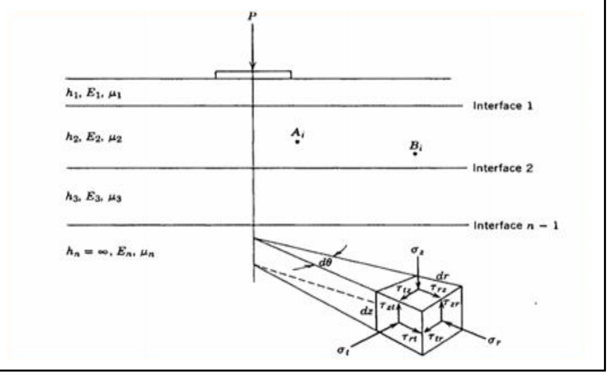

Fig. 1. State of stress at a point in cylindric coordinates

The calculus made with the software ALIZE 3 provides all the information related to the stress and strain tensors for each pavement structure. From these informations, the following values are chosen and compared to admissible values in order to design the pavement structure.

TABLE V. MAXIMUM STRESS OR STRAIN TO CONSIDERATE [5]

Material	Stress or strain (max)
Hydrocarbon materials	ε_t
Concrete and hydraulic binder treated materials	σ_t
Untreated soil and materials	ε_z

We note that the admissible values are found in [5].

TABLE VI. ADMISSIBLE DEFLECTION IN FUNCTION OF TRAFFIC CLASS [5]

Traffic class	Admissible deflections (in 1/100 mm)
T1	125
T2	90
T3	65
T4	40

C. Description of the procedure

To study the thickness sensitivities of the surface course under the change of the Poisson coefficient of the bituminous concrete, we follow the steps below :

- The pavement is designed firstly with the recommended values *E* and υ ;
- The Poisson coefficient of the bituminous concrete is modified subject to keep the thicknesses of the base course and subbase constant.

III. PRESENTATION OF THE RESULTS

A. Case study of the pavement n°1

In this case, we have the input data :

- Traffic class T1 ;
- Pavement materials and parameters (*E* and υ) (Table VII) ;
- Subgrade (soil) mechanical characteristics (*E* and υ) (Table VII).

TABLE VII. MECHANICAL CHARACTERISTICS OF THE PAVEMENT N°1

Layer	Material/ Category	E (MPa)	υ
Surface course	BC	2 450	υ_{BC}
Base course	CG/ Ci	400	0.35
Subgrade	S2	50	0.35

With these entries, the software ALIZE 3 gives us different thicknesses of the surface course as shown in the table VIII and the figure 2.

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TABLE VIII. THICKNESS OF THE SURFACE COURSE IN FUNCTION OF THE POISSON COEFFICIENT OF THE BITUMINOUS CONCRETE

υ_{BC}	Thickness (cm)
0.25	3
0.35	3
0.36	3
0.42	3
0.43	3
0.45	3

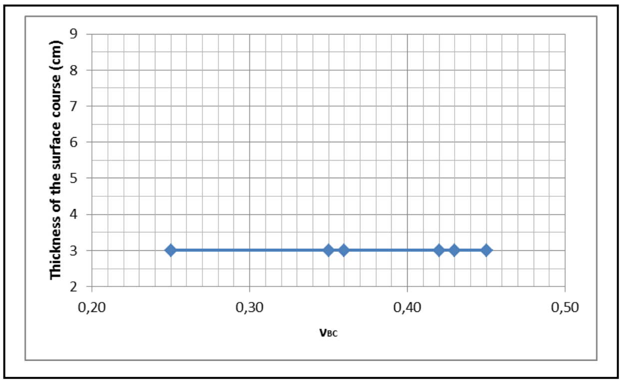

Fig. 2. Thickness of the surface course in function of the Poisson coefficient of the bituminous concrete for the pavement n°1

In the figure 2, we can see that the thickness of the surface course remains constant under the change of the prescribed Poisson coefficient of the bituminous concrete.

B. Application on a finite number of pavement structures

We applied the procedure described in the previous section to determine the thickness of the surface course under the change of the Poisson coefficient of the bituminous concrete for 36 pavement structures.

These pavement structures are presented in the table IX.

TABLE IX. DESCRIPTION OF THE PAVEMENT STRUCTURES

Type of Pavement	**Numbered pavement**	***Surface course***	***Base course***
		Material	Material
1	1	BC	CG/ Ci
	2	BC	CG/ Ci
	3	BC	CG/ Ci
	4	BC	CG/ Ci
	5	BC	CG/ Ci
	6	BC	CG/ Ci
	7	BC	CG/ Ci
	8	BC	CG/ Ci
	9	BC	CG/ Ci
	10	BC	CG/ Ci
	11	BC	CG/ Ci
	12	BC	CG/ Ci
2	13	BC	BG
	14	BC	BG
	15	BC	BG
	16	BC	BG
	17	BC	BG
	18	BC	BG
	19	BC	BG
	20	BC	BG
	21	BC	BG
	22	BC	BG
	23	BC	BG
	24	BC	BG
3	25	BC	CeG
	26	BC	CeG
	27	BC	CeG
	28	BC	CeG
	29	BC	CeG
	30	BC	CeG
	31	BC	CeG
	32	BC	CeG
	33	BC	CeG
	34	BC	CeG
	35	BC	CeG
	36	BC	CeG

Type of Pavement	**Numbered pavement**	***Subbase***	***Subgrade***	***Traffic class***
		Material	Category	
1	1	NLG	S2	T1
	2	NLG	S3	T1
	3	NLG	S4	T1
	4	NLG	S2	T2
	5	NLG	S3	T2
	6	NLG	S4	T2
	7	NLG	S2	T3
	8	NLG	S3	T3
	9	NLG	S4	T3
	10	NLG	S2	T4
	11	NLG	S3	T4
	12	NLG	S4	T4
2	13	-	S2	T1
	14	-	S3	T1
	15	-	S4	T1
	16	-	S2	T2
	17	-	S3	T2
	18	-	S4	T2
	19	-	S2	T3
	20	-	S3	T3
	21	-	S4	T3
	22	-	S2	T4
	23	-	S3	T4
	24	-	S4	T4
3	25	-	S2	T1
	26	-	S3	T1
	27	-	S4	T1
	28	-	S2	T2
	29	-	S3	T2
	30	-	S4	T2
	31	-	S2	T3
	32	-	S3	T3
	33	-	S4	T3
	34	-	S2	T4
	35	-	S3	T4
	36	-	S4	T4

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The next tables and figures show that the thickness of surface course can vary when the prescribed Poisson coefficient of the bituminous concrete changes.

TABLE X. THICKNESS OF THE SURFACE COURSE IN FUNCTION OF THE POISSON COEFFICIENT OF THE BITUMINOUS CONCRETE FOR THE FLEXIBLE PAVEMENTS

Numbered pavement	*Thickness of the surface course (cm)*					
	υ_{BC} = 0.25	υ_{BC} = 0.35	υ_{BC} = 0.36	υ_{BC} = 0.42	υ_{BC} = 0.43	υ_{BC} = 0.45
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
4	3	3	3	3	3	3
5	3	3	3	3	3	3
6	3	3	3	3	3	3
7	4	4	4	4	4	4
8	4	4	4	4	4	4
9	4	4	4	4	4	4
10	4	4	4	4	4	4
11	4	4	4	4	4	4
12	4	4	4	4	4	4

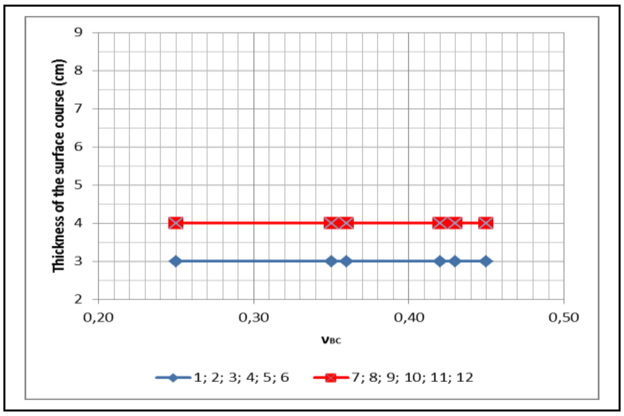

Fig. 3. Thickness of the surface course in function of the Poisson coefficient of the bituminous concrete for flexible pavements

In the figure 3, we can see that the thickness of the surface course of the bituminous pavement does not change under the prescribed Poisson coefficient of the bituminous concrete.

TABLE XI. THICKNESS OF THE SURFACE COURSE IN FUNCTION OF THE POISSON COEFFICIENT OF THE BITUMINOUS CONCRETE FOR THE BITUMINOUS PAVEMENTS

Numbered pavement	*Thickness of the surface course (cm)*					
	υ_{BC} = 0.25	υ_{BC} = 0.35	υ_{BC} = 0.36	υ_{BC} = 0.42	υ_{BC} = 0.43	υ_{BC} = 0.45
13	3	3	3	3	3	3
14	3	3	3	3	3	3
15	3	3	3	3	3	3
16	4	4	4	4	4	4
17	4	4	4	4	4	4
18	5	5	5	4	4	4
19	7	7	7	6	6	6
20	7	6	6	6	6	5
21	7	7	6	6	6	6
22	8	7	7	6	6	6
23	8	7	7	7	7	6
24	8	7	7	6	6	6

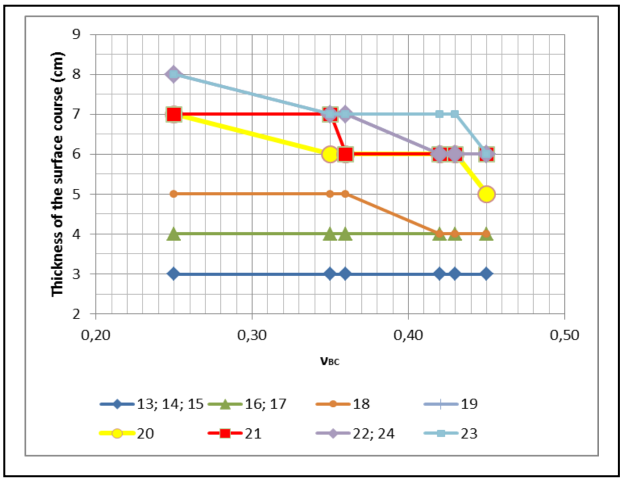

Fig. 4. Thickness of the surface course in function of the Poisson coefficient of the bituminous concrete for bituminous pavements

In the figure 4, the thickness of the surface course of the bituminous pavement changes under the prescribed Poisson coefficient of the bituminous concrete for the pavements numbered from 18 to 23 in contrary to those numbered from 13 to 17.

TABLE XII. THICKNESS OF THE SURFACE COURSE IN FUNCTION OF THE POISSON COEFFICIENT OF THE BITUMINOUS CONCRETE FOR THE SEMI-RIGID PAVEMENTS

Numbered pavement	*Thickness of the surface course (cm)*					
	υ_{BC} = 0.25	υ_{BC} = 0.35	υ_{BC} = 0.36	υ_{BC} = 0.42	υ_{BC} = 0.43	υ_{BC} = 0.45
25	4	3	3	3	3	3
26	6	5	5	4	4	4
27	4	3	3	3	3	3
28	6	5	5	4	4	4
29	5	4	4	3	3	3
30	8	7	7	6	6	6
31	7	6	6	5	5	5
32	6	5	5	4	4	4
33	9	8	7	7	6	6
34	8	7	7	6	6	6
35	7	6	6	5	5	5
36	7	6	6	5	5	5

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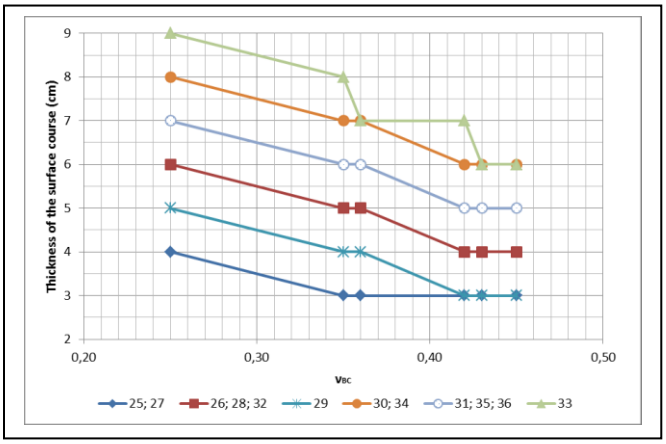

Fig. 5. Thickness of the surface course in function of the Poisson coefficient of the bituminous concrete for semi-rigid pavements

In the figure 5, we observe that the thickness of the surface course of the semi-rigid pavement changes under the prescribed Poisson coefficient of the bituminous concrete for the corresponding pavements.

IV. CONCLUSION

In this paper, the French method has been applied to study the thickness sensitivities of the surface course under the variation of the Poisson coefficient of the bituminous concrete. The case study of flexible pavements has shown that the prescribed values taken between 0.25 and 0.45 do not change the thickness of the surface course. In opposition, the analysis of the semi-rigid and bituminous pavements has shown that the change in Poisson coefficient can modify the thickness of the surface course considerably. We conclude that this second case study is sensitive under the variation of the Poisson coefficient than the flexible pavements. It is important to take into account the influence of the variation of the Poisson coefficient before recommending the mechanical values for these pavements design in tropical countries.

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