Экспериментальные исследования

OPTIMISATION CEMENT CONTENT FOR GRAVELLY LATÉRITIC FOR REALIZATION OF PAVEMENTS BASE IN NORTH BENIN

Dr. ZEVOUNOU Crépin, *Dr , Ecole polytechnique d'Abomey-Calavi Directeur Général du LERGC, Zevounoucrepin@gmail.com*
Dr. GIBIGAYE Mohamed, *Dr , Ecole polytechnique d'Abomey-Calavi Directeur Général du LERGC, Gibigaye_mohamed@yahoo.fr*
Dr. ALLOBA I. Ezéchiel, *Ecole Polytechnique d'Abomey-Calavi, EPAC allobidé@yahoo.fr*
Ing. YABI Crespin P., *yabicrespin@yahoo.fr*

In some countries and especially in Benin, some premature fissuring of semi-rigid structures in gravelly lateritic built, for the most, with important investment costs is often established. This is mostly due to the bad proportion in binding agent and sometimes to an overexploitation of the piece of work. The present study enters within the general context of the research of alternative solutions for an efficient exploitation of local materials (gravelly) in road technique in Benin. This work has consisted to do two borrowing in each one of two zones on which a complete identification has been realized. The materials had afterwards ameliorated at 2%, 3% and 4% of cement in sight of the determination of optimal dose in cement which guarantees satisfactory mechanic characteristics. Accorded to this approach, it was determined that the using of these materials at the natural condition is possible only in sub base course. The formulation study of heterogeneous gravelly-cement in base course has revealed optimal dose relative to every borrowing. Therefore, for security reasons depended on loss of yard, all these values have been brought back at 3.5% at the implementing of gravelly-cement within study zones. The application of this study will guarantee then relative economy no less important.

KEYWORDS: gravelly lateritic, road, pavements, mechanic characteristics.

Nomenclature:
CEBTP: Centre Expérimental du Bâtiment et des Travaux Publics
CNERTP: Centre National d'Essais et de Recherches en Travaux Publics
ES: Equivalent of sand test
HRB: Highway Research Board
IBR: ImmediateBearing ratio
LCPC: Laboratoire Central des Ponts et Chaussées
LBTP : Laboratoire du Bâtiment et des Travaux Publics
OPM Modified Proctor Optimum
Rc: Compression resistance after 7 days of curing at the air
R'c: Compression resistance after 7 days of curing then 3 at the air and 4 at in water
Rt: Traction resistance after 7 days of curing at the air
Author contact (1): zevounoucrepin@gmail.com

Introduction

It is often established in some countries and especially in Benin, some premature fissuring of semi-rigid structures in gravelly lateritic built, for the most, with important investment costs. This work has consisted to do two borrowing in each one of two zones on which a complete identification has been realized. The materials had afterwards ameliorated at 2%, 3% and 4% of cement in sight of the determination of optimal dose in cement which guarantees satisfactory mechanic characteristics.

This work focused on borrowing by two targeted areas.

1 . Methodology:

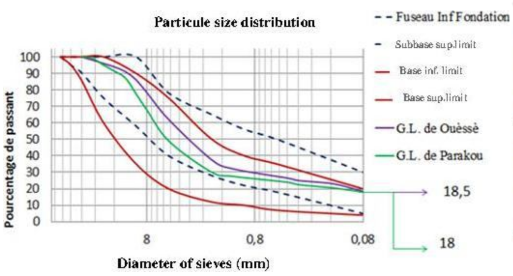
To carry out this work, the approach we have adopted consists in to seek and explore the sites of lateritic gravel in areas specified then proceed to collect the samples. After a complete identification of the two borrowings selected, the materials have been improved to 2%, 3% and 4% cement at various ages (1day, 3days, 7days, 14days, 21days and 28days) for the determination of cement content which guarantees satisfactory mechanical properties. Thus the optimum dosage looked for- values of which, the characteristics meet the criteria and recommendations for the use of lateritic gravel subbase for realizing the pavement to heavy traffic- was determined from the curve of resistance compression according to the cement content.

Zones	Zone I : Savè-Parakou-Malanville		Zone II : Savalou-Djougou-Natitingou	
Borrowings	**Parakou**	**Ouèssè**	**Komdé**	**Yétapo**
Department	Borgou	Collines	Donga	Atacora
Main road	Parakou-Kika	Djègbé-Ouèssè	Badjoudé-Sèmèrè	Natitingou-Djougou
Point Kilometric	KP 13+900	KP 6+100	KP 6+600	KP 14+000
Designation	G.L Parakou	G.L Ouèssè	G.L Komdé	G.L Yétapo

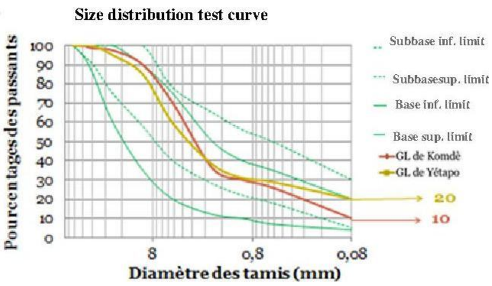
2 . Results and analysis

2.1 . Tests for determining the mechanical properties of soils

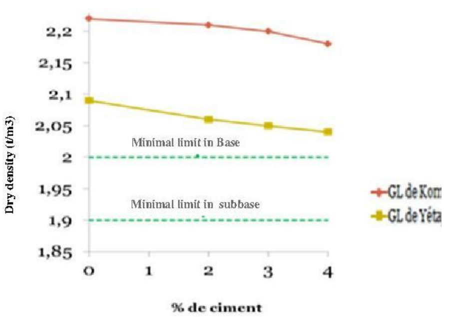
It is noticed that the sieving curves of the two zones are inserted correctly in both the recommended in subbase and the recommended in base courses. The materials of these borrowing can be used in subbasecourse in terms of size. The values of the percentage of fines obtained are generally below the recommended maximum in the pavement except base course for the traffic in excess of T3, where they exceed the limit value of 15.



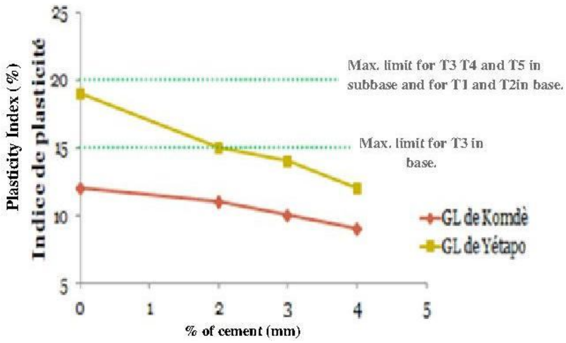
Graph 1 : Sieving curve of zone 1 borrowing



Graph 2 : Sieving curve of zone 1 materials

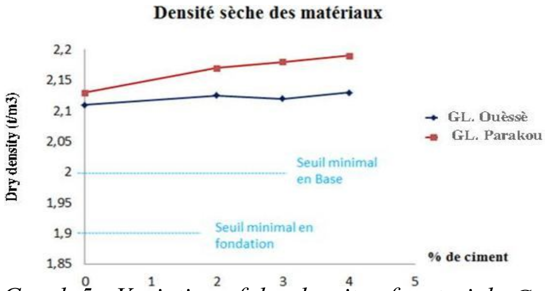


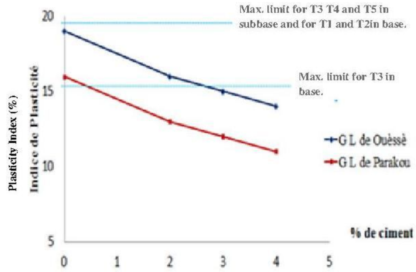
Graph 4 : Plasticity index according to the cement proportion of zone 2 materials.



Graph 3 : Plasticity index according to the cement proportion of zone 1 materials.

CBR indices obtained in a natural state for all these materials are of the order of 60. Thus the use of these lateritic materials in base course can be considered for the T1 traffic for which the minimum is 60. However, they can be used for all traffic, in subbase (foundation) layer where the recommended minimum value is 30. It was also noticed that the CBR increases with the cement proportion. At 2% the values are already higher than 160 (minimum value allowed in base course for soil-cement) except for the GL Yétapo for which we have to reach 3.15%.

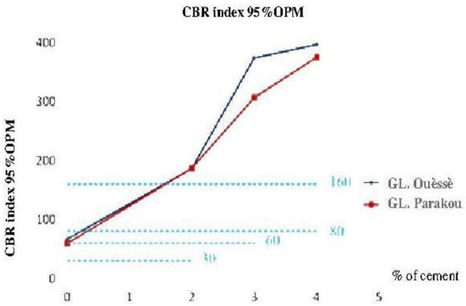


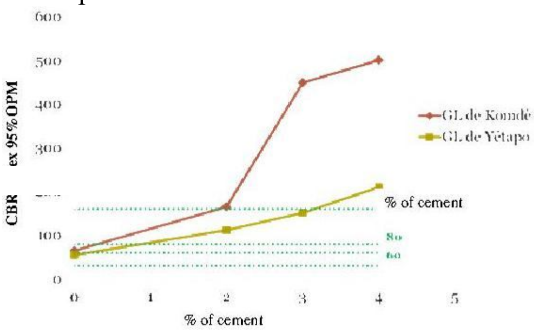


Graph 5 : Variation of dry density of material in zone 1 according to the cement proportion

Graph 6 : Variation of dry density of material in zone 2 according to the cement proportion

There is a decrease of plasticity index with the cement proportion. The values 16 and 19 obtained in the natural state (that is to say at 0% of cement) for the materials in zone 1 just as 12 and 19 show that these materials are admissible except for the base course of T3 traffic where the maximum permitted is 15%.

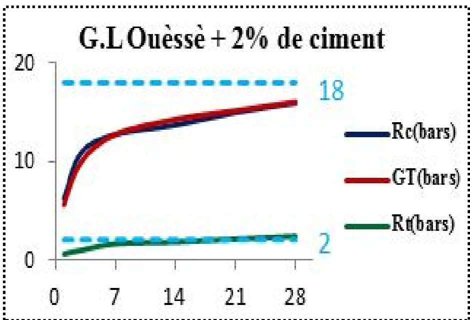


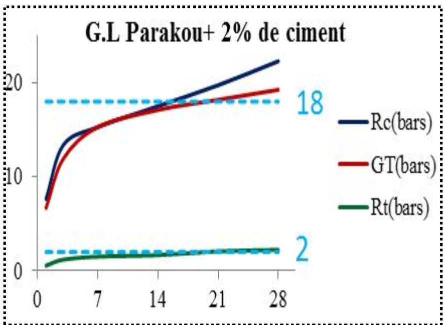


Graph 7: *Variation of materials CBR in zone 1 according to the cement proportion.*

Graph 7 : Variation of CBR materials in zone 2 according to the cement.

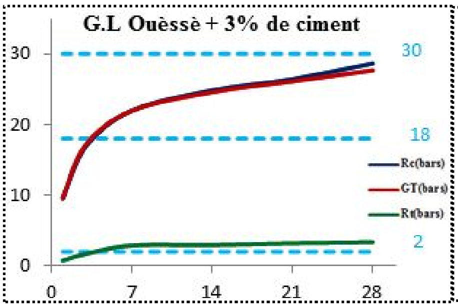
These graphics show the variation of resistances compression Rc and traction Rt. We see also the values according to age of samples. We draw the graphics G.T according the relations published by J.M. BARYLA and CEBTPC. We note also that for the materials from zone 1 the resultants of mechanicals properties are good at 7 days; but not for the case of 2% cement. The growing of traction resistance is high until 7 days but start modered for 14d days, 21 days and 28 days. The minimal value (18 bars) of resistance on compression at 7 days is attended for 3% and 4% cement for the two zones.



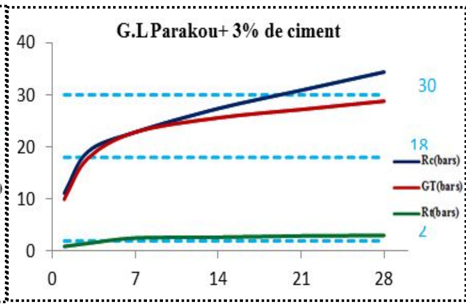


R'c7 = 6,95 > 5 ; R't7 = 1,29 > 0,5
Rc7/Rc28 = 0,80 > 0,70
R'c7/Rc7 = 0,55 > 0,50
Rt7/Rc7= 0,13 □ [0,04;0,16]

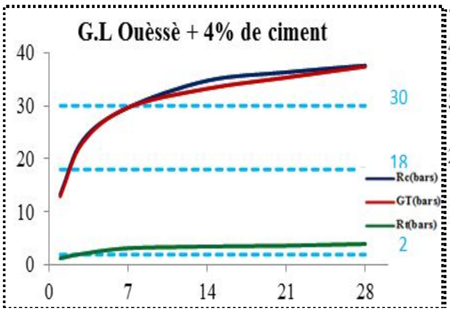
R'c7 = 8,46 > 5 ; R't7 = 0,95 > 0,5
Rc7/Rc28 = 0,69 < 0,70
R'c7/Rc7 = 0,55 > 0,50
Rt7/Rc7= 0,10 □ [0,04;0,16]



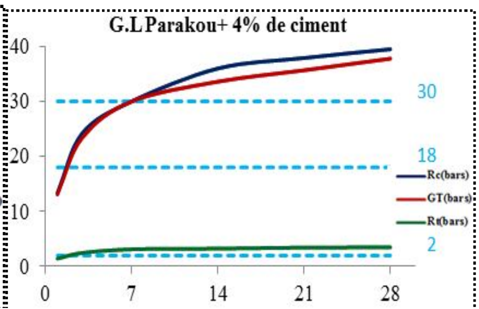
R’c7 = 13,37 > 5 ; R’t7 = 1,62 > 0,5
Rc7/Rc28 = 0,77 > 0,70 ; R’c7/Rc7= 0,61 >0,50
Rt7/Rc7= 0,13 □ [0,04;0,16]



R’c7 = 11,91 > 5 ; R’t7 = 1,35> 0,5
Rc7/Rc28 =0,66□ 0,70 ; R’c7/Rc7 =0,52>0,50
Rt7/Rc7= 0,11□ [0,04;0,16]

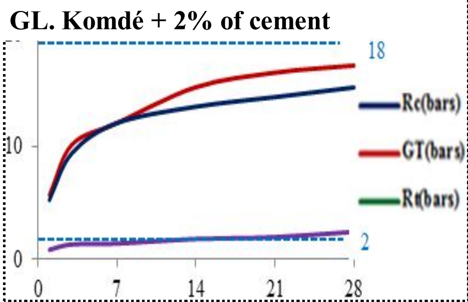


R’c7 = 16,64 > 5 ; R’t7 = 1,94 > 0,5
Rc7/Rc28 = 0,79 > 0,70 ; R’c7/Rc7 =0,56 > 0,50
Rt7/Rc7= 0,11 □ [0,04;0,16]

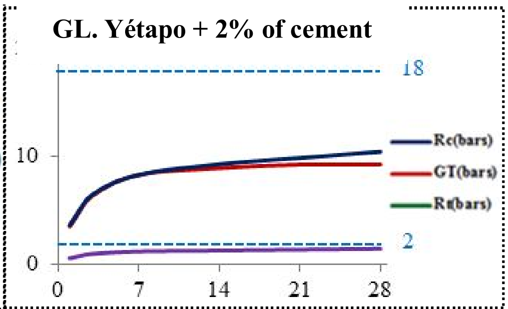


R’c7 = 15,19 > 5 ; R’t7 = 1,61 > 0,5
Rc7/Rc28= 0,76>0,70 ; R’c7/Rc7=0,51>0,50
Rt7/Rc7= 0,10 □ [0,04;0,16]

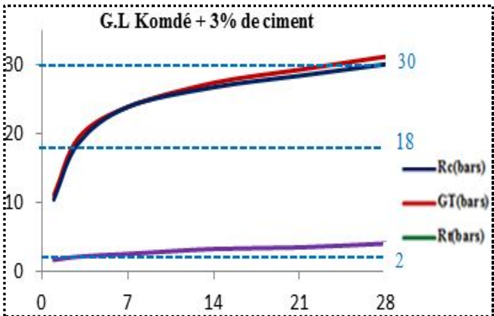
Graph 8 : Variation of resistances Rc, and Rt des materials of according to age for cement proportion



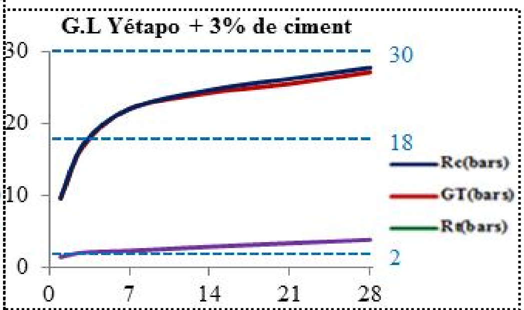
R’c7 = 6,37 > 5 ; R’t7 = 0,80> 0,5
Rc7/Rc28=0,704>0,70; R’c7/Rc7=0,53> 0,50
Rt7/Rc7= 0,12□ [0,04;0,16]



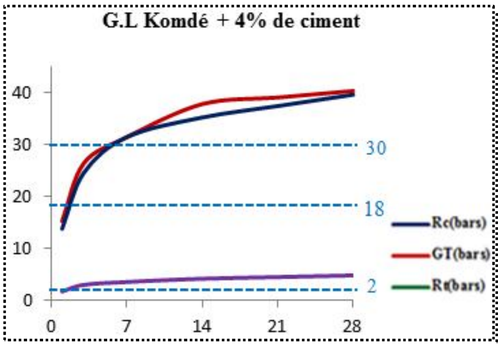
R’c7 = 4,78 > 5 ; R’t7 = 0,64> 0,5
Rc7/Rc28= 0,90> 0,70; R’c7/Rc7= 0,58> 0,50
Rt7/Rc7= 0,14□ [0,04;0,16]

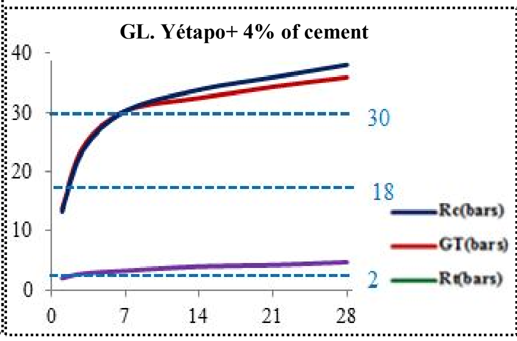


R’c7 = 13,68 > 5 ; R’t7 = 0,96> 0,5
Rc7/Rc28=0,77 >0,70; R’c7/Rc7=0,57> 0,50
Rt7/Rc7= 0,11□ [0,04;0,16]



R’c7 = 11,14 > 5 ; R’t7 = 0,80> 0,5
Rc7/Rc28=0,81>0,70 ; R’c7/Rc7=0,51 >0,50
Rt7/Rc7= 0,10□ [0,04;0,16]





R'c7 = 15,92 > 5 ; R't7 = 1,59> 0,5
Rc7/Rc28 = 0,80> 0,70
R'c7/Rc7 = 0,51> 0,50
Rt7/Rc7= 0,11□ [0,04;0,16]

R'c7 = 15,92 > 5 ; R't7 = 1,35> 0,5
Rc7/Rc28 = 0,84> 0,70
R'c7/Rc7 = 0,53> 0,50
Rt7/Rc7= 0,11□ [0,04;0,16]

Graph 9 : Variation of resistances Rc, and Rt of materials of zone 2 according to age cement proportion

On the other hand, the values obtained for 4% of cement are almost 30 bars (the superior limit value not exceeded) for materials of zone 1 and slightly greater than 30 for those in zone 2. These treated materials showed good water resistance because the soaked specimens gave at all percentages in both compression and traction, satisfactory values. Finally, ratios $R_{c7}/R_{c28}$are for the most higher than 0.70 which indicates a rapid increase of compressive resistance at early ages.

Table 1 : Summary of analysis of mechanical tests

Material	Dosage	Progression							Conclusion
		R_{c7}	$\frac{R_{c14}}{R_{c7}}$	$\frac{R_{c21}}{R_{c7}}$	$\frac{R_{c28}}{R_{c7}}$	$\frac{R_{c7}}{R_{c28}}$	$\frac{R'_{c7}}{R_{c7}}$	$\frac{R_{t7}}{R_{c7}}$	
Reference values		-	1,12	1,19	1,26	> 0,70	> 0,50	0,04-0,16	-
G.L. of Onèssè	2 %	12,73	1,08	1,18	1,25	0,80	0,55	0,13	Draws near of BARYLA progression and the other ratios are satisfactory.
	3 %	21,95	1,13	1,20	1,31	0,77	0,61	0,13	
	4 %	29,65	1,17	1,22	1,27	0,79	0,56	0,11	
G.L. of Parakou	2 %	15,28	1,15	1,29	1,46	0,69	0,55	0,10	Deviates of BARYLA progression and the other ratios are satisfactory.
	3 %	22,85	1,20	1,35	1,50	0,66	0,52	0,11	
	4 %	29,97	1,20	1,26	1,32	0,76	0,51	0,10	
G.L of Komdè	2 %	12,1	1,26	1,37	1,42	0,704	0,53	0,12	Draws near of BARYLA progression and the other ratios are satisfactory.
	3 %	23,88	1,15	1,23	1,31	0,77	0,57	0,11	
	4 %	31,51	1,20	1,24	1,28	0,80	0,505	0,11	
G.L of Yétapo	2 %	8,28	1,08	1,12	1,12	0,90	0,58	0,14	Draws near of BARYLA progression and the other ratios are satisfactory.
	3 %	21,97	1,10	1,16	1,23	0,81	0,507	0,10	
	4 %	30,24	1,07	1,14	1,19	0,84	0,53	0,11	

Once the amended study materials give satisfactory results in terms of characteristics, we moved to the determination of optimal dosage.

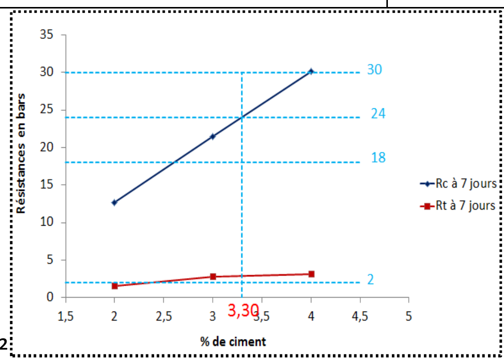
3. Optimal dosage:

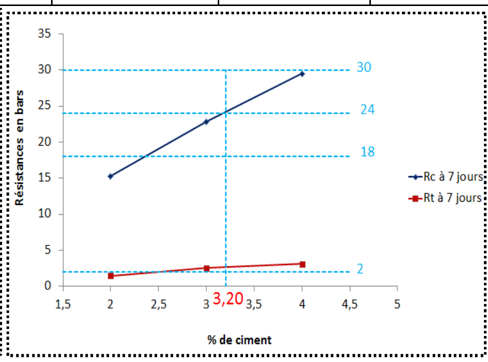
It is a cement content which guarantees a minimum compression resistance of 18 bars, a maximum compression resistance of 30 bars and a traction resistance of at least 2 bars.

The methodology was therefore to draw the curves for each borrowing reflecting the variation at 7 days of mechanical properties (Rc and Rt) as a function of cement proportion. We then looked for the dosage giving a compression resistance equal to 24 bars that represents, the average of two extremes recommended (18 bars and 30 bars) for soil-cement pavement bases avoiding. Thus, it is necessary to determine whether this assay corresponds to a specific traction resistance of at least 2 bars. All optimal dosage of less than 3% -minimum recommended for use in base course of gravel treated with hydraulic binding agent- would be outlawed, and when these conditions are satisfied the dosage is definitely selected as the optimal.

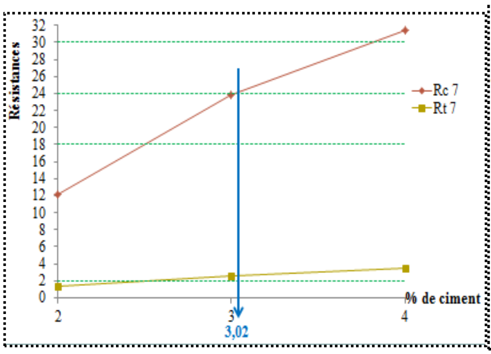
So according to this approach, and graphs that follow, we obtained the results as presented in the table below:

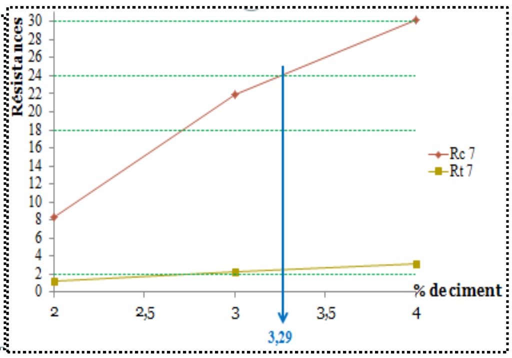
ZONE	ZONE 1		ZONE 2	
Borrowing of	Ouèssè	Parakou	Komdé	Yétapo
Theoretical optimal dosage	3,30	3,20	3,02	3,29
Traction resistance	3,0	2,65	2,57	2,50
Optimal dosage at execution	3,50	3,50	3,50	3,50
Theoretical Rc at execution	26	25,95	27,80	26,11
Theoretical Rt at execution	3,25	3,10	3,03	2,99
Hoped Rc at execution	18,2	18,17	19,46	18,28
Hoped Rt at execution	2,28	2,17	2,12	2,09
Verification Rc_{max}=18 and Rt_{min} = 2	OK!	OK!	OK!	OK!





G.L Ouèssè **G.L Parakou**





G.L Komdé **G.L Yétapo**

Graph 10 : Determination of the optimum cement content of materials of various borrowings

We noticed that all the traction resistances obtained with optimal dosages determined (and shown in the table) are above the 2% minimum. Moreover, these values are theoretical. At execution, the CEBTP recommended in [1], a safety factor of 0.70 for the comparison of traction stresses handled and performance of materials treated with hydraulic binding agent. In addition, the Laboratory of Building and Construction - LBTP - states in [2] that for security reasons and to accommodate the vagaries of implementation, we must round up to 0.5% higher, the dosage found in laboratory (eg. 3.2% will be rounded to 3.5%).

The work was therefore to rounding in accordance with the recommendation of LBTP optimal dosages determined in the laboratory on gravelly studied. This led us to a dosage of 3.5%, the execution of all materials for both study areas. Then, a safety factor of 0.70 was applied to the resistances to 3.5%. The values obtained are higher than the recommended minimum (18 and 2 bars).

3 . Representativeness of the studied materials in the target areas:

By observing correctly the national geological map, it is noticed that the base of area Savè-Parakou (zone 1) is essentially composed of migmatites, gneiss, biotite gneiss and muscovite.

Similarly, it is noticed that the base of the zone Djougou-Natitingou (zone 2) is mainly composed of muscovite gneiss, with two-mica, leptynites; orthogneiss biotitic or biotite and amphibole quartzite, mica schist and micaschists with granit. Note that this is metamorphic rock; we also find abundant syntectonic granites calc-alkaline which are igneous rocks.

Remember, this is the decomposition of these metamorphic rocks that give rise to lateritic gravel [3]. The existence of the same geological formations on the full extent of the study area ensure to the lateritic gravelly of these areas a low disparity in terms of mineralogical composition. This trend is confirmed by the results from different trials that vary little from one loan to another.

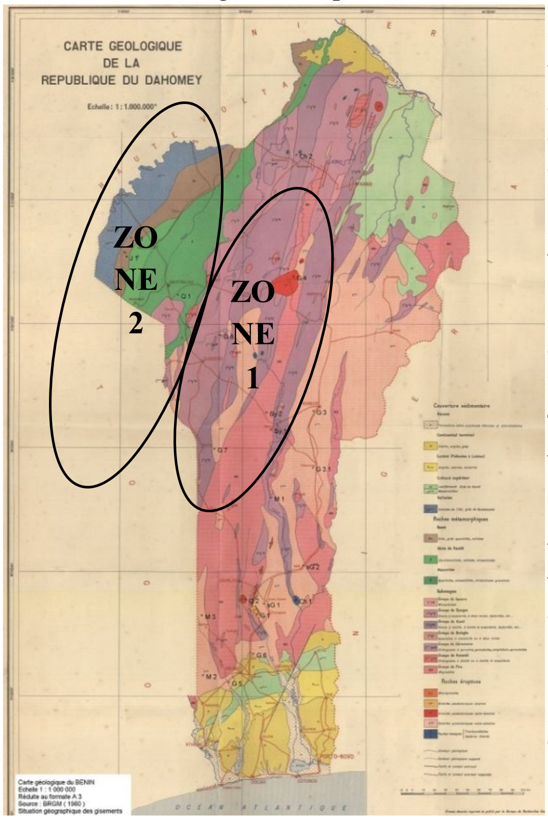


Fig 1 : Geological Map of the Republic of Dahomey (OBGM)

We therefore recommend that designers of future road projects aimed at the area of Save-Parakou to check around for a complete identification if the quarries selected borrowings check criteria of ability for treatment by cement. When this ability is proven, the gravel from such quarries may be, without further formulation study, treated with 3.5% of cement to the implementation as we indicated in the previous chapter.

4 . Economic study

Assumption:

- width of the platform = 9.20 m;
- thickness (e) of the layer to be treated e = 15 cm (this is the smallest thickness recommended for gravel-cement in base course (1));
- cement content: C% = 4%;
- maximum dry density of the material (taking that of Ouessè 4%): γ_dam T/m3 = 2.13;
- cement proportion determined after optimization: C% = 3.5%

The calculation is used to record an

quantity of cement to save 0.01413 per linear meter or 14.13 tons per ton is a section of 1000 ml, we will have.
It is obvious that for several miles of meter, the potential savings will be very sensitive, allowing us to conclude that the optimization study is essential in the design chain of a rigid or semi-rigid structures.

Conclusion

In Benin, the use of lateritic gravel-cement in base and subbase courses of pavement is an example of a local material recovery encountered in abundance in tropical Africa. This approach of composite material, despite its technical and economic advantages, is now problematic because of its susceptibility to cracking. This is partly due to too excessive rigidity of the treated layer caused by an overdose of cement.

The study of the optimum cement proportion of gravelly of area Savè-Parakou, improved to the subbase and base courses, is therefore of paramount importance to satisfy significantly the insufficiencies of semi-rigid structures. After the complete identification, it was found that the studied gravel are usable in its natural state, that the subbase course.

Similarly, it was noted that the mechanical characteristics (CBR, Rc, Rt ...) of gravel-cement grow almost proportionally with cement proportions. Despite the distance separating the two areas studied by borrowing, they presented to all testing characteristics that vicinity. It is this situation that prompted the question of generalizing the results. The economic study based on assumptions made with regard to the history of soil-cement in Benin, has shown that it is possible to realized under the conditions specified in the assumptions an economy of 14 T / Km. *However, it is usual that future work is investigating the possibility of establishing a nationally catalog of standard structures in natural lateritic gravel or gravelly lateritic cement.* It would also be appropriate to undertake research on the influence of clay type on the reaction of cement with lateritic gravel in order to elucidate the dispersions observed so far from one area to another.

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ОПТИМАЛЬНОЕ СОДЕРЖАНИЕ ЦЕМЕНТА ДЛЯ УЛУЧШЕНИЯ ГРАВЕЛИСТОЙ ДОРОЖНОЙ ОСНОВЫ В СЕВЕРНОМ БЕНИНЕ

Зевуну К, Гибиге М., Аллоба И.Е., Яби К.П.
Политехническая школа, Бенин

Статья посвящена исследованию альтернативных решений по эффективной эксплуатации местных материалов, в частности, гравийно-цементной смеси в технологии дорожного строительства Северного Бенина.

КЛЮЧЕВЫЕ СЛОВА: дорога, тротуар, гравий, механические характеристики.