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RESEARCH ARTICLE

STUDY ON THE COMPACTING OF MATERIALS FOR THE VARIOUS LAYERS OF THE ROADWAY: THE CASE OF ACCESS ROADS TO THE SECOND WOURI BRIDGE IN CAMEROON

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ABSTRACT

In order to achieve an adequate layout of the various roadway components of the project for the construction of the second Wouri bridge, with the aim of limiting the short term degradation due to the joint action of weather conditions and the intense traffic of heavy-duty vehicles, a study has been carried out and results presented on some parameters, ranging from geotechnical tests on soil Shrinkage/Swelling, materials bearing capacity, water content rate and other properties linked to the mechanical behaviour, that have an influence of the compacting of materials used in the project. Then a computer modeling was carried out on the layoutof ALIZE-LCPC roadways in order to illustrate the influence of the variation in the thickness of layers of the runway on the lifespan of the latter. In the final analysis, results of the Compacting Trial area carried out on the Bituminous Graves (GB3-0/20) are presented in order to optimize the implementation process, so as to come out with an optimum compacting energy necessary to achieve the adequate level of compactness (a VacuumPercentage of ≤ 9%according to NF P 98-150-1 and an implementation Compactness against the Real relative densityC/MVRe$_{max}$ ≥ 89%). By applying thefour compacting energies defined in our test board, corresponding energy No.1, 12 passages of thewheel compactor and 4 passages of the vibratory compactor enabled us to achieve a Minimum Vacuum Percentage of 5.3% corresponding to a maximum compactness as compared to the Real Relative DensityC/MVRe$_{max}$ equal to94.6%,in conformity with the Project'sSpecial Technical Specifications, with norms NF P 98-150-1 and NF P 18-545,and with the Control Plan ofVRD – SOG – PES - EXE 6101.

INTRODUCTION

The necessity to improve the lifespan of roads is a major preoccupation of road managers. As a matter of fact, due to frequent stress caused on our roads fromhigh overloading of heavy-duty vehicles, their behaviour is significantly disturbed; consequently our roadways are prematurely degraded, whereas they behaved normally before. The situation is further compounded by the new conception of heavy-duty vehicles loads that use more and more extra-large tyres with higher inflating pressures, in replacement of twin wheels. On the basis of these elements, it became necessary to adapt layout and implementation methodologies, in order to pertinently and pertinently respond to the exigencies of the Project'sSpecial Technical Specifications. Soil identification, as well as the carrying out of geotechnical tests helps to give geotechnical properties of the given type of soil; this helps to objectively organize the putting in place of the various layers and to derive their various mechanical parameters, before calculating the layout of roads. The ability to compact materials in the field depends on the quality of geotechnical tests. Within a general context of sustainable development endorsed by Cameroon, geotechnical laboratories should be innovative and consider an optimum use of local materials in order to reduce the cost of road constructions, within the strict respect of accepted safety constraints and the optimal use of materials on the building site.

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This study will be applied to the project for the construction of the second Wouri Bridge.

Project Presentation

The project for the construction of a second bridge over the Wouri River and its access roads consists in the construction of two infrastructures aimed at splitting the existing bridge into two. One of these, which is a road infrastructure, includes a2x3 roadways and a pavement. The other, a railway infrastructure, is made up of two railways. The project shall probably include two separate superstructures, one railway and one roadway. As standard section,the road area shall be of about 25 meters, corresponding to six lanes (three on the West side and 3 on the East side of the river), an emergency laneand a security pavement. This layout of the bridge is coherent with the present traffic, and thus more so, with short term traffic forecast studies based on lower or medial hypotheses. The construction fits into the Transports Scheme of the city of Douala, the economic capital of Cameroon, which counts 2.5 million inhabitants, and which provides for a separate site for mass transportation.

Figure 1 Situation plan for the construction project of the 2nd Wouri Bridge

Identification of materials and compacting parameters

Boreholes that were carried out showed that at the level of the North Deido access road, there is an alternation of layers of fine blackish sand, rough sand and silty layers. The soil identification campaign consisted in : the performance of eleven boreholes using a heavy dynamic penetrometer at 15 m(SPT) that helped to obtain the peak dynamic resistance$\mathbf{q_d}$ and to determine the various layers of soil present; the carrying out of twenty boreholes(CPT) at 15, 16, 19 and 20m that helped to determine soil resistance to the penetration of a 10 cm^2 cone as well as lateral friction on the mantle ; the carrying out of six pressiometric boreholes at 15 and 16 m to determine both the soil breaking threshold and soil pressiometric module. Geotechnical soil identification borehole points on the Deido end access road between earthworks gauge rods PT13 and PT 135.

The main criteria to be taken into consideration that impact the layout of soft roadways are the following:
The platform (80 <PF<120 MPa);
The traffic (Heavy duty vehicles 3.5 tons);
The nature and the thickness of the roadway materials and the quality of works;
Climatic variations(rainfall, temperature, hygrometry).

Materials that are subjected to geotechnical test studies in our analysis are mainly:

- Pozzolan aggregates (CBR ≥ 30, Dmax ≤ 50mm. Forthe forming layer);
- Clayey sand (CBR ≥ 15, IP ≤ 25. For the body of the embankment and theSTP);
- Crushed aggregates (0/d), d ≤ 50mm, asFoundation layer for thegranular category(0/31,5), asBasic layer for GB 0/20and asRolling surfacefor category(BB 0/14).

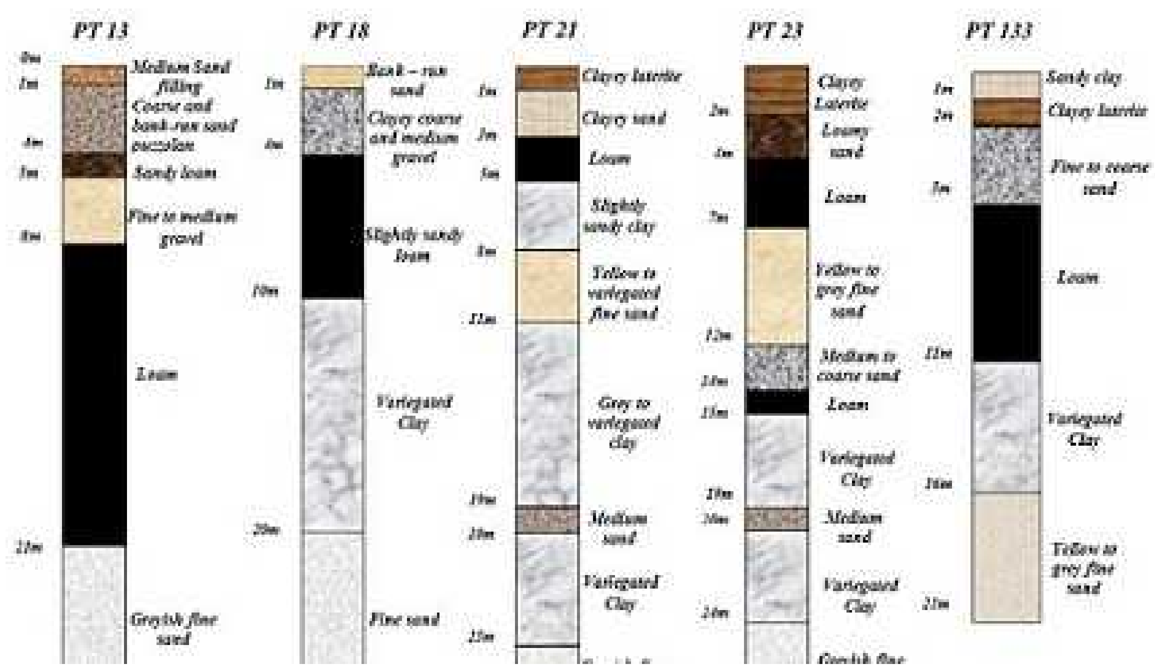
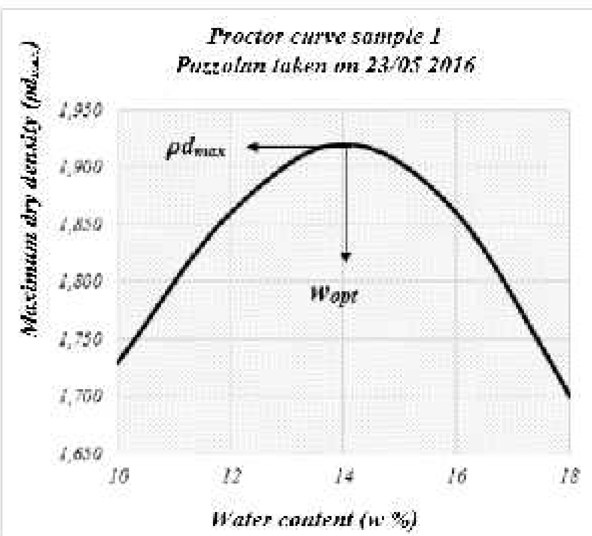


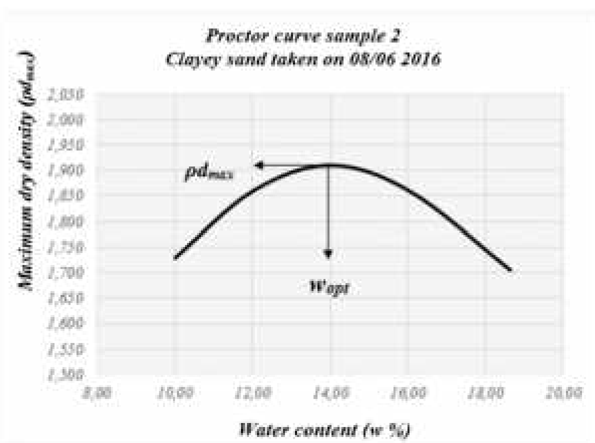
Figure 2 Borehole points on the Deido side access road

For these materials to fully play their role, they must fulfill certain conditions:Granularity, characterized by the size D of larger components;the percentage of fine particles; the percentage of elements smaller than 80µm; Angularity and Shape;Cleanness. Parameters that influence the choice of materials during the layout of roadways are defined following criteria such as:

- Thenature(Granularity and clayey nature);
- The mechanical behaviour (resistance to stress, resistance to erosion, CBR index, distortion module EV2, and rigidity module);
- The moisture status(depending on the environment, Very moist, Moist, Average Moisture, Dry and Very Dry).

Pozzolan is the material that needs water the mostto humidify its components. In addition, the curve is pointed and its compactness range is low. Conversely, **clayey sand** needs less water to humidify its components and the curve is flat. This soil contains little fine elements but has a high compactness range. The interpretation of the results given by the various Proctor curves shows that there is a water content range for which the material can be compacted, and outside which the compacting threshold could not be attained.





The long term prediction of the behaviour of materials to be used for the construction of roadsis essential to limit the degradation of infrastructures. Compacting, be it as an embankment, a platform, a capping layer, or a roadway body, helps to reduce the vacuum rates in soil constituents, while increasing soil dry density. Be it for grainy soil or fine soil, the objectives of compacting in road projects are to define the densification thresholds of the various layers. Compactness is highly influenced by the soil water content during the compacting phase. The difficulty of compacting is as difficult as the content of fine particles is important; this phenomenon can be explained by the fact that the percentage of fine particles being low in a given material, they do not act as lubricants and thus blocks the rearrangement process**.**

Compacting is the final phase of putting the materials of the roadway in place. The quality of its implementation shall be crucial, especially as concerns the life span of the infrastructure, through the compactness that will be obtained.

Achieving the desired quality entails carefully selecting the equipment and the method of compacting materials according to the climatic conditions and the environment of the construction site.

Compacted soil results from the application of a given compacting energy to a given soil. This energy is applied either in Laboratory, thus corresponding to the compacting energyat Normal Proctor test, or to the compacting energy at Modified Proctor test; eitheron site (on the construction site), which represents: a precise number of passages of compacting equipment; the weight of compacting equipment and the volume of the materials used.

Implementation

Before building an embankment, it is advised to construct a Trial areain order to determine the conditions under which the materials will be used and select the most adequate compacting equipment. The thickness of materials layers and the number of passages of compacting equipment are determined during this test. TheTest board was constructed on30 June 2016 as part of the compacting of the Bitumen aggregate (GB) of category 3 and level 2(GB3 – 0/20),made up of pure bitumen of 50/70 grade, as roadway layers on the Bonassama stretch between PK 0+340 and PK 0+ 420 of the project in order to optimize the implementation process so as to define an optimum compacting energy to attain the compacting level required by thespecial technical specifications.The methodology adopted in formulatingour GB3 – 0/20Bitumen Aggregate is presented following the algorithm:

Granular categories examined, that helped us to produce the GB3-0/20, are as follows : 0/2, 2/6, 6/10 and 10/20 as proportions in the compound, that is: 40.6% for crushed sand 0/2 EKONA quarry (Buea) ; 17.6% for crushed gravelly sand 2/6 EKONA quarry (Buea) ; 14.8% for crushed gravel 6/10 EKONA quarry (Buea) ; 27% for crushed gravel 10/20 EKONA quarry (Buea)

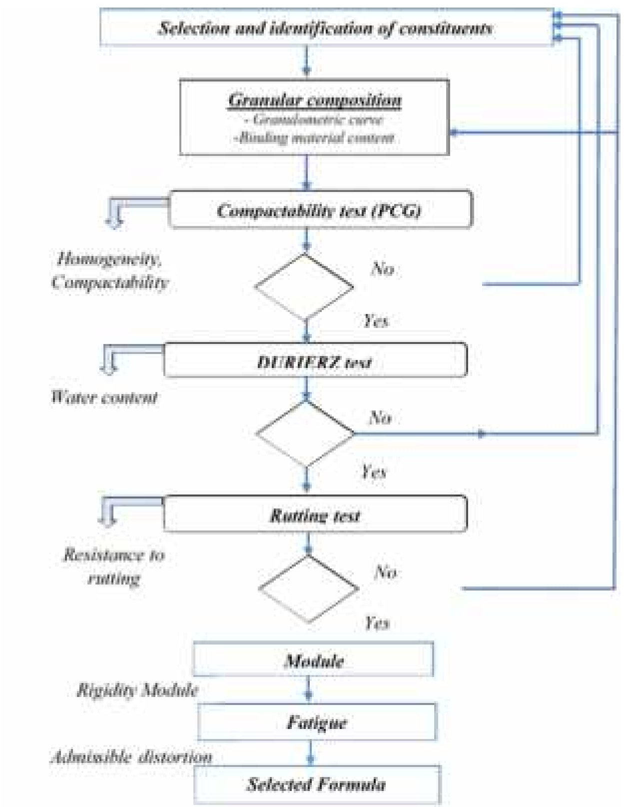


Figure 3 Algorithmfor the formulation of Bitumen Aggregates GB3 -0/20

Cameroon, crushed into four fractions: **0/2, 2/6, 6/10**and**10/20**. A blank compound was produced at the end of these tests and helped to draw the granulometric curve of the compound, which fits perfectly into the granulometric interval of the 0/20. The Trial area carried out was done on a stretch of**80m long**and**3.5m width** on the basis of the foundation layer of crushed aggregates of 0/31.5 previously acquired.

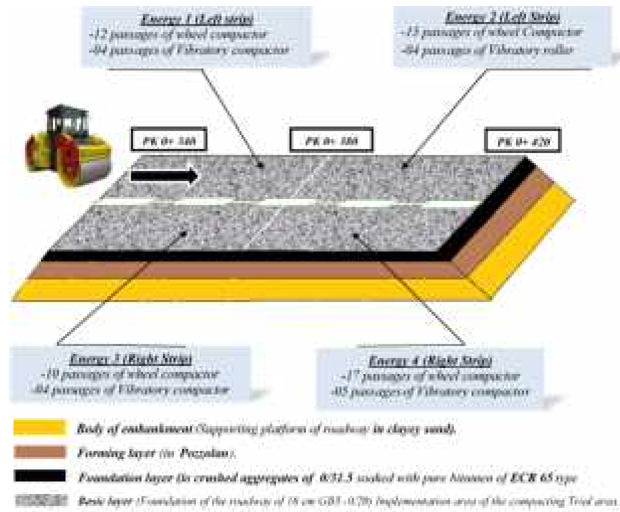


Figure 4 Cross-section of the Trial area

After applying the various energies defined during our Trial area, the following results were obtained:

Tableau 1 Tests carried out on Bitumen Aggregate GB3 -0/20

Tests carried out on GB3-0/20	Values	special technical specificationsRequirements
% of Bitumen againstthe coating (AOD Sogea Satom central)	4.17%	-
% Bitumen against the aggregate (AOD Sogea Satom central)	4.57%	4.65%±0.25%
Thickness of materials (On Site)		8 -16cm (in 2 layers)
Temperature of materials (On Site)	-	≥ 125^{0}C Conformity with the NF P98-150 - 1
Compactness of materials as compared to the Real Relative Density C/MVRe (On Site)	-	C ≥ 89%
% of vacuums(On Site)	-	≤ 9%
Marshall Test : (LABOGENIE)		
- Marshall Stability at 60^{0}C	13.65KN	> 9KN
-Compactness On sites % of the Marshall	-	>97%
Duriez test :(LABOGENIE)		
-Immersion Resistance r to water at 18^{0}C	8MPa	≥ 6MPa
-R Dry Resistance at 18^{0}C in open air	9.1MPa	-
-Water content r/R	0.88%	≥0,77%
Potholing test :(LABOGENIE) -Pothole depth (60^{0}C – 100mm) after 30 000cycles for % of vacuums ≤ 9%	-	≤ 10
Module : (AOD Sogea Satom Central) - Rigidity module (15^{0}C -100Hz) in MPa	-	≥ 9MPa
Fatigue :(AOD Sogea Satom Central) -Admissible distorsion by fatigue (In millions cycles)	-	≥ 90.10^{-6}
Creep: (AOD Sogea Satom Central)	3.375mm	<4mm

The asphalt aggregates studied was produced using aggregates from the EKONA quarry(Buea)in the South-West Region of

Results obtained are in accordance with the Special technical specificationsrequirements and with NF P 98-150-1 and NF P

18-545 standards on the one hand, and with the VRD- SOG - PES - EXE 6101 control plan on the other hand.

prolonged life span of the infrastructure according to the damage suffered.

Tableau 2 Results of the Trial area carried out on the GB3 -0/20

Left strip							
Energy 1 -12 passages of wheel Compactor -04 passages of Vibratory compactor				**Energy 2** -15 passages of wheel Compactor -04 passages of Vibratory compactor			
PK	% Vacuum	Compactness	Real Max DensityOn Site	PK	% Vacuum	Compactness	Real Max Density On Site
0 + 345 (Left)	5.9%	94.1%	2.504 T/m^3	0 + 385 (Left)	8.2%	91.8%	2.442 T/m^3
0 +360 (Axle)	5.1%	94.9%	2.525 T/m^3	0 +400 (Right)	8.1%	91.9 %	2.444 T/m^3
0 + 370 (Right)	5.2%	94.8%	2.521 T/m^3	0 +420 (Axle)	7.6%	92.4%	2.458 T/m^3
Average	5.4%	94.6%	2.517 T/m^3	Average	8.0%	92.03%	2.448 T/m^3

Right Strip Energy 3 : -10 passages of Vibratory compactor; -04 passages of Vibratory compactor			
PK	% Vacuum	Compactness	Real Max Density On Site
0 + 320 (Left)	7.9 %	92.1%	2.449 T/m^3
0 + 340 (Axle)	7.5%	92.5%	2.460 T/m^3
0 + 360 (Right)	8.2%	91.8%	2.442 T/m^3
Average	**7.87%**	**92.13%**	**2.450 T/m^3**

The three compacting energies applied during the Trial area help in getting a vacuum percentage lower than9 %.(NF P 98-150-1 requirements).

For the next phases of the project, we selected workshop No.1 (Energy 1), that is:12 passages of wheel Compactor(PS500); 04 passages of Vibratory compactorVT1/VT0.

These elements enabled us to obtain a minimum Density equal to 5.3%as compared to the other energies for a maximum compactness equal to 94.6%.

Life span of the roadway and proposed maintenance plan

In order to guarantee the optimum and efficient use of the roadway during its life span, it is important to ensure its maintenance in order to increase its life span.

Thus, due to possible damages**(Distortions**, **Cracks, Upwelling, Wrenches)**that may result from poor compacting of the various layers of the road leading to their short term degradation, we availed ourselves to propose a theoretical multiannual maintenance plan that may help to determine the

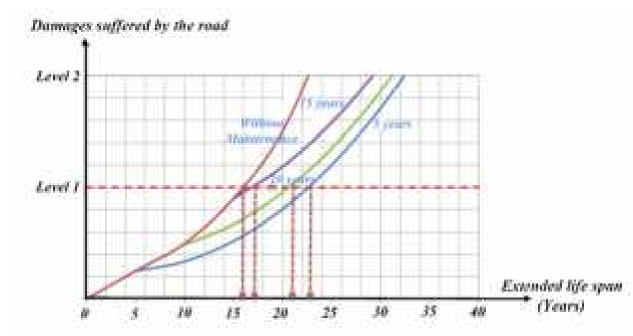


Figure 5 Assessment of the extension of the road's lifespan after maintenance and according to damages

The proposed maintenance plan was studied considering the evolution of the damage over a period of 40 years. The interpretation of the chart below shows an extension of the life span of the road, taking into account the appearance of the first damages.

Some proposals for maintenance are given in Table 3.

Table3 Result of progressive maintenance of roadways after life span

Condition of the roadway after the scheduled life span	Extended life span
Without maintenance	to 16 years
Maintenance after 5 years of service	to 23 years
Maintenance after 10 years of service	to 21 years
Maintenance after 15 years of service	to 18years

It should therefore be appropriate to plan for early maintenance works to ensure the normal life span of the road.

As part of the construction project of the second bridge on the Wouri River, the life span of roads to be built was evaluated at 15 years of service:projections were made on the basis of the following calculations: VRD-BHY- NTE- PRO-6860 -Ind A;VRD-BHY- NDC- EXE-2010 -IndD, thus offering the probability for the appearance of degradations at the end of this period as shown in the table below:

Table 4 Projected degradation risks for roads of the Wouri project.

Sections / Number of lanes	Aggregated Traffic (millions of PL)	Traffic Class LCPC	Proposed Structure	Admissible Déflexion (mm)	Risk of Degradation
Ordinary Section between the BONASSAMA roundabout and the DEIDO roundabout / 2X3 Lanes	5.12170	T1^{+}	7cm (BB) + 16cm (GB) +25cm (GC 0/31.5) +50cm Pozzolan +PF2	36/100	5%
Port Boulevard / 2X2 Lanes	5.04390	T1^{+}	7cm (BB) + 12cm (GB) +25cm (GC 0/31.5) +50cm Pozzolan +PF2	36/100	5%
Access towards the old bridge / 2X1 Lanes	1.92420	T2^{+}	7cm (BB) + 12cm (GB) +20cm (GC 0/31.5) +30cm Pouzzolane +PF2	42.6/100	10%
Access to the Industrial Zone through the lower way / 2X1 Lanes	4.80340	T1^{+}	7cm (BB) + 16cm (GB) +25cm (GC 0/31.5) +50cm Pozzolan +PF2	36/100	5%
Connecting Deido gyratory to the DEIDO roundabout / 2X3 Lanes	1.87470	T2^{+}	7cm (BB) + 16cm (GB) +25cm (GC 0/31.5) +50cm Pozzolan +PF2	36/100	10%

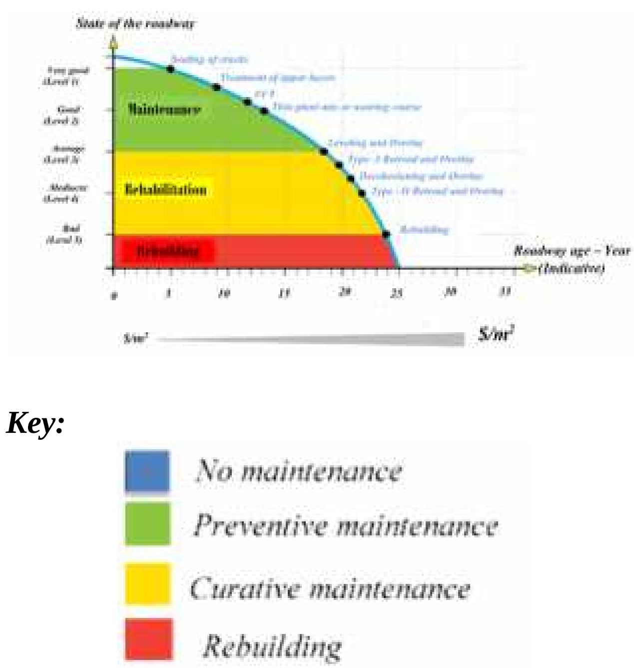


Figure 6 Roadway maintenance forecasts

CONCLUSION

Roads play a primordial role both at national and regional levels by ensuring various exchanges. It should be given special attention, since their construction often require very costly investments so that our States get into loans, generally from financial institutions to build them.

The aim of this paper was to examine the influence of geotechnical tests on the compacting of materials during the sizing of roadways of the construction project of the second Wouri Bridge. This study has enabled us to draw conclusions on the following issues: the sizing of layers of materials that make up the structure of road sis a fundamental step in a road construction project which is based on the nature, sensitiveness to water and bearing ratio, given its role in supportingthe road and ensuring mechanical performances in a sustainable manner ; the definition of geotechnical parameters of materials composing a type of soil, that have an impact on the Shrinkage/Swell of soil, sensitiveness to water, long term bearing capacity, the attitude relating to the mechanical behaviour during their use is assessed through the carrying out of a certain number of geotechnical tests.

As part of the construction project of the second Wouri Bridge, for a cost-effectiveness of resources invested for the construction of this project, we are therefore proposing that thorough studies should be carried out from the sizing phase up to that of maintenance to increase the life span of roads. This is possible through the type and the quality of materials used for the various layers of roadways that will react efficiently to the loads that they will have to bear on the one hand, and through the definition of a compactive effort through trial areas on the other hand, in order to obtain the vacuum percentage, a requirement of the NF P 98-150-1 so as to achieve their optimal compactness ratio.

As a way forward, it should also be useful that upcoming studies include the construction of toll gates in compliance with the regulations in force in the Ministry of Public Works on norms relating to sizing, because the high costs involved in road construction are mainly due to the overloading of heavy-duty vehicles that in turn cause very high short term costs, thus more traffic to manage.

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