Mechanical Behavior of Corps Roadways Reinforced by Geosynthetics

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ABSTRACT

Road construction is subject to the availability of good quality material, especially regarding the construction of the base layer and foundation. The use of geosynthetic reinforcement in these layers has an interesting perspective address this failure. This work is in the context of evaluating the mechanical behavior of flexible pavements reinforced by alveolar type of geosynthetics in which we began modeling software FLAC 2D Version 4, which aims to evaluate the deformation. Also, and to validate the results by modeling the Plaxis V7.2 software was initiated to verify the results. For this, the assumptions are considered as materials of the pavement are modeled by a law of elastic-plastic mechanical behavior. Geosynthetics, meanwhile, are not modeled structural elements which are distinguished element cable. The pavement is subjected to a static loading a value corresponding to 13 tonnes per axle. So, to understand the role of the geosynthetic in the roadway, a parametric study was performed by varying the Young's modulus of geosynthetic and the thickness of the base layer.

KEYWORDS: pavement, reinforcement, geosynthetics, moving, FLAC2D PLAXIS 7.2.

INTRODUCTION

In most developing countries, equally Algeria, flexible pavements constitute almost all the road network. These roads are subject to the availability of good quality material, especially regarding the construction of the base layer and foundation. And then every time the shortage of good materials and problems operating their transportation and cost, the reinforcement solution is essential.

Geosynthetics have an interesting face these obstacles perspective; they are employed in a variety of purposes such as: increasing service life and resistance to fatigue; minimize differential settlement, and reduce the total settlement; reduce the ruts; so it's building a sustainable structure.

The purpose of this report is to evaluate, using numerical modeling on FLAC2D v4 software (code calculation by Finite Difference) and PLAXIS v7.2 (code calculation Finite Element), the behavior of the body a flexible pavement in the elastic-plastic domain with and without geosynthetic layers. As a parametric study was used for the same purpose. Both programs were not used to compare their potential but to validate the results.

OPERATION OF A FLEXIBLE PAVEMENT

These roads are named as they have the ability to reversibly deform under stress. They consist of a bituminous layer on the surface and a seat granular material. They have the ability to deform without cracking. They distribute the surface of efforts through the base layers and foundations. This distribution is done so that the load on the platform is compatible with the resistance of the infrastructure and soil sitting granular material [CTTP 2001] (Figure 1) (Figure 2).

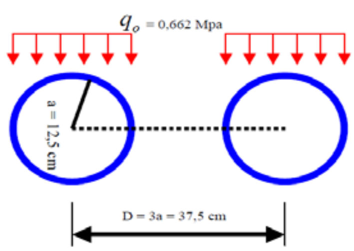


Figure 1: Principle of application of the load

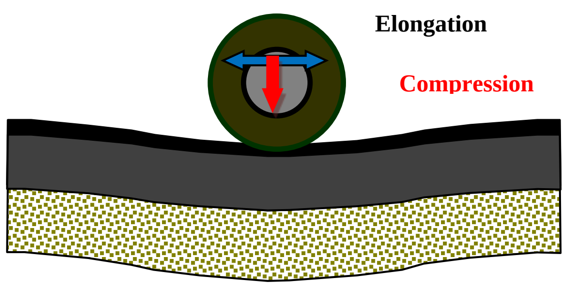


Figure 2: Operation of a flexible pavement under Application of a rolling load

REINFORCEMENT MECHANISMS

Methods of soil reinforcement geosynthetics can be divided into two broad categories: micro and macro reinforcement.

The micro-reinforcement is obtained by mixture of soil and reinforcing elements or by short fibers (5 to 10 cm) or small non-woven tapes (<5 cm $^{2)}$, or by small elements grids.

But the principle of macro-building by geosynthetic soil has three different mechanisms of action: the mechanism type "membrane", the mechanism type "shear armature" and type mechanism "frame anchor"

- The membrane effect acts effectively when geosynthetic is placed on a deformable soil and vertical loads are applied. The tensile stress in the ground is transmitted to geosynthetic, relieving the basement incapable to absorb it. This strength in the plan is balanced with the horizontal component of the load from the dissemination of applied vertical loads (plane problem and uniform load). This effect is therefore of great importance in the construction of temporary roads, where it can reduce rutting tremendously. The higher the initial modulus of the geosynthetic, the higher the possibility of reducing rutting is great. (DuPontTM Typar® SF GEOTEXTILE 2007).
- Strengthening of type "armature shear" and reinforcing the type "frame anchor" are obtained when a vertical stress is applied to the geosynthetic placed between two soil layers, the first has two different soil layers the second two layers of the same soil, then the geosynthetic can resume tangential stresses induced by the ground, ie that the two materials are sheared their interface;

MODELING AND LAW OF BEHAVIOR

Behavior law Soil and asphalt Bituminous

The FLAC2D v4 and PLAXIS v 7.2 modeling software enables problem solving stress-strain in a continuous medium, as they allow to define the different rheological laws in order to better model the behavior of materials. In our work we assume the most commonly used model, we use the elasto-plastic model to characterize the soil is considered isotropic materials with linear behavior (Soda M. 2011), and also to characterize the asphalt (Dang Truc Ngyen 2006).

The elasto-plastic model "Mohr-Coulomb" is characterized by five parameters, namely:

- elasticity:
  - E Young's modulus of elasticity,
  - ν Poisson's ratio,
- plasticityt :
  - C cohesion,
  - Φ angle of friction,
  - ψ dilatance angle.

Under triaxial stress, the model parameters can be displayed (Figure 3):

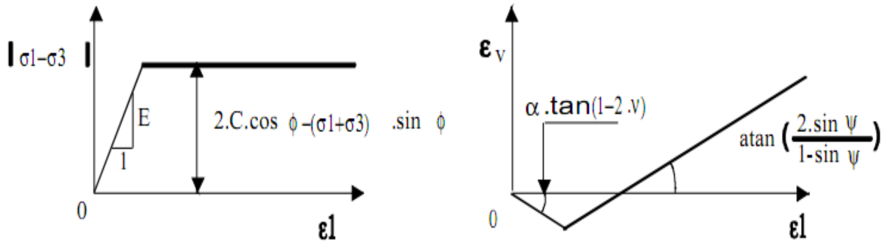


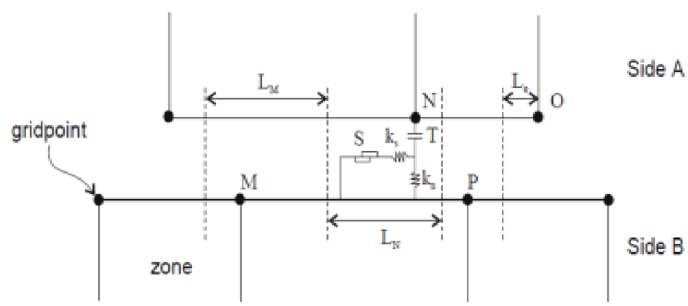
Figure 3: Rheological model applied to the soil

Modeling Interface

In general, the interface is the border, real or imaginary, between two elements. In the roadway structure, for interface between pavement layers, the contact area is defined between two layers of materials. The first theoretical approaches interfaces on simplifying assumptions were considered either (LCPC 94):

- The perfect grip,
- Total slip,
- Semi glued.

The hypothesis for the type of interface is the perfect adherence (glued) as we considered that the interface has an isotropic linear elastic behavior (Reif. Diakh 96- 2007, Frank 2013). FLAC provides interfaces which are characterized by coulomb which these properties are: friction, cohesion, dilation, normal stiffness and shear stiffness. An interface is represented in the FLAC D2 software as a normal stiffness Kn and Ks shear between two plans that may come in contact with another (Figure 4).



S= slider
T= Tensile strength
k n = normal stiffness
k s = Shear strength
L n = length N associated with the grid points
Lm = length associated with M grid points refers to the limits of common segments (located midway between adjacent grid points)

Figure 4: An interface represented by sides A and B, connected by Shear (ks) and normal stiffness springs (kn) [ITA-93]

Plaxis 7.2 allows us to define the interface is the resistance using the hard option. This is used so that the interface does not influence the resistance of the surrounding soil.

Law behavior geosynthetics and their interface

To simulate reinforcement plies geosynthetic by FLAC 2D, structural elements are implemented. The type of element to model the reinforcing plies: the cable elements.

This reinforcing element (figure 5) has a membrane behavior. The cable element formulation considers the effect of the reinforcement: the resistance to deformation is taken into account along the total length.

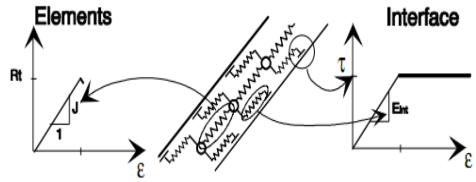


Figure 5: Model applied to the cable element and its interface [ITA-93]

The behavior of the geosynthetic element is governed by perfect elastic-plastic law (figure 6)

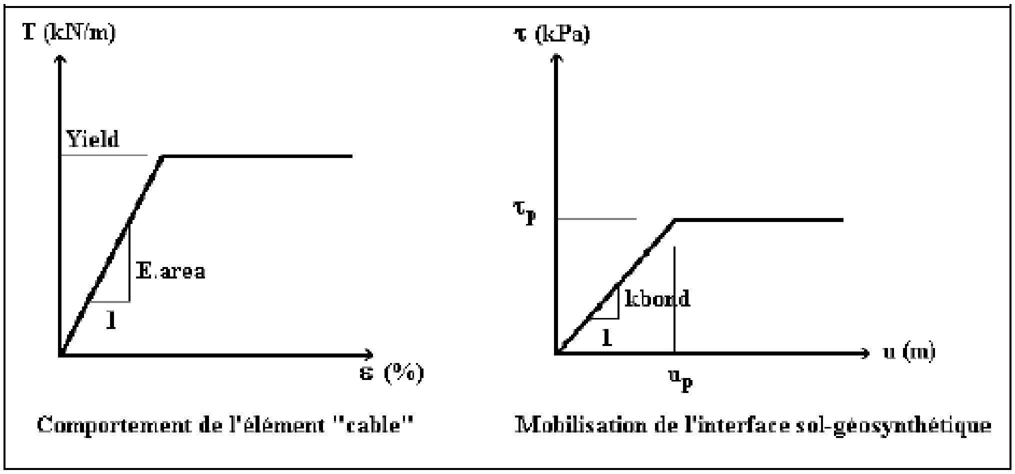


Figure 6: Modeling element "cable", FLAC 2D v4

The input parameters are:

- The section of the web,

- The perimeter of the sheet,

- The modulus of elasticity E of the geosynthetic,

- Plasticizing of web tension.

Included in the definition of the element "cable", the interface is also governed by an elastoplastic.

The parameters to enter the computer code are:

For the elastic range of the interface, the slope **k** jump;

In the plastic range of the interface, the shear stress is limited by the Mohr-Coulomb, namely: the friction angle **Φ s** sg by friction, cohesion **C** by sg **s** leap.

For PLAXIS 7.2 geosynthetic layers are modeled by a structural element called "geotextile element". This element is governed by a perfectly elastic behavior without any limitation of internal tension. Logically support any bending moment, the element is only characterized by its axial stiffness EA, that is to say, the stiffness modulus J geosynthetic (Figure 7).

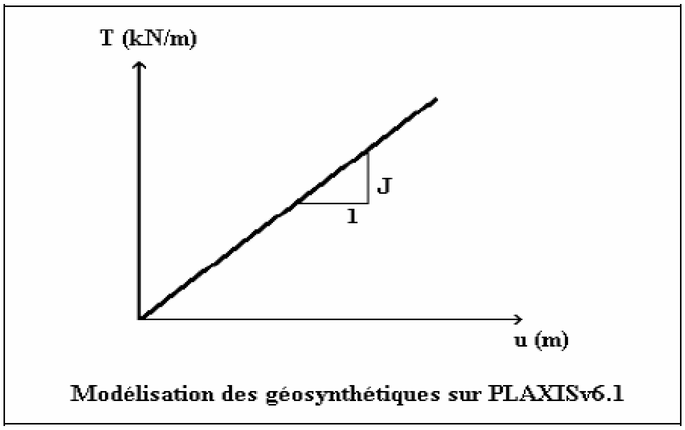


Figure 7: Modeling the behavior of the element "geotextile" on PLAXISv7.2

GEOMETRIC CHARACTERISTICS AND MECHANICAL BOUNDARY CONDITIONS

The roadway is subjected to a static loading a value corresponding to 13t per axle [CTTP 2001]. It is governed by the law of elastic perfectly plastic Mohr-Coulomb.

The cross section of the proposed roadway will include a platform 12,50 m supports bidirectional roadway 6m with both sides a shoulder of 1.0 m. The proposed geometries are presented in Figures 8 and 9 [B40 STANDARD].

Modeling is carried from the roadway in two steps without a building and another by introducing the geosynthetic.

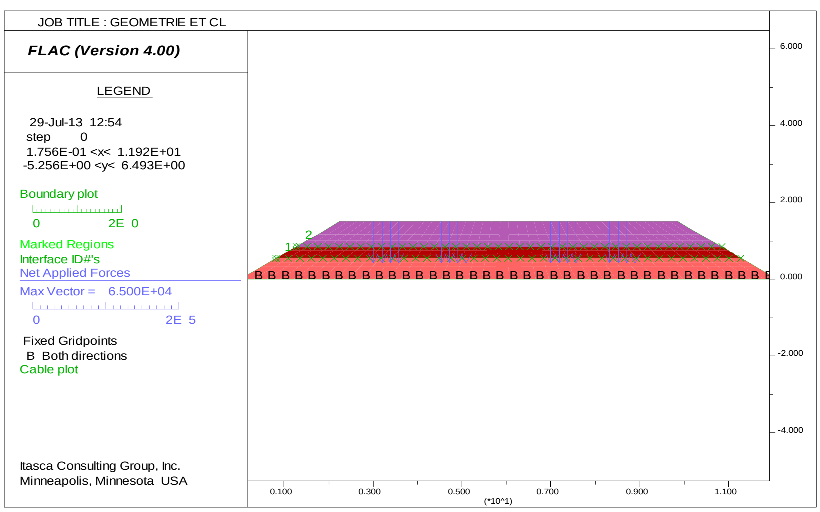


Figure 8: The geometry of an unreinforced roadway fixed base and suffered a load an axle of 13 tons (FLAC2D)

The study was carried out by considering the mechanical properties of various materials used in the model (soil, geosynthetics) (Table 1).
The mechanical parameters characterizing the behavior of soil and asphalt are from reference values for a soil category called "all-comers" and for serious bitumen and asphalt layers [CTTP 2001].

Table 1: Characteristics of materials

	Thickness (cm)	Young's modulus (MPa)	Unit weight (kN / m^{3})	Cohesion (kPa)	Friction angle (°)	Poisson coefficient
Subbase	55	20	18	10	30	0.35
Base layer	30	120	20	5	30	0.35
bituminous asphalt layer	20	5400	22	50	28	0.35

Applying the nonwoven geotextile ALVEOTER® AFITEX of the company in the base layer, to a height of 75cm from the ground supporting and representing characteristics Table 2,

Table 2: Characteristic of the geosynthetic

Young's modulus (Pa)	Tensile strength (N)	Section (m^{2})	Interface elastic modulus (Pa)	Maximum shear stress to the interface (N / m^{2})
2×10^{9}	**5000**	**2×10^{-4}**	**2×10^{8}**	**10^{6}**

The characteristics of the soil-soil interface were determined by considering good bonding characteristics. $K_n = 7.6 \cdot 10^{10}$ Pa / mm, $K_S = 7.6 \cdot 10^{10}$ Pa / mm (Mr. Diakhate 2007).

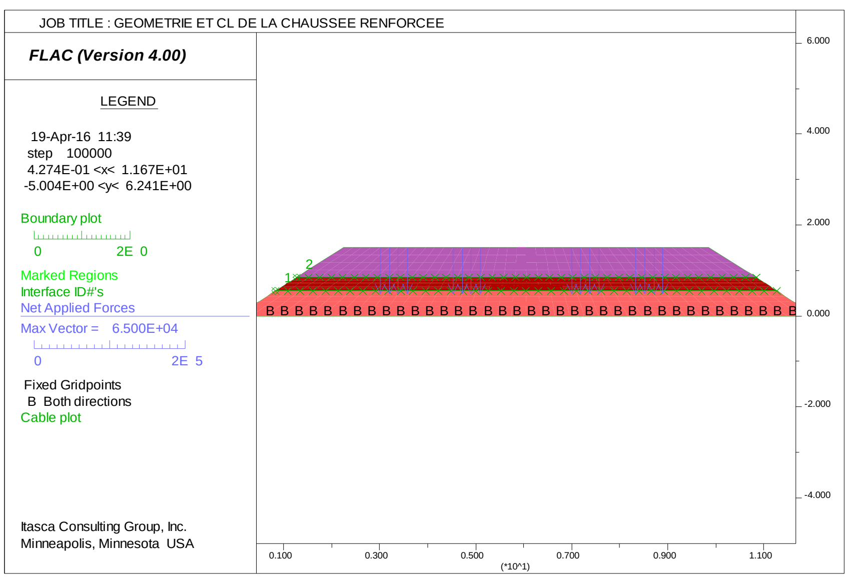


Figure 9: The geometry of a pavement reinforced by ALVEOTER in the base layer

Simulations and interpretations

After initializing the geometry and boundary condition and upon completion of calculation, we get the results that carry data and the maximum total vertical displacement. The choice of these maximum values turns out to be fairly representative indicators of the state building.

The graphs from the calculations (10, 11, 12, and 13) carried on FLAC 2D v4 and PLAXIS v 7.2 show a pretty good likeness (10, 11, 12, 13). The relative differences recorded on the values compiled by FLAC 2D v4 and PLAXIS v7.2 is remarkably low, less than 2% (Table 3).

Table 3: Results of the total displacement

	total displacement u (cm) FLAC 2D	total displacement u (cm) 7.2 PLAXIS
without geosynthetic	15.59	14.73

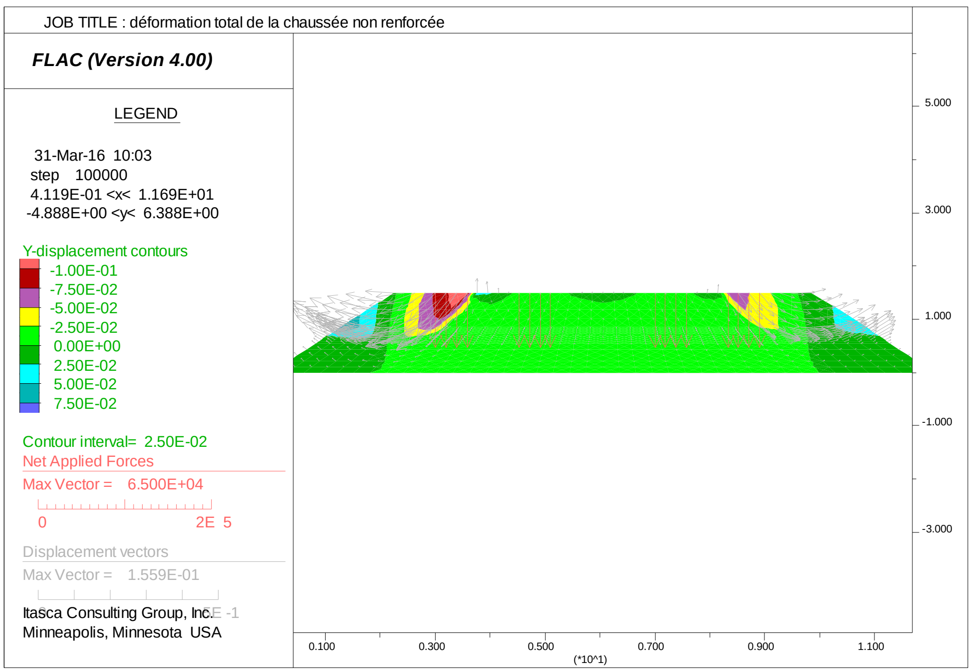


Figure 10: Total deformation of the pavement without geosynthétic (FLAC 2Dv4)

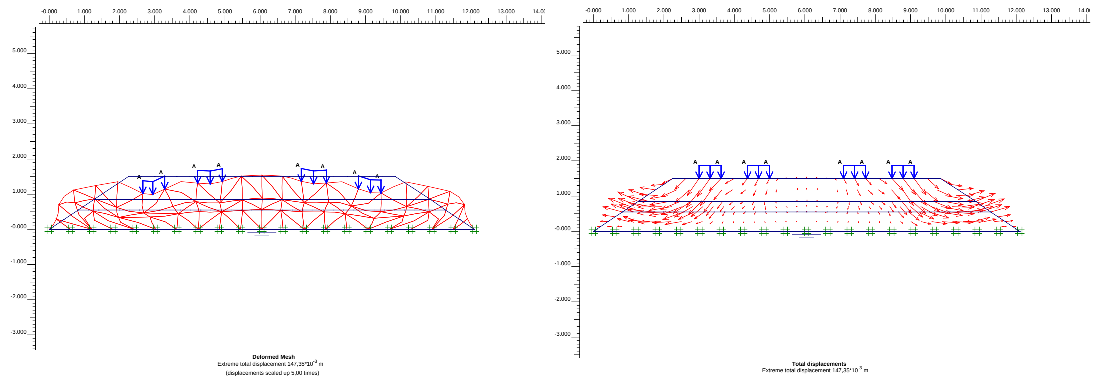


Figure 11: Total deformation of the pavement without geosgynthétic (Plaxis v7.2)

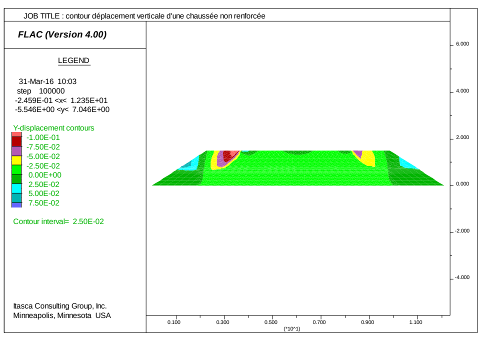


Figure 12: Moving a vertical unreinforced floor (FLAC 2D v4)

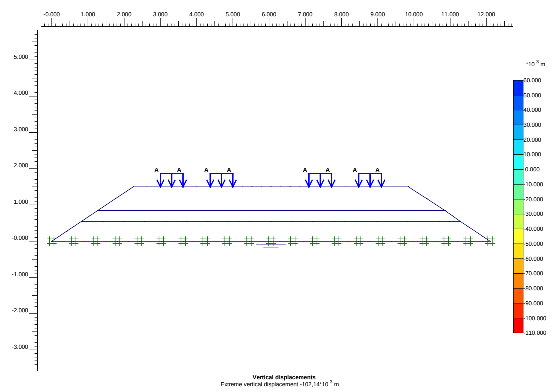


Figure 13: Moving a vertical unreinforced floor (PLAXIS v7.2)

Also the calculations carried out on the body pavement of unreinforced and reinforced by geosynthetic sheets show encouraging and interesting results (Figures 10 to 17). Well we notice in these curves that the total displacement in the unreinforced case is reduced by about 40% in the reinforced cases (Table 4).

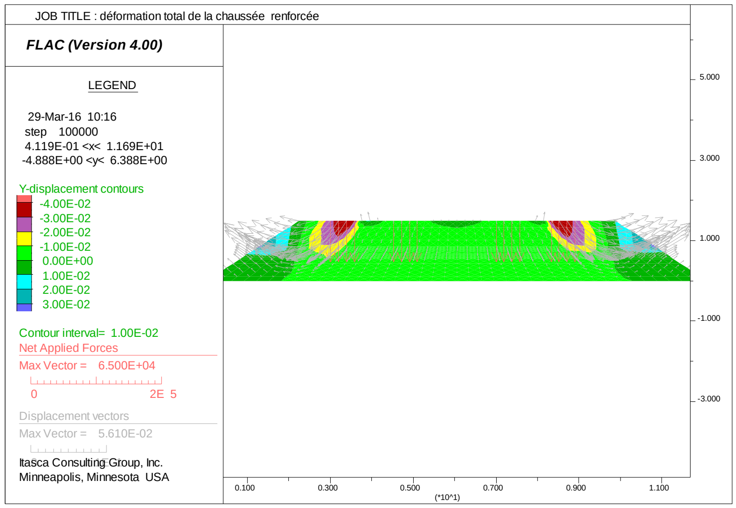


Figure 14: Total deformation of the floor with geosynthetics (FLAC 2Dv4)

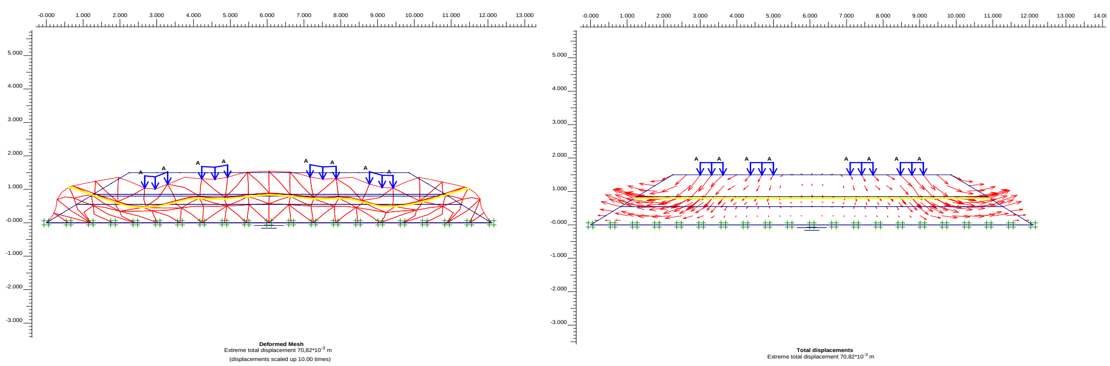


Figure 15: Total deformation of the floor with geosynthetics (PLAXIS 7.2)

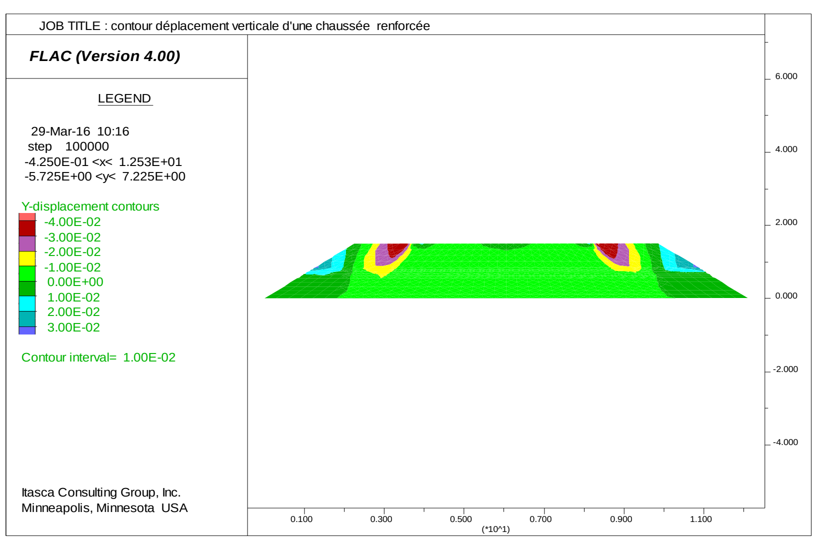


Figure 16: vertical displacement of reinforced roadway (FLAC 2D v4)

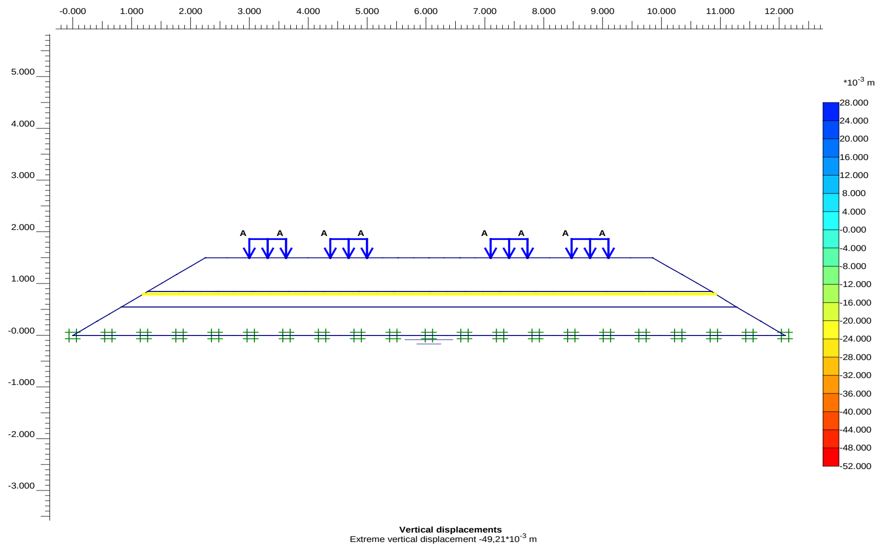


Figure 17: vertical displacement of reinforced roadway (PLAXIS

Table 4: Results of the total displacement of reinforced and unreinforced pavement

	Total displacement u (cm) FLAC 2D	Total displacement u (cm) 7.2 PLAXIS
without geosynthetic	15.59	14.73
with geosynthetic	5.61	7.08

From the second case represents the strengthening of the geosynthetic we trace the deformation of the ALVEOTER® table gives the figures (18, 19) below:

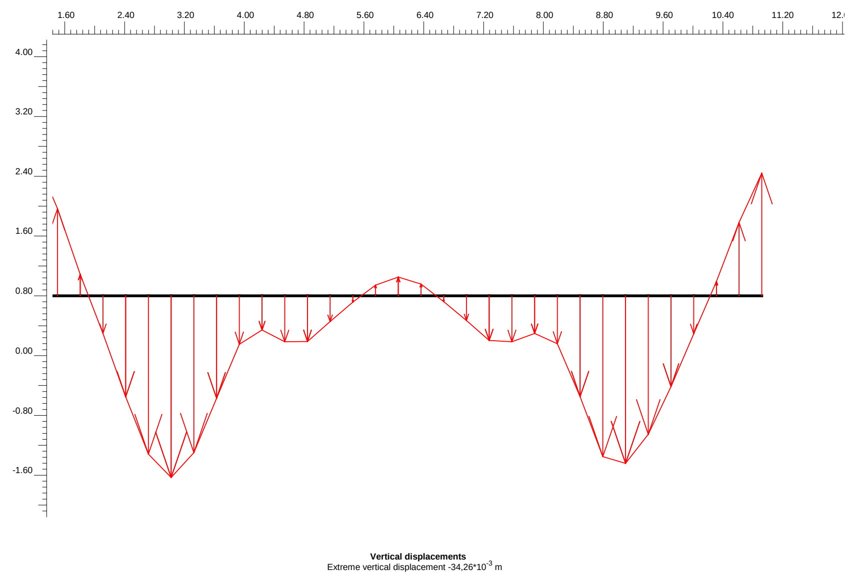


Figure 18: illustration of the vertical deformation of the web geosynthetic (PLAXIS 7.2)

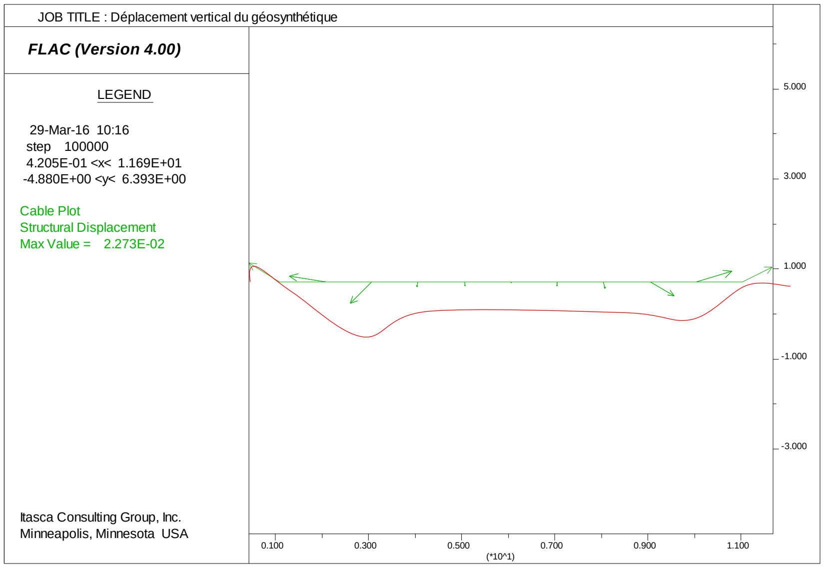


Figure 19: illustration of the vertical deformation of the web geosynthetic FLAC 2D v4

The geosynthetic moved about 3cm (FLAC 2D, PLAXIS), this value is tolerable because the total displacement of the pavement is about 7 cm (FLAC 2D ,PLAXIS). So the geosynthetic helped strengthen.

This calculation example, it confirms the role of geosynthetic reduce vertical displacements under static loading. Also, the ability of geosynthetic one notices to curve, it allows us to consider this behavior as membrane behavior.

It is therefore interesting to study from this model the influence of the physical parameters of the geosynthetic and the different dimensions.

PARAMETRIC STUDY

Influence of Rigidity

The web stiffness geosynthetic plays an important role in strengthening as it helps to reduce the possible deformation of the road; this is why it is essential to know its influence on the pavement structure.

To determine the influence of this parameter, fixed the position of the geosynthetic fleece between the base layer and the wearing course, we keep the thickness of the aforementioned layers and varying the Young's modulus, the results are presented in table (5):

Table 5: Total displacement depending on the rigidity of geosynthetic

Rigidity (Pa)	5^E8	2^E9	1^E10
u(cm)	10.25	6.23	4.58

In this table, there is a proportionally inverse variation in rigidity with movement which is logical since it is the rigidity of the geosynthetic will minimize soil movement and deformation of the structure.

Influence of Thickness of Base Layer

The base layer brings to the floor the strength necessary to reduce the vertical loads induced by traffic. The sizing of interest is to minimize the dimensions of a structure in order to reduce construction costs.

In this case, we still use the nonwoven geotextile ALVEOTER ® (J = 2 ^{E} 9 N / m²), placed in the base layer, the other layers are kept dimensions and varying the thickness of this layer. Table (6) shows the results obtained:

Table 6: variation of the thickness of the base layer

Thickness (cm)	total displacement u (cm) without Alveoter	total displacement u (cm) with Alveoter
30	14.87	6.23
27	19.38	9.99
25	22.00	11.11

This table determines that the displacement of the soil increases with the thickness of the layer. This is true, since it tries to minimize the thickness of layers saved for the necessary supplies for the road stretches for kilometers.

CONCLUSION

View the results made from the FLACv4 software and PLAXISv7.2 interesting conclusions seem to appear.

We conducted the modeling of the carriageway in two steps without a strengthening and another by introducing the geosynthetic in the base layer. This choice of the layer is done in order not to repeat what happens in practice i.e. in the upper part of the earthworks or part of asphalt.

On the other hand the calculations led to the following conclusions:

1. The results show that there is an inversely proportional change in stiffness with the movement which is logical since it is the stiffness of the geosynthetic which will minimize the movement of soil and the deformation of the structure. So under a static load, the load capacity increases with the increase of this rigidity, as it helps to improve.
2. The thickness of the base layer which will have an optimum value; it must be a fairly large to improve the rigidity of the pavement without reaching the threshold of over sizing. Then these thicknesses are reduced is introducing geosynthetics in the narrower base layer: economic gain on the thickness of the base layer.
3. The set of pavement and geosynthetics are curved and corresponds to the membrane effect.

In terms of outlook, we can offer additional studies are used to choose the type of geosynthetic reinforcement such as three-dimensional type generally used for slope.

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