Comparison of Geotextile-Reinforced and Geogrid-Reinforced Flexible Pavements by Numerical Analyses

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Abstract. Over the past three decades, geosynthetics have been used successfully around the world in many areas of civil engineering, and are now a well-accepted building material. Their use provides excellent economic alternatives to conventional solutions to many engineering problems. Therefore, students and practicing engineers need exposure to the fundamentals of geosynthetics as a building material. The Geosynthetics is a generic term for all synthetic materials used in conjunction with the soil, rock and/or other-related civil engineering material as an integral part of a project, structure or system. Geomembranes are used to distinguish their sealing qualities or permeability and geotextiles used for their mechanical functions. This study is to analyze the behavior of the pavement structure reinforced with layers of geotextiles. This analysis is done through a numerical modeling with the code PLAXIS V8. The latter is based on the principle of finite elements, this criterion will help us to better understand the behavior of the pavement structure and the ground vis-à-vis the parameter analysis of stress and strain. The principle of this analysis is based on a comparison designed pavement with and without geotextiles and will focus on the radial stresses settings, vertical stresses and displacements for two types of materials processed bitumen treated materials bitumen structures and materials treated with hydraulic binders.

Keywords: Flexible pavement · Hydraulic binders · Stress · Displacement · Geotextile · Plaxis · Modelling

1 Introduction

The pavement body is a multilayer structure. Its overall behavior depends on the nature of the materials that compose it, and their importance to achieve a good bond at the interface between pavement layers throughout his life. The stress caused by the traffic and environmental conditions are the main causes of damage to the pavement layer, leading to more degradation modes, night security, and quality of service, reduce maintenance costs a building pavement is needed and on the other hand speak of geotextiles as strengthening of the pavement structure solution and begin a numerical modeling with a code based on the principle of finite elements. The latter is based on the principle of finite elements, this criterion will help us to better understand the

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behavior of the body floor and vis-à-vis ground analysis of the parameters of stress and strain (Jeuffroy 1911). This study will help us to analyze and understand the behavior of the body influence pavement geotextile towards the vertical stress parameters; radial strain and displacement (January and Mamadou 2007; Boussinesq 1885; Peyronne and Caroff 1984).

A geosynthetic is the generic term for a product of which at least one of constituents is based on synthetic or natural polymer, in the form of band, or three-dimensional structure, used in contact with the ground or with other materials in the fields of geotechnics or civil engineering. Geosynthetics are classified into two main families:

1. Permeable products: geotextiles and geotextile-related products,
2. Essentially impermeable products: geomembranes and related products geomembranes (Bhandari and Han 2010; Alexiew et al. 2010).

The type of Geosynthetics utilised in this work is the Geotextile, they are products from the textile industry, from natural origins (fibers of cotton and jute) or synthetic (polyester, polyethylene, polypropylene, rarely polyamide). Products related to geotextiles are mainly geogrids, Geobags, geotubes, polymer geocontenters. Geotextiles are used and better known as geo membranes used in particular for waterproofing works. In all the works, geotextiles meet at least five basic functions: the separation, filtration, drainage, reinforcement and the fight against erosion. Geotextiles are classified according to their structure, that is to say, depending on the manufacturing process which, from polymeric fibers (mainly polypropylene) yielded a finished material. These "families" have names from the textile industry. Thus, the geotextilles can be woven geotextille products from son monofilaments, multifilaments son, or tape; nonwoven geotextiles can be needled or thermally bonded, or even knited.

2 Approach Adopted

In this work we tried to follow the successive steps to reach the objectives which are:

1. The influence of the behavior of geotextile flexible pavements.
2. The influence of geotextile on two types of body flexible pavements: *Structure Treated with Bitumen (STB) and* Structure with materials hydraulic binders (SMHB). For the PLAXIS software to do the calculations correctly and completely, we must take it all the project data.

2.1 Assumptions

The assumptions for modeling two structures are summarized in the following points (Quang and Tran 2004):

- The deformations are considered flat.
- All interfaces are glued except base courses are half-pasted.
- Material properties of each layer are homogeneous,

- The layers are infinite in lateral directions
- Solutions constraints are characterized by two main properties of each layer "of the fish coefficient and the elastic modulus E".

2.2 Geometry

The structures are modeled by planar geometric patterns in two dimensions (2D) 35 m wide and 15 m deep. An example of the models is shown in the following Fig. 1.

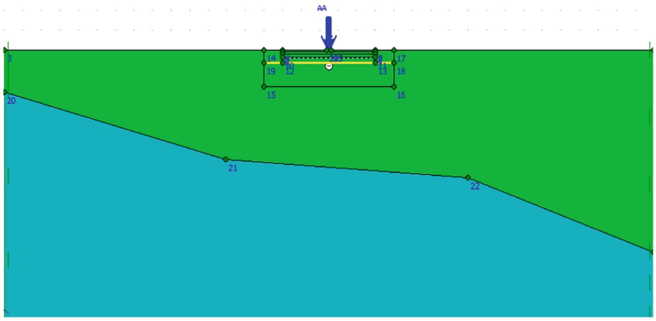


Fig. 1. Physical model

2.3 Properties of Soil Layers

The massif is composed of two types, characteristics are shown in Table 1.

Table 1. Properties of soil layers integrated in the model

Parameters	Name	Soil 1	Soil 2		Unit
		Mohr coulomb			
Type of behavior		Drained	Drained	Drained	
Dry unit weight	$\gamma unsat$	18	13	17	kN/m^3
Wet volume weight	γsat	21	17	19	KN/m
Poisson's ratio	V	0	0	0	-
Horizontal permeability	Kx	0	0	0	m/day
Vertical permeability	Ky	50	50	60	m/day
Young's modulus	Eref	0.35	0.35	0.35	Mpa
Cohesion	c_{ref}	30	5	5	-
Friction angle	Φ	25	20	35	kN/m^3
Angle of expansion	ψ	0	0	0	°
Rigidity factor interface	Rinter	Rigid	Rigid	Rigid	°

2.4 Pavement Dimensions

For the materials treated in the bitumen structure:

- Width: 5 m
- Thickness: 0.67 m

The material structure hydraulically bound:

- Width: 5 m
- Thickness: 0.82 m

Modelled roads are broken into four layers, Tables 2 and 3 summarize the mechanical properties and the thickness of each layer.

Table 2. Mechanical characteristics of layer structure TMB

Materials	E (MPa)	Poisson's ratio	Thickness (cm)
Asphaltic concrete	3600	0.35	8
Grave bitumen	6300	0.35	14
Grave bitumen	6300	0.35	15
Severe untreated	500	0.35	30

Table 3. Mechanical properties of the structural layers HTMB

Materials	E (MPa)	Poisson's ratio	Thickness (cm)
Asphaltic concrete	3600	0.35	10
Dairy grave	23000	0.25	21
Dairy grave	23000	0.25	21
Severe untreated	500	0.35	30

¬ Properties of geotextiles:
Geotextiles used are woven geotextiles with the properties listed in Table 4:
¬ Loading:

Table 4. Characteristics of geotextile

Parameter	Name	Value	Unit
Axial stiffness	EA	$6.87 * 10^{05}$	Kn/m
Behavior		Elastique	Mm
Thickness under 2 kPa		1	g/m^2
Area weight		200	kn/m^2
Tensile strength		16	Mm
Dynamic perforation (cone drop)		17	Kn
Static punching		0.9	Kn
Permeability		0.045	m/s
Filtration opening		75	Mm

The reference axle single wheel isolated 130 km. In the design, there is a reference half-axle and the modeled as a uniformly distributed load of 0.662 MPa to a disc of 0.125 m radius (Peyronne and Caroff 1984).

3 Data to Introduce

3.1 Materials Treated with Bitumen (TMB)

3.1.1 Properties of Materials Used for the Body Pavement in Tables 5 and 6

Table 5. Characteristic material used in the body of shoes

Parameters	Name	AC	GB	GB	Unit
		Linear elastic			
Type of behavior		Non porous	Non porous	Drained	
Dry unit weight	*γunsat*	22	22	22	kN/m^3
Wet volume weight	*γsat*	-	-	22.8	KN/m^3
Horizontal permeability	Kx	-	-	-	m/day
Vertical permeability	Ky	-	-	-	m/day
Young's modulus	Eref	4000	7000	500	Mpa
Poisson's ratio	*V*	0.35	0.35	0.35	-
Cohesion	c_{ref}	-	-	-	kN/m^3
Friction angle	*Φ*	-	-	-	°
Angle of expansion	*ψ*	-	-	-	°
Rigidity factor interface	Rinter	Rigid	0.8	Rigid	

Table 6. Characteristics of materials used in the body of shoes

Paramètres	Nom	BB	GL	GU	Unit
Type Model	*Model*	élastique linéaire			
Type of behavior	*Type*	Non	Drained	Drained	
Dry unit weight		poreux	23	22	
Wet volume Weight		22	23.8	22.8	
horizontal	*γunsat*	-	-	-	kN/ m^3
permeability	*γsat*	-	-	-	kN/ m^3
vertical permeability	*Kx*	-	23000	500	m/day
Young's modulus	*Ky*	4000	0.25	0.35	m/day
Poisson's ratio	*Eref*	0.35	-	-	Mpa
Cohesion	ν	-	-	-	-
Friction angle	c_{ref}	-	-	-	kN/m3
Angle of expansion	*φ*	-	0.8	Rigid	°
Rigidity factor	*ψ*	Rigid			
interface	*Kinter*				

3.1.2 Mesh

The generation of the structure with materials treated with bitumen MTB model mesh is made by 15-node elements. The number of elements is 261 elements, and the number of nodes is 2209 nodes. A possibility of mesh refinement obtained may be carried out with the PLAXIS software, where the final number of elements is 551 and the number of nodes is 4581 nodes. Figure 2 shows the mesh mad (PLAXIS V8).

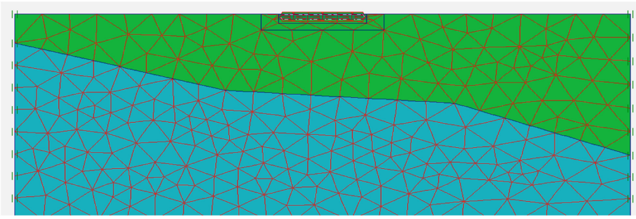


Fig. 2. Final mesh structure

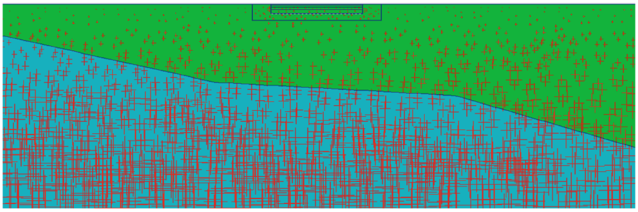


Fig. 3. Initiation effective stress

3.1.3 Initial Conditions

The initial conditions require the generation of initial stresses (Fig. 3):

For the calculation of the initial stresses, disable and structural elements the pavement element created by default.

Is generated by taking the initial constraint values Ko automatically proposed according to the formula Jaky. We keep the weight of the soil to 1, which corresponds to a total application of gravity (Plaxis, V8).

3.1.4 Calculation Procedures

– The Calculation of the reference model is defined in 3 stages in the order as follows:

Phase 0 (initial phase):

– Initiation of constraints (K_0 procedure); the initial effective stress is determined.

Phase 1:

– Establish a relaxing pavement layers directly on the sub grade.
– Activation of the charge of a single tire with a pressure value is = 0.662 MPa.

Phase 2:

- Take phase 0 as a starting phase
- To restore the structure by placing the pavement layers, this time on a thick layer of fill of 1 m
- Activation of the load of the single tire with a value of 0.662 Mpa.

Phase 3:

- Take phase 0 as a starting phase
- Add a layer of geotextile under the layer of GNT
- Activate the load the tire.

3.2 Structure Treated Materials Hydraulic Binders (SMHB)

3.2.1 Ownership of the Materials Used for the Body Pavement

The following table shows the characteristics of the materials used in the body of shoes.

3.2.2 Mesh

The generation of the MTB model mesh is made by 15-node elements. The number of elements is 259 elements, and the number of nodes is 2193 nodes. A possibility of mesh refinement obtained may be carried out with the PLAXIS software, where the final number of elements is 549 and the number of nodes is 4565 Nodes presented in Fig. 4.

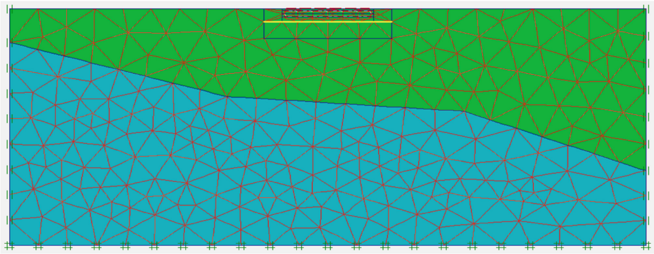


Fig. 4. Mesh generation

3.2.3 Initial Conditions

Procedure same as previously described structure (Figs. 5 and 6).

3.2.4 Calculation Procedures

- The Calculation of the reference model is defined in 3 stages in the order as follows:

Phase 0 (initial phase):

- Initiation of constraints (K0 procedure); the initial effective stress is determined.

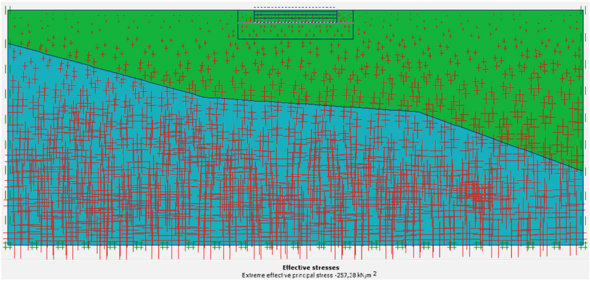
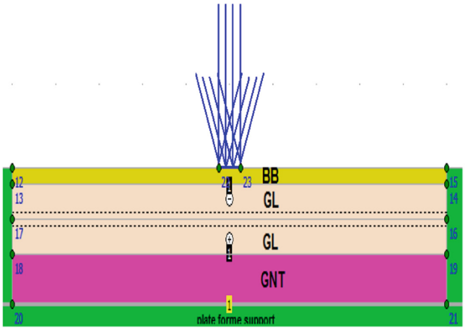
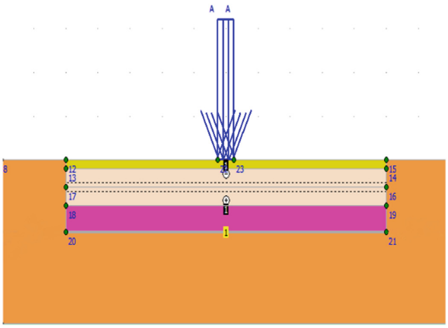


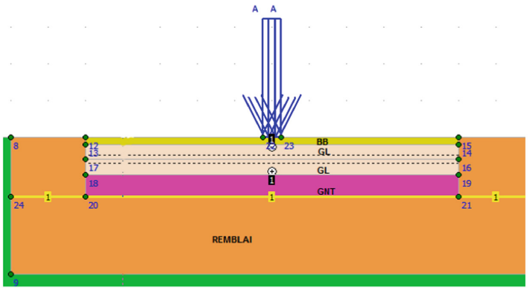
Fig. 5. Initial stress





a. Initial STR1structur **b. Structure of STR2**

embankment



c. Structure reinforced with geotextile STR3

Fig. 6. Types of structures

Phase 1:

- Establishment of pavement layers resting directly on the subgrad.
- Activation of the charge of a single tire with a pressure value is = 0.662 Mpa.

Phase 2:

- Take phase 0 as a starting phase
- To renovate the structure by placing the pavement layers this time on a thick layer of fill 1 m
- Activation The charge of a single tire with a value of N = 0.662 Mpa.

Phase 3:

- Take phase 0 as a starting phase
- Add a layer of geotextile under the layer of GNT
- Activate the load the tire.

4 Results and Analysis

Modeling has gone through various stages, and according to the results found guidance was performed to achieve the best results. These key steps are:

- Pavement located on natural ground. "STR1" Pavement located on natural ground strengthened by an embankment "STR2".
- Consolidated pavement located on natural ground by an embankment and reinforced by geotextile "STR3".
  - The comparison is based on the three parameters for both TMB and STHB structures.
  - to.

    a. the vertical displacement
    b. the radial stress;
    c. the vertical constraints;

4.1 TMB Model

(1) Displacement

Figure 7 shows the behavior of the constituent layers of the pavement and the ground under the effect of a charge of a single tire.

As regards the displacement can be estimated three intervals which are: On the surface of the three curves start with a maximum displacement worth 6.19 to 1 STR (initial structure); 5.48 to STR2 (structure embankment); and 4.87 for STR3 (structure reinforced by géotextile). The displacement will decreases approaching the géotextile web; below the water table and the two curves STR2 STR3 follow the same pace; time that STR1 curve follows a path aggressive; Until the three curves meet at the same point. Beyond this point the three curves follow the same pace; and displacement of values weakens until they cancel out.

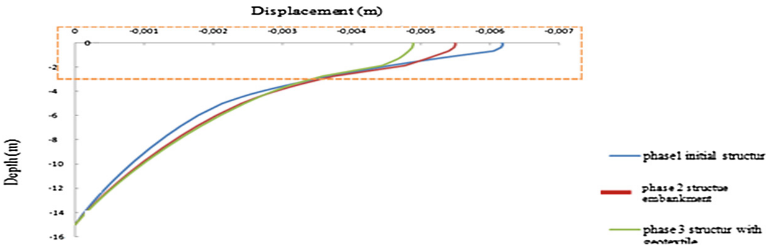


Fig. 7. Vertical displacement for the three structures MTB

(2) Radial Stress

Three structures STR1, STR2, STR3. From Fig. 8 we see a good correlation between the three curves (STR1, STR2, STR3) with remarkable gap with STR3 curve, this difference shows a good distribution of the radial stress distribution at the surface the load. The vertical stress note for the three profiles digressive distribution of vertical stress; the load is maximum at the surface.

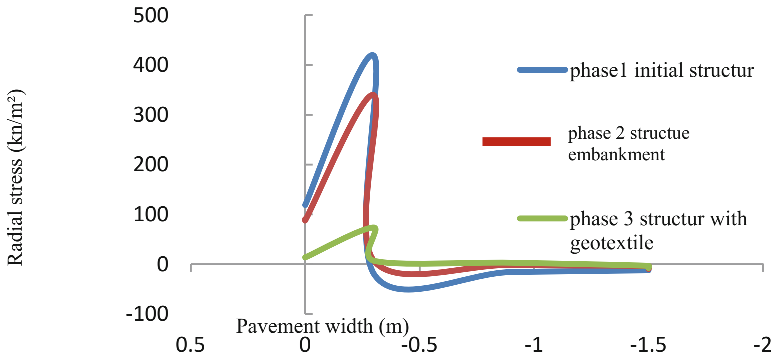


Fig. 8. Comparison of the distribution of the radial stress for the three structures STR1, STR2, STR3.

The load is picked up by the top layer of the floor and then diffuses into the other layers of floor to the distribution in the soil until the cancellation. The geotextile is influenced by the vertical stress at the base layer.

4.2 Structure Bills of Materials for Hydraulic Binders (STHB)

(1) Vertical Displacement

From Fig. 9, we see that the three curves follow similar appearance to those of bitumen processed structure, but with a minimum displacement and close values (4.87 mm for STR1, STR2 4.52 mm, 4.32 mm STR3).

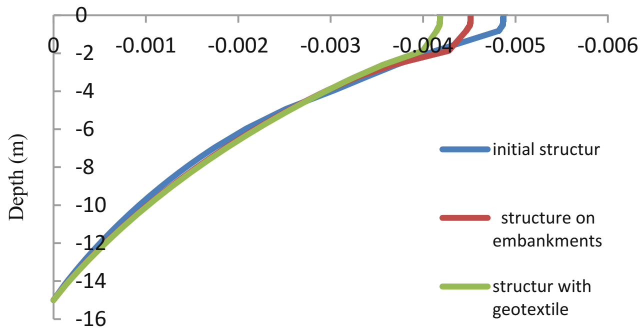


Fig. 9. Comparison of traveling between the three structures STR1, STR2, STR3 hydraulically bound

The radial stress in the structures treated with hydraulic binders is manifested by a significant compression that develops at the surface layer. Hose compressive stresses develop tensile stresses between the interfaces of the upper layers of the pavement. We notice the same behavior for the three structures, with minimum values for the pavement structure with geotextile. Through Fig. 10 we see that the three curves are perfectly superimposed on the body of the pavement. A slight difference occurs at ground level (Figs. 11, 12 and 13).

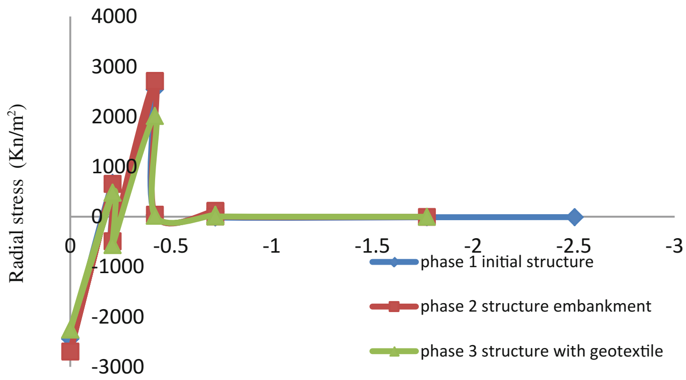


Fig. 10. Comparison of radial stress for the three structures STR1, STR2, STR3 treated with hydraulic binders.

4.3 Comparison Between Both Structure Treated with Hydraulic Binders (STHB) and Structure Treated Bitumen (STB) Models

(1) Vertical Displacement

We note that the use of geotextile greatly reduces the displacement for the two types of structures. Also we note that travel for STHB structures are smaller than for MTB structures.

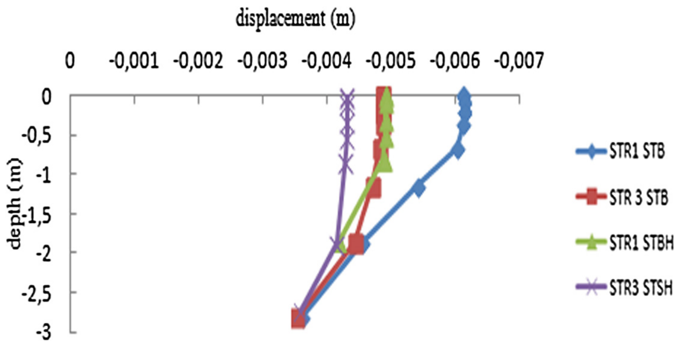


Fig. 11. Shows the comparison of displacement profiles for both types of STB and STHB structures with and without webs of geotextile.

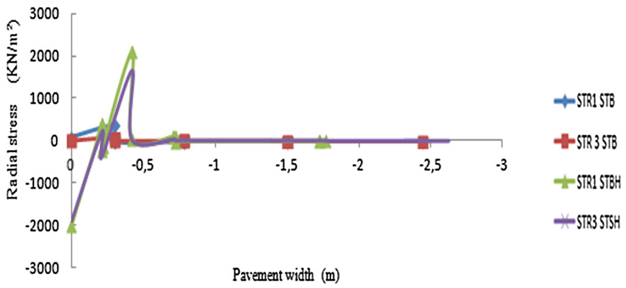


Fig. 12. Radial stress comparison between both TMB and STHB structures (STR 1: without geotextile, STR3: with geotextile)

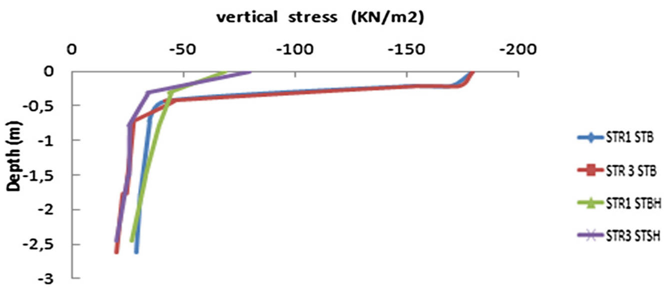


Fig. 13. Vertical stress comparison between both STB and STHB structures (STR 1: without geotextile STR3: with geotextile)

(2) Radial Stress

The comparison shows a very big difference between the results of the MTB model and those of MTLH model; wave propagation in radial stresses, deep below the body of the floor, almost the same pace for all the observed curves. therefore the interpretation is made on the [0 −2.68] which is representative for the reinforcement with a geotextile mat on this section we can see that the difference is more marked in the coating zone, or coercion takes very deferential values: Starts with negative values for MTLH and positive values for the MTB in two different paces.

(2) Vertical Stress

The vertical stress is maximum at the surface (the contact pressure). In depth, this constraint decreases almost linearly through the coating, the structure undergoes STHB larger vertical stress values than those suffered by the STB and takes a STHB the appearance of a small slope to the level or we placed the geotextile from the coating-geotextile interface fourths curves follow the same path from the ground pavement in the body, or the vertical stress continues to decrease and tends to be canceled on the basis of the model.

5 Analysis

By paying attention to the location area of the geotextile, we note that the curves have experienced remarkable changes. However the two structures and STB sudden STHB different results:

1. Structure treated with Bitumen: concerning this structure we have:
   - A minimum shift large reduction in radial stress
   - Not a large difference of the vertical stress before and after the addition of the geotextile.
2. And for Structure Treated with Hdraulic Bituminen was:
   - Small decrease of displacement.
   - The addition of the geotextile seems has no influence to the decrease in radial and vertical constraints.

Ultimately, we can attribute the great difference between the two structures to the quality of materials used and the proportionality of the geotextile with each structure, and believe that with the use of a geotextile STB structure the same can be achieved STHB performance of a structure subjected to the same conditions (traffic, climate, soil bearing). In the end we say that the analysis performed is only approximate because many input parameters were approached (cohesion, friction angle, etc.).

6 Conclusions

The principle of building roadways as for other civil engineering structures is to determine the stresses caused by a vehicle and compare them with the parameters limit values of the various constituent materials of the structure. This level of stress is evaluated by a mechanical model of the pavement. The latter that researchers are trying to develop it to make it more representative of physical reality.

Especially as the theory assumes many simplifying assumptions. The development of the mechanical model was not possible without the development of the numerical model and the widespread use of digital computers which helped to solve very complicated problems.

Modelling in the field of road is mediocre, given the complexity of the structure and the many parameters involved "traffic, climate, soil, materials, etc."

The objective of this work was to create a model that takes into account body composition of the roadway, the insertion of the geotextile in two types of structure, treated with bitumen and the other treated with u hydraulic binder, with a recent numerical tool scientifically. Our choice is fixed on the PLAXIS V8 software. The latter is based on the principle of finite elements; this test will help us to better understand the behavior of the body of the pavement and analysis vis-à-vis the stress and strain parameters behaviour (Alexiew and Hangen 2013).

Through this study, we can conclude is that:

The location of géotextille tablecloths in the flexible pavement structure influences in a remarkable way of moving Rating Decrease. Similarly, the radial stress influence is remarkable.

The geotextile is influenced by the vertical stress at the core layer. The use of geotextile can significantly reduce the displacement for the two types of structures (Arab 2015).

Travel for SMHB structures are weaker than for STB structures. The comparison shows a very big difference between the results of the model and those of TMB STHB model; the spread of radial stress waves are different for the different behavior of the materials treated with binders and materials treated with hydraulic bitumen.

The strengthening effect in the traffic lanes structures are generally, but only under certain conditions of deformation and interface (Pameira 2009). The use of geosynthetics can effectively improve the deformation behavior of road structures. In the road sector, studies on the two-dimensional reinforcement sheet (geotextiles, geogrid, geocomposite and a single table or multi-table) do not yield easily generalizable. However, the results are very satisfactory in terms of extending the service life, reduce the appearance.

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