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RESEARCH ARTICLE

CALCULATION OF PERMANENT DISTORTIONS AGGREGATED BY THE ALIZE METHOD AND THE FINISHED ELEMENTS METHOD

[1,*]Elime Bouboama, A., [2]Mamba Mpele and [1]Ipoule Nguibissa, P. Y.

[1]Civil Engineer LMMS Laboratory, National Advanced School of Engineering, Cameroon
[2]LMMS Laboratory, National Advanced School of Engineering, Cameroon

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ABSTRACT

In this article, shortcomings of various traditional road sizing methods will be examined and the main conclusion arrived at is the following: they are too simplistic in a set of situations where the elastic layers model cannot be justified. In order to fine tune these methods and make them build on progress made in the domain of geomaterial rheology, it is necessary to use realistic behavioural laws that have been developed in sizing techniques relating to the calculation by the Finished Elements Method for roadway constituent materials. A computation of vertical permanent distortions aggregated over 15 years of traffic on a Cameroonian roadway using the CEBTP-ALIZE method, and then the Finished Elements Method (FEM) was carried out. Results show that distortions derived from the FEM are largely higher than those provided by ALIZE. In order to ascertain the liability of results given by classical methods, it is advisable to confirm them using the Finished Elements Method.

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INTRODUCTION

Lines of communication in general and road infrastructure in particular are an important and unavoidable factor for sustainable economic, cultural and social development of a country or of a continent. For the sake of sustainable development, it is very important for countries to build roads with long lifespan (at least 50 years) and for which maintenance costs can be borne by their budgets. Moreover, in spite of tremendous progress made in domains of soil and geostructure experimentation and modeling, methods used by the trade for roadway sizing have not evolved much. They use theories that are sometimes based on unrealistic theories:

- Soil behaviour is elastic,
- Limited methods of analysis associated with static loads while roads structures undergo dynamic stress.

This work aims at critically taking stock of the various methods used for the sizing of soft roadways and comparing some of the results obtained through modeling with finished elements using a more realistic behavioural model which does not request the use of sophisticated tests to determine its parameters.

Corresponding author: **Elime Bouboama, A.,**
Civil Engineer LMMS Laboratory, National Advanced School of Engineering, Cameroon.

The roadway

The roadway is a plane structure laid on a conceived and sized platform or a supporting soil, so as to allow the safe and secure flow of vehicles, in ideal visibility and comfort conditions for users, during the entire lifespan of the infrastructure. From a geometrical point of view, this plane structure is made up of a pile of layers whose number can go up to six. Moving from the basis to the surface (Figure 1) we can name: the platform or supporting soil, the forming layer, the foundation layer, the linking layer and the surface. The function of the various roadway layers and their roles were sufficiently dealt with in specialized literature (TRAN 2009, Jeuffroy 1983….)

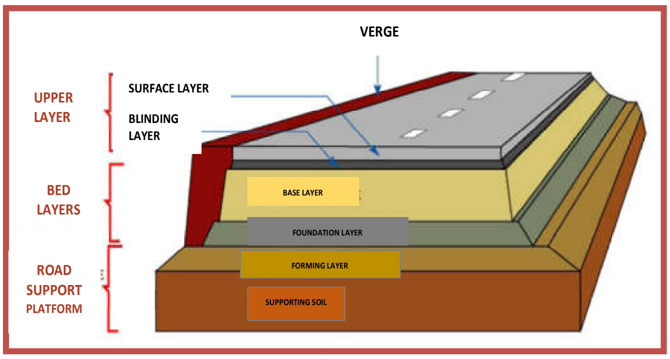

Figure 1. Components of a tarred roadway [KOVAL, 2008]

From a mechanical perspective, the main role of a roadway is the lateral spread of constraints resulting from rolling loads applied on the surface, in order to bring them down to levels that are compatible with the mechanical characteristics of the underlying soil or of natural soil in place. Depending on the mechanical behaviour of a roadway, we will have the following types of roadway: soft, semi-rigid and rigid; and depending on the type of surface, we will have tarred or untarred roads. In this article, we shall only deal with soft tarred roads that are subjected to mechanical constraints resulting from the flow of vehicles (although their impact is not negligible, we shall not take into consideration the effects due to climatic or chemical agents).

Constraints due to the traffic of vehicles

In real terms, traffic rolling loads are applied to roads through the tyres that exert pressure on the contact surface. In real terms and according to Perret 2003, contact pressure distribution between the roadway and the tyres depends on many factors such as: load intensity, tyre pressure, tyre type (profile, simple or twin, brand, etc.) and speed of the vehicle.
The above-mentioned factors have some impacts on the value of the load due to traffic; it would therefore be important that modeling reproduces the effects of these factors.

Modeling of constraints

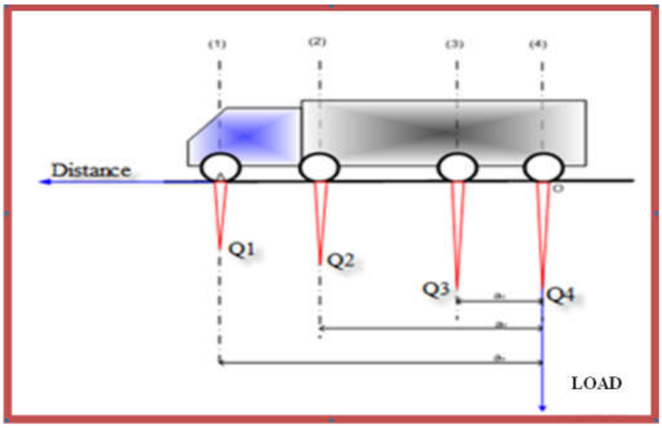

Figure 2. Standing vehicle (Ipoule, 2011)

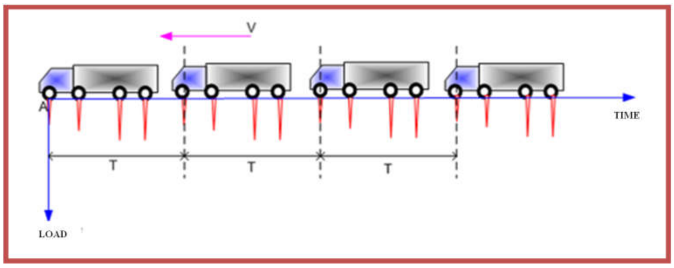

Figure 3. Case of a convoy of identical vehicles moving at a constant speed (Ipoule, 2011)

Let's consider a four-axle truck (Figure2) at standstill position on a roadway, each axle « i » of the vehicle exerts a static load Qi on the roadway through the tyres. Let's consider a convoy made of the above-mentioned trucks (Figure3) moving at constant speed V; we will notice that at point A:

1. Intensity peaks are always separated by phases of no intensity.
2. The time of application of the intensity peak depends on the speed of vehicles and the type of traffic.
3. No intensity phases also depend on the speed of vehicles and the type of traffic.

The conclusions above (Figure 4) apply to all the efforts exerted by a vehicle on a roadway (vertical, longitudinal and transverse efforts).

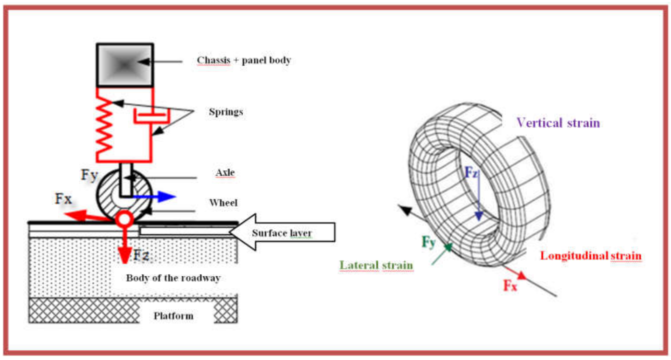

Figure 4. Efforts of a vehicle on the road (Ipoule, 2011)

This analysis shows that constraints due to the flow of vehicles are dynamic: load intensity peaks going always together with a no intensity phase. The duration of the peak or of the phase depends on the speed of vehicles, the type of vehicles, and the type of traffic.

MATERIALS

In the domain of road construction, if bituminous concrete and cement concrete are used for the construction of surface layers, on the contrary, stabilized and non-stabilized soil is generally used for the putting in place of base layers, foundation layers, binding layers or forming layers. Many studies have been carried out by many authors on the behaviour of these geomaterials subjected to various constraints. And the major conclusions to be drawn from these studies are as follows:

- Bituminous concrete is a composite and heterogeneous material, made up of a mixture of aggregates and a hydrocarbonate binding material. Its behaviour (Cuisinier Delphine et al.2007, Dubois Fréderic, 2004) is both thermo-elastoviscoplastic and elastoplastic. Moreover, this material can crack and the damaging; models proposed by many authors, especially by Perret 2003 can be used for modeling its behaviour.
- Settled cement concrete is an elastoplastic material that can be damaged;
- Treated and non-treated soil have an elastoplastic behaviour.

Methods used for roadway sizing

The sizing of a roadway consists in determining the nature and thickness of its various layers so that they can resist to constraints it will have to bear during its lifetime. To this end, engineers use methods that can be classified into two categories:

Empirical methods (CBR, Group index, …) based on the behaviour of a large number of existing roadways (some of which were constructed in order to lay down the method) so as to establish correlations between the traffic and weather conditions to withstand on the one hand, and the type of structures and the thickness of layers to adopt on the other hand.

Rational or semi empirical methods (Boussinesq 1885, Westergaard 1926, Hogg 1938, Burmister 1943, Jeuffroy 1955 et CEBTP 1982 models) which cannot do without the contribution «from the field» but are also based on the use of mechanical behaviour models for road materials and structures. This dual approach helps not only to size projects, but is also used in the elaboration phase of the method in order to reduce the importance of observations to be carried out on the field. Many of these methods are based on the fact that soil is an elastic, homogeneous and isotropic milieu.

All the classical methods used for sizing roads we have just mentioned also include a corpus of technical rules and recommendations dealing with implementation and construction conditions of these geostructures (technological constraints; constraints for transverse profiles and slopes …)

Loopholes of classical roadway sizing methods

Roadway sizing methods (empirical and rational) according to Ipoule Y. 2011 have some loopholes on several aspects:

Roadway constituent layers are supposed to be elastic and isotropic, while they show an inducted anisotropy resulting from their compacting and traffic effects.

The elastic materials hypothesis is unrealistic for modeling thermo-elasto-viscoplastic bituminous concrete) or elastoplastic (for underlying or foundation layers' materials) materials.

The potholing verification formula (derived from the material's elastic behaviour) is exclusively based on traffic constraints. This reduces the effects of weather (temperature and water).

The traffic is characterized by an equivalent number of reference axles which is a non-dynamic static load.

Modeling using the Finished Elements Method

Traditional roadway sizing methods appear to be too simplistic in a set of situations where the elastic layers model has no justification. For roadway constituent materials, it is necessary to include quite realistic behavioural laws; to make a bi or tri-dimensional representation of the geometry taking into account discontinuities of the issue under study in order to better simulate loads applied and side effects in a liable manner. These concerns prompted engineers to develop 'CESAR - LCPC2005, PLAXIS for the calculation of the Finished Elements Method in the area of roadway sizing (Brinkreve 2003). In this article, we shall calculate distortions due to traffic on the Nandéké – Mbéré stretch of the Garoua – Boulaï-Nandéké NR1 using Alize LCPC (2005) and Plaxis software.

Traffic and materials' characteristics

Based on the February 2007 updated economic studies (BRECG 2009), the maximum traffic of the main road Garoua-Boulai – Ngaoundéré will reach 1 615 000 axles equivalent to 13 tons (for the Nandéké - Mbéré section) over a period of 15 years. And the geotechnical characteristics of this section are provided in Table 1.

Table 1. Materials characteristics (BRECG 2009)

Layers	Type of material	Young Module	Poissons Coefficient
Rolling surface	Bituminous concrete	2 500 MPa	0.45
Underlying layer	Crushed gravel 0/25	500 MPa	0.35
Foundation layer	Lateritic gravels	240 MPa	0.35
Platform	Lateritic gravels	75 MPa	0.35

Alize method

By defining the thickness of the various layers using the CEBTP method and by verifying distortions using the Alize method, we have the results shown in Table 2.

Plaxis

Trafic Modeling

Let's consider a 6.5 tons load representing the reference charge of a twin wheel half axle on a circular surface of radius 12.5. The load pressure obtained is 0.662 MPa for each wheel. The traffic taken into account is made up of 1 615 000 axles of 13 tons over a period of 15 years. We shall consider that a cycle is represented by the passage of one axle that will be modeled in PLAXIS by a load and a discharge; therefore, we need to simulate a load of 1 615 000 cycles corresponding to the passing of our axles for 15 years with a loading frequency of 0.5Hertz; that is a period of t=2s. This process is modeled in the graph of Figure 5**:**

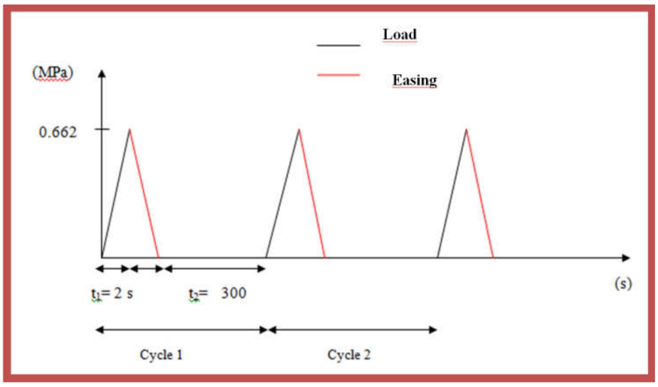

Figure 5. Traffic modeling (Ipoule 2011)

To represent crossing time, we carried out various simplifications using the work by Fang (2001). Passing time simplification is the operation of replacing the load's step by step application on the way by a single load increment applied on the passage way. The second simplification is related to the number of crossings N. In this case, we are proposing to replace to replace the computation of the N increments of time T by a computation with an equal single time increment N×T, which helped us to significantly reduce the computation time (Fang 2001).

Roadway modeling

Let's consider a cross section of a roadway as represented in Figure 6. This roadway is modeled in PLAXIS by taking the roadway section situated beneath the load.

Table 2. Distortion calculated by ALIZE (Ipoule Y.2011)

Structure Nature	Thickness (cm)	Module E (bars)	Poisson Coefficient	Stress	Calculated Value	Admissible value
BB	5	25 000	0.45	ε_t	1.91 E-04	
GC	20	5 000	0.35	ε_z	6.68 E-4	6.7 E-04
GL	20	2 400	0.35	-	-	-
GL	20	750	0.35	-	-	-

With BC: Bituminous concrete; CG: Crushed gravels; LG: Lateritic gravels.

Table 3. Models' parameters

Layers	Model used	Thickness (cm)	E_{50} (MPa)	υ	C (KPa)	φ (°)
Surface layer: BC	Linear elastic	5	2500	0.45	-	-
Supporting layer CG	HSM	20	365	0.35	20	44
Foundation layer: LG	HSM	20	175	0.35	60	48
Supporting soil: LG	HSM	150	55	0.35	70	45

Conditions at boundaries and the structure's grid used are shown in 7 and 8.

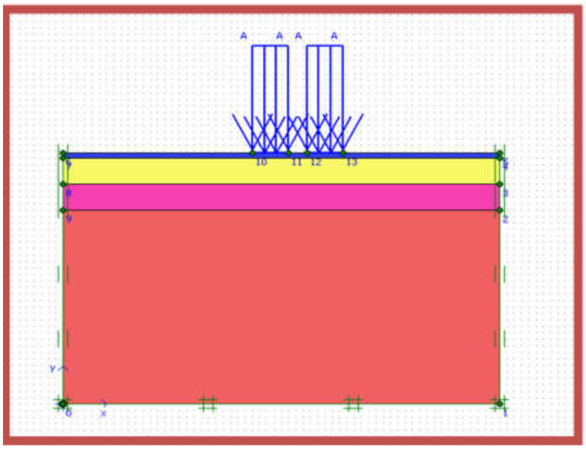

Figure 7. Conditions at boundaries

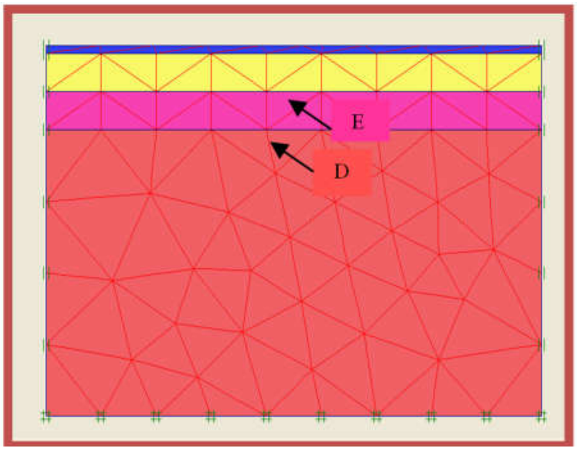

Figure 8. Structure's grid

NOTE : Point D represents the interface between the supporting soil and the foundation layer;
Point E represents the interface between the foundation layer and the underlying layer.

Laws on the behaviour of materials and grid

In our study, we will use the Hardening Soil Model (HSM) of PLAXIS for modeling the behaviour of the underlying layer, the foundation layer and the supporting soil of our roadway. In fact, this is a hyperbolic elastoplastic model formulated within the framework of plasticity with work-hardening. Parameters for this model are obtained from classical tri-axial tests, and values used for the various layers of the roadway are shown in Table 3. For the surface layer, we will use the linear elastic model. The model's parameters for this layer are given in Tableau 3 below:

Presentation of results

Results analysis

Computation results summarized in Figures 9 to 12 show that permanent distortions cumulated over 15 years between the supporting soil and the foundation layer are of $2{,}7.10^{-3}$ (Figure 8). When we look at the distribution of vertical stress (Figure 11) we note that higher stress values are concentrated at the level of the surface layer and that they reduce as we move deeper. When we compare (Tableau 4) permanent distortions given by both software, we notice that the value obtained with the Finished Elements Method (Plaxis) is far higher than the admissible distortion and that it is 304% higher than that given by ALIZE LCPC software.

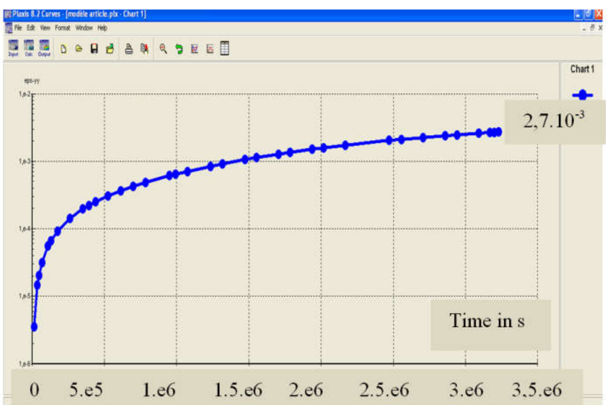

Figure 9. Evolution of vertical distortions at D depending on time

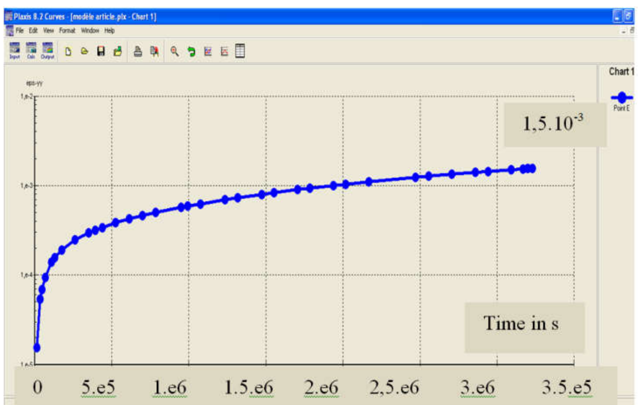

Figure 10. Evolution of vertical distortions at point E depending on time

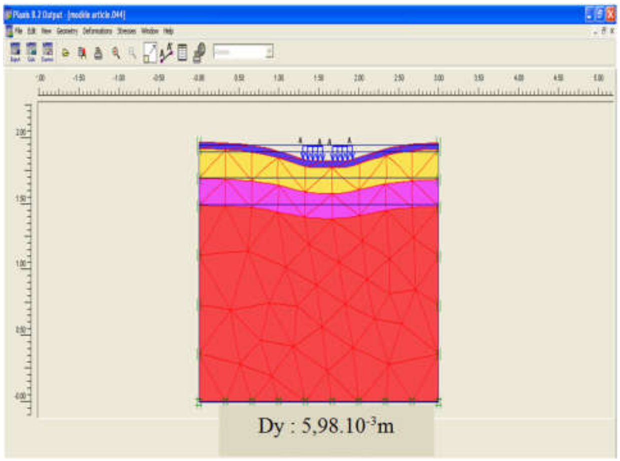

Figure 11. Vertical shift: Dy

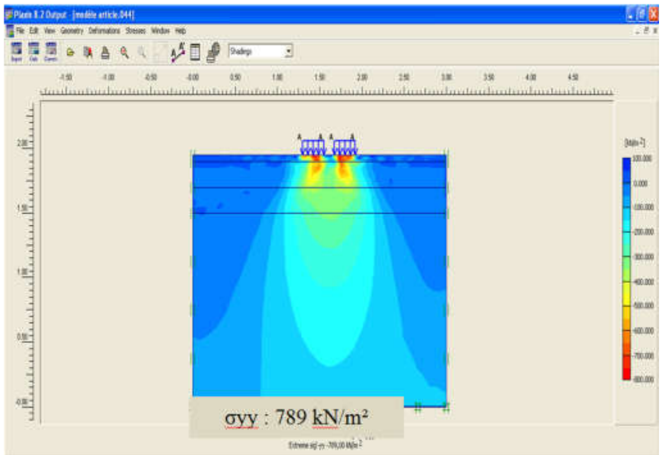

Figure 12. Actual vertical stress: σyy

These discrepancies are probably due not only to quite realistic behavioural laws introduced in the underlying and foundation layers and in the supporting soil, but also to the fact that the simulated load may be more realistic.

Table 4. Permanent distortions provided by both methods

Cumulated permanent distortions	
ALIZE-LCPC	Finished Elements Methods (Plaxis)
6.68×10^{-4}	2.7×10^{-3}

Conclusion

Classical Roadway sizing methods which are characterized by their simplicity pose no difficulty in their implementation; they should therefore be used for roadway sizing. Unfortunately, mechanical models used by these methods are unrealistic in order to confirm the liability of results obtained with classical methods, we are recommending, for safety purposes, to always verify these results with computation software through the Finished Elements Method.

REFERENCES

ALIZE LCPC 2005 logiciel de dimensionnement de chaussée. Diffuseur ITECH

Brinkreve R. B. J., 2003. PLAXIS Version 8: Manuel de référence. PLAXIS b.v, DELFT, Pays-Bas, 192 p.

CESAR -LCPC 2005, progiciel modules de calcul ainsi que de pré et post processeur graphique spécifiques aux applications routières. Diffuseur ITECH

Cuisinier Delphine, Berthaud Y et François M., 2007 ; Orniérage des chaussées : identification des paramètres Elastoplastiques d'un enrobé bitumineux à partir d'un essai structurel. 18ième Congrès Français de Mécanique. Du 27 au 31 août 2007 Grenoble-France.

Dat Tran Q., 2004. Modèle simplifié pour les chaussées fissurées multicouches. Thèse de doctorat. Ecole Nationale des Ponts et Chaussées, 162 p.

Diakhate M., 2007. Fatigue et comportement des couches d'accrochage dans les structures de chaussée. Thèse de doctorat. Université de Limoges, 241 p.

Dubois Fréderic 2004. Modélisation Numérique des comportements viscoélastiques vieillissants des matériaux du génie civil. Mémoire de Recherche présenté en vue de l'Habilitation à Diriger les Recherches. Faculté des Sciences de l'Université de Limoge. Juillet 2004.

Fang H., 2001. Rational Approach To Rutting Rehabilitation Decisions, Thesis submitted to the faculty Purdue University on partial fulfilment of the requirement for the degree of doctor philosophy.

Ipoule Y., 2011, Etat de l'Art des méthodes de dimensionnement des Chaussées : Critiques et proposition. Mémoire d'ingénieur de conception de génie civil. Ecole Nationale Supérieure Polytechnique de Yaoundé, 101p.

Jeuffroy G., 1983. Conception et construction des chaussées Tomes I : Les véhicules, les sols, le calcul des structures. Eyrolles, 61, boulevard Saint-Germain -75005 PARIS, 460 p.

Koval G. J., 2008. Comportement d'interface des matériaux granulaires. Thèse de doctorat. Ecole Nationale des Ponts et Chaussées, 264 p.

Ladjal Samira, 2004. *Modélisation des non-linéarités de comportement des sols fins sous sollicitations homogène application à la simulation des résultats d'essais triaxiaux classiques*. Mémoire de fin d'études. Université Mohamed Boudiaf de M'sila Ecole Nationale Supérieure Polytechnique de Yaoundé, 166 p.

LCPC, 2010. Manuel d'utilisation du logiciel ALIZE-LCPC version 1.3., 82 p.

Malek. L., 2004. *Analyse par le calcul des structures du comportement cyclique à long terme des infrastructures de transport.* Thèse de doctorat. Ecole Nationale des Ponts et Chaussées, 245 p.

Nguyen D-T., 2006. Prédiction des déformations permanentes des couches de surface des chaussées bitumineuses. Thèse de doctorat. Ecole Nationale des Ponts et Chaussées, 169 p.

Perret J., 2003. Déformations des couches bitumineuses au passage d'une charge de trafic. Thèse de doctorat. Ecole polytechnique fédérale de Lausanne, 223 p.

SETRA-LCPC, 1994. *Conception et dimensionnement des structures de chaussées*. Guide technique, 260 p.

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