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THEME

IMPROVEMENT OF THE BEARING CAPACITY OF A DUNE SAND BY INCLUSION OF A PERFORATED GEOTEXTILE

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Regards and gratitude

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Dedication

Thank God, who blessed us. God, Not only with our effort and diligence, but with your compatibility, generosity and gifts for us, which overtook us and informed us from your flag doors. God, after all the years of effort, exhaustion and perseverance here, we say that our study journey for this stage ended with her sweetness and happiness.

To the source of my joy and hope in life... To the meaning of love and the meaning of tenderness and dedication in the feature of life and the secret of existence to the secret of my success (dear mother)

To Sindy and my mountain in life that made me stand on my man repeatedly and for which I stand here today who taught me to give without waiting. To those who proudly bear his name... (Dear Father)

My brothers and sisters with whom I shared my joy and sorrow. I grew up next to them. I hope you always be proud of me.

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To all our classmates and to all the professors and workers of the Department of Civil Engineering and Irrigation

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DIF MOHAMMED ABDERRAOUF & MABEDI YASSINE

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ABREVIATIONS

GTX: Geotextile

GTX-N: Non-woven geotextile

GTX-W: Woven geotextile

DS: Dune Sand

CBR: California Bearing Ratio

DST: Double Surface Treatment

E: Equivalent thickness

I_{CBR}: CBR index

P: Load per wheel

TPL: Heavy weight traffic

EV1: Deformation corresponding to the first load cycle

EV2: Deformation corresponding to the second load cycle

K: Soil stiffness coefficient

Greek letters

τ: annual growth rate

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GENERAL INTRODUCTION

The road network is an important economic artery for countries. Algeria is geographically well placed to claim a road transport portal to the African continent. This is to increase social and economic exchanges with African countries and contribute to the development of various regions. In this regard, engineers face problems in road design. The most common is the lack of suitable natural building materials, difficulty in providing them, and poor quality if any.

The South of Algeria is a vast territory containing, here and there, excellent materials for road construction. These are sufficiently available in some regions but non-existent in most other regions. Dune sand is recognized as abundant in almost all of the southern zone of Algeria. This material is quite identified and characterized from a mechanical point of view. It indeed possesses some good qualities, but also intrinsic defects. A synthetic material, called geotextile, is associated with the dune sand in order to compensate for the physical and mechanical defects observed on the latter. The compound (sand + geotextile) is presumed to combine the advantages of one and the other in order to be usable in pavement structures. Sand is advantageous from the point of view of availability and free. The geotextile offers the required mechanical characteristics.

The analytical approach adopted, with a view to verifying the likelihood of the targeted objective, is typically experimental. The sand/geotextile compound is tested through the 'plate loading test' to assess its stiffness/bearing capacity. The sand is always the same, but the geometric configuration of the geotextile is varied until to achieve optimum mechanical performance. The varied parameters are notably the pattern of perforation of the geotextile (diameter of the perforations and spacing between them) and the depth of anchoring of the latter in the sand. The results obtained from the plate loading test are processed and presented in order to better observe the effects of the input parameters.

The note contains five separate main chapters. The first chapter dealt with some bibliographic research as technical rules consisting of the concepts and types of piers as well as the definition of geotextile composition.

The second chapter is the subject of the definition of the materials and methods used in the plat loading test. It also provides an explanation of the experimental protocol of the plate test.

In the third chapter, the results of the tests conducted during this study are described trough tables and charts. In addition, explanations are given for the results recorded in the test.

The fourth chapter, ‘technical and economic study’ shows the quantitative and estimated cost of achieving the foundation layer using both methods (Tuff) and dune-sand/geotextile compound, by duration, manpower, technical means and global costs.

The conclusion is the end chapter. It attaches importance to recalling the relevant findings of the study conducted ans also some points of view mentioned in the conducted study. In addition to emphasis was focus on some of the factors affecting the proper application of the test.

CHAPTER 1: TECHNICAL RULES

1.1 INTRODUCTION

In this chapter, the geological material denoted by soil is reviewed and studied. The study uses a specific type of geotextile to highlight the importance and method of using this material to improve the mechanical properties of the soil. The applications of such a composite material can be diverse and serve in particular works such as roads, dams, stabilized slopes, railways, landing strips and large-scale embankments.

The potential objective aimed at in all this is the correction and improvement of the mechanical characteristics of the sand through integration of the GTX.

1.2 DEFINITION OF PAEMENTS

A pavement is defined as layers of material stacked on top of each other. All of these layers ensure the transmission of forces from traffic to the supporting soil. The period of correct operation of this system is called conventional service life of the pavement.

The pavements are presented in multi-layer structures, implemented on the natural ground called soil-support. The natural soil is generally terraced and topped with a capping layer.

From a geometric point of view, a pavement is the surface of the road on which vehicles circulate. In the structural sense, the pavement is the set of layers of materials allowing the restitution and distribution of loads.

1.3 DIFFERENT LAYERS OF A PAVED ROAD

Different layers of roads are an important element in their design and construction, The roads are the overlay of different layers of materials Each layer in the road is used for specific purposes and provide specific functions where the different layers in the methods depend on the different materials used in each layer.

The various layers making up a pavement are arranged as shown in Figure 1.1.

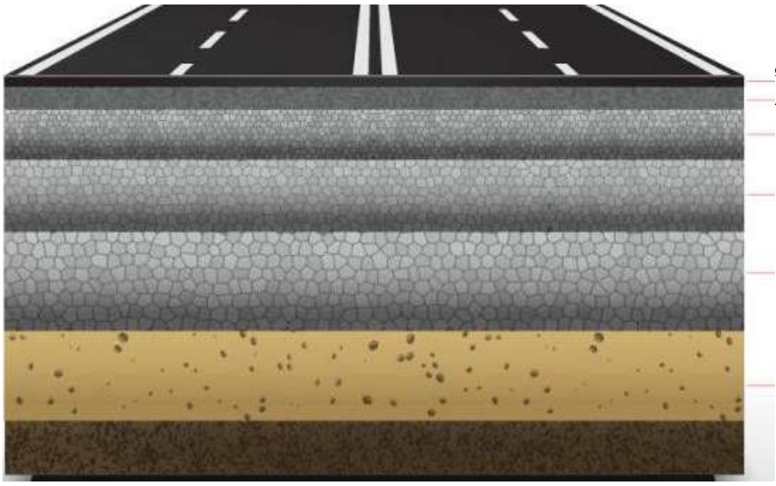

Figure 1.1: Typical pavement structure

In general, the structure model of the temple road consists of:

- **Supporting platform or supporting ground:** The supporting ground or platform corresponds to the ground occupying the upper parts of the dirt works (30 to 100 cm). It must be rigid enough to allow moving machines to pass over the ground.
- **Subgrade:** Also called shape layer. Its location is below the supporting platform and above the earthworks. This layer is used to rest the road on a good quality homogeneous platform.
- **Sub-base:** The sub-base (also said foundation layer) is sandwiched between the base layer and the earthwork. Its role is to ensure a homogeneous distribution of the stresses applied to the shape layer.
- **Ground layer:** Form the sidewalk base along with the base layer. The ground layer is exposed to vertical deformations and puncture effect due to tire pressure and shear pressure. These effects are applied in the base for materials treated with white binders, and are quite vulnerable given the thin thickness of the surface layer.
- **Surface layer:** The surface layer consists of:
  - The rolling layer: this is the top layer of the road. This layer is directly exposed to traffic stress and climatic factors.
  - A binding layer: it is generally placed before the lamination layers in order to ensure the connection of the latter with the base layer.

1.3.1 Pavement Structures

- **Flexible pavements:** The so-called flexible pavements are road surfaces that are designed to be flexible, allowing them to bend and deform slightly under traffic loads. They are typically composed of a base layer, subbase layer, and asphalt concrete surface layer.
- **Rigid pavements:** This type of pavements includes road surfaces that are designed to be relatively rigid, allowing them to resist deformation and cracking under traffic loads. They are typically made of concrete and are composed of a single layer of reinforced concrete slabs.
- **Mixed pavements:** Also known as composite pavements, these are road surfaces that are designed to combine the benefits of both flexible and rigid pavements. They typically consist of a rigid base layer, a flexible asphalt concrete layer, and a surface layer of either asphalt or concrete.
- **Thick bituminous pavements:** Also known as asphalt concrete pavements or hot mix asphalt pavements, these are road surfaces that are constructed using multiple layers of asphalt concrete. These pavements are composed of a base layer, a binder layer, and a surface layer, all made of asphalt concrete
- **Pavements with inverted structures:** Also known as Double Surface Treatment (DST), this type of roads is based on inverted construction technique compared to traditional pavements. The surface layer consists of coarse stone aggregates, which are covered with a mixture of binder and sand. This top layer is then compacted to create a strong and resistant surface.

Table1.1 provides a comparison of the various materials used in different layers of the road.

Table 1.1: Comparison of pavement types by constituent layers

Type of pavement	Width	Subgrade	Excise Layer (Base Layer and Foundation Layer)	Covering
Flexible pavements	Between 30 and 60 cm. Always less than 80 cm.	Untreated materials	Unbound or untreated granular materials	non-thick bitumen coating
Semi-rigid pavements	20 to 50 cm.	Untreated materials	Materials treated with hydraulic binders	Bituminous surfacing
Rigid pavements	15 to 40 cm	Materials treated with hydraulic or lean concrete binders	Cement concrete or compacted concrete	Slab of concrete
Mixed pavements	20 to 60 cm	Good bearing capacity materials	Bituminous materials and materials treated with hydraulic binders	Bituminous surfacing
Thick bituminous pavements	60 cm	Bituminous materials	Bituminous materials	Bituminous surfacing
Pavements with reverse structures	60 to 80 cm	Good bearing capacity materials	Materials treated with hydraulic binders and serious untreated	

1.4 METHODS OF SIZING PAVEMENT STRUCTURES

1.4.1 dimensioning pavements

The purpose of dimensioning pavements is to design a structure capable of supporting traffic for a fixed life duration. Several approaches have been developed for this purpose, namely empirical and theoretical approaches.

1.4.2 Empirical Approaches

Due to the complexity of the problems observed, the design methods developed are based on empirical rules derived from the observation of the behavior of pavement structures or experimental sections. These different methods are based on new techniques and use more efficient materials to design the road structure. The methods below indicated are quite often reported in the technical bibliography related to pavement dimensioning.

- The French 'Laboratoire Central des Ponts et Chaussées (LCPC)' and 'Service d'Etudes sur les Transports, les Routes et leurs Aménagements (SETRA)' methods.

- The 'American Association of State Highway and Transportation Officials (AASHTO)' method.
- The 'Design Manual for Roads and Bridges (DMRB)' UK method.
- The Shell method 'Shell Pavement Design Method (SPDM)'.
- The 'European standard of maximum dimensions and permissible weights for trucks, buses95/53/CE'.

Table 1.2 shows some difference in aspects characterizing pavement design methods of roads according to different design methods.

Table 1.2: Some aspects characterizing pavement design methods

Method	French LCPC/SETRA(*)	American AASHTO	English DMRB	Shell SPDM	European 95/53/CE
The maximum traffic single road axle load	twin wheel single axle130 kN	twin wheel single axle 18 ki (82kN)	twin wheel single axle80 kN	twin wheel single axle 80kN	twin wheel single axle110 kN
Road platform performance	3 levels: PF2 (50 MPa) PF3 (120 MPa) PF4(200 MPa	Elastic module value between 1 and 40 kpsi (7-276MPa)	CBR_{min}=15%	unavailable	unavailable

*/ formerly: Technical Studies Service, Roads and Motorways.

1.4.2.1 C.B.R Method

The California Bearing Ratio (CBR) method is a semi-empirical method used for pavement sizing. It is based on a punching test applied on a sample of the supporting soil. The soil specimen is compacted to 90% to 100% of the modified Proctor Optimum. According to Boussinesq's theory, the pavement can withstand (distributed) loads of an intensity lower than a limit stress proportional to that of the so-called CBR index.

The CBR method of pavement design is expressed as indicated by the formula below:

$$e = \frac{100+\sqrt{P}(75+50\log\frac{N}{10})}{I_{CBR}+5} \qquad (cm)$$

with:

- **e**: equivalent thickness (cm)
- **I_{CBR}**: CBR index of the supporting soil (%)
- **N**: daily number of unladen HGVs over the year.

- **P**: load per wheel P = 6.5 t (13 t axle)
- **Log:** decimal logarithm

1.4.2.2 Structure Catalogue Method

The structure catalogue method derives from the Algerian regulation B60-B61. It consists in determining the thickness of new pavements according to sheets classification through two parameters:

- Traffic for Heavyweight vehicles
- Classification of supporting soil

❖ **Determination of traffic class**

The determination of Heavyweight is assessed for a standardized period of 20 years. Table 1.3 indicates the class specific to each magnitude of passage of trucks on a road over a period of 20 years.

Table 1.3: **Designation of the traffic class.**

Traffic class	Heavyweight traffic cumulated over 20 years
T_1	$T < 7.3\ 10^5$
T_2	$7.3\ 10^5 < T < 2\ 10^6$
T_3	$2\ 10^6 < T < 7.3\ 10^6$
T_4	$7.3\ 10^6 < T < 4\ 10^7$
T_5	$T > 4\ 10^7$

The cumulative traffic is given by the expression:

$$T_C = Tpl\left[1 + \frac{(1+\tau)^{n+1} - 1}{\tau}\right] \times 365$$

with:

Tpl: Heavy weight traffic in the year of entry into service

τ: annual growth rate

n: Number of years expressing pavement life

❖ **Determination of soil class**

The supporting soil must be classified according to its CBR value. The different classes of the supporting soil are summarized as shown on table 1.4.

Table 1.4: Soil classes

Soil class	S1	S2	S3	S4
C.B.R index (%)	25-40	10-25	05-10	< 05

1.4.3 Theoretical approach

The theoretical approach is primarily concerned with establishing a pavement model that better reproduces the mechanical operation and stress state of the structure under the effect of a given load (traffic). This is called 'pavement mechanics'.

1.4.3.1 Models of pavement mechanics

Pavement mechanics concentrates on understanding the operation of structures and the rules of dimensioning. Thus, the magnitude of the stress on the structure is determined by a computational model. The latter should be a realistic representation of the structure functioning.

Today, several calculation codes are used in the design and analysis of pavement structures. The codes below are cited among the most common ones.

- The 'LCPC's '(Central Laboratory of Bridges and Roadways, Freance.), 'ALIZE 3' and 'CESAR' programmes.
- The 'NOEL 8' program of the University of Nantes, France.
- The code calculates 'FENLAP', University of Nottingham, England.
- The 'DIANA' program at Delft University.
- The 'ELMOD DYNATEST' program, Denmark.

1.5 OVERVIEW ON GEOTEXTILES

Geotextiles are synthetic products that have the primary role of creating a permeable physical barrier between the natural terrain and other materials. In this case, the geotextile is called separation and/or filtration. This type of geotextile also serves to protect drains and drainage structures from clogging, and thus to contribute to their sustainability. Geotextiles are also used to reinforce road and rail platforms, as well as to arm the mass of earth fill. The polymer based on geotextile can produce two types of GTX: the woven ones (GTX-W) and the non-woven ones (GTX-N).

1.5.1 Non-woven GTX

A non-woven geotextile (GTX-N) is a textile network obtained by placing, usually at random, fibres or yarns bound together following three possible techniques:

- **Mechanical bonding:** The Mechanical bonding is achieved by connecting a series of needles that penetrate the operating thread during the manufacturing process. In some cases, the vibration or rotation of the needle improves the entanglement process (figure 1.2).

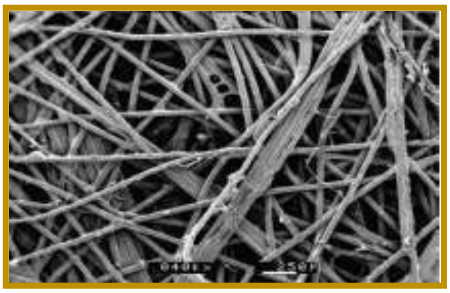

Figure 1.2: Structure of a mechanically bonded non-woven fabric.

- **Chemical bonding:** The chemical bonding of the GTX-N is obtained by the addition of resins or emulsions which glue the fibres or wires to their contact points. This connection is the least used, because the thicknesses of such GTX are 0.5mm to 3 mm (figure1.3).

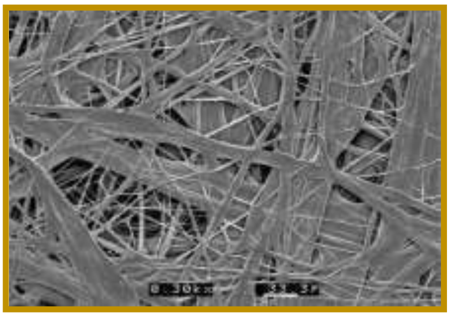

Figure 1.3: Structure of a chemical bonded non-woven GTX.

- **Thermal bonding:** The thermal bonding is achieved by the combined effect of heat and pressure on the fibres or wires that pass between two rollers during the manufacturing process (calendaring). A partial melting of the wire contact points is then obtained. The geotextiles thus manufactured are generally 0.5mm to 3 mm thick (figure 1.4).

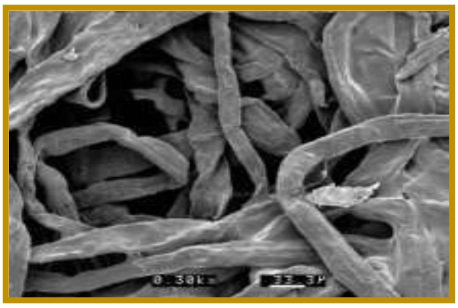

Figure 1.4: Structure of a thermal bonded non-woven GTX.

1.5.2 Woven GTX

A woven geotextile (GTX-W) is a textile cloth produced using conventional weaving techniques. That is, by interweaving two threads or filaments, several bundles of fibres, strips or other components. The

Figure 1.5: woven geotextile (GTX-W).

weaving process gives them a characteristic appearance, which shows two sets of parallel threads interwoven at right angles (figure1.5).

1.5.3 Knitted GTX

A knitted geotextile is obtained by assembling two layers of parallel yarns by means of a connecting yarn, in order to obtain the desired geometric distribution. Knitted fabrics can be found as panels or tubes. In addition to these products, a distinction must be made between certain related products, also widely used in the field of geotechnical and civil engineering. (Figure 1.6) shows a structure of this type of knitted geotextile.

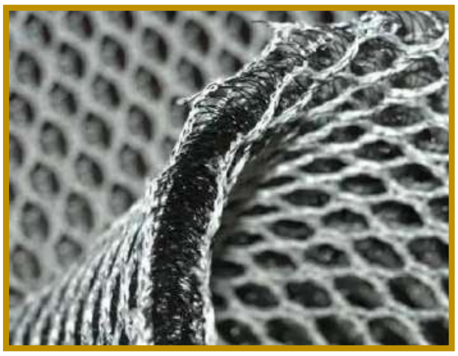

Figure 1.6: Knitted geotextile.

1.5.4 Functions of Geotextiles

Geotextiles are widely used in almost the vast majority of civil and engineering structures. The technical literature reveals hundreds of examples of use and application areas. The main functions performed by the GTX are:

1.5.4.1 Separation

Geotextiles are used to prevent the mixing of two layers of soil or materials of different particle size compositions. The geotextile is therefore stored between the two layers to be separated. The separation of the layers of materials, by the GTX, keeps the integrity and properties of each of them. In other words, it prevents the migration of elements from one layer to the other (Figure 1.7).

Figure 1.7: Geotextiles for separation.

1.5.4.2 Reinforcement

The mechanical properties of geotextiles and geogrid (100 % polyester grid) make them ideal for reinforcing slopes and other soil structures. Reinforcing with appropriate product prevents vertical soil walls and steep slopes (figure 1.8).

Figure 1.8: Geotextiles for reinforcement.

1.5.4.3 Filtrating

Filtration through a GTX means taking a measurement so that a water flow rate, at no desired pressure, can be established between two layers of different particle size compositions. GTX filtration applications are carried out for the purpose of filtration of waste water, draining ballast, protection of banks (river or irrigation channel) and coasts (figure 1.9).

Figure 1.9: Geotextiles for filtration.

1.5.4.4 Drainage

In geotechnical sense, drainage is the collection and disposal of water stored in the soil. Drainage GTX (also known as geo-drains) are specifically designed to perform this task, especially when the soil is low permeable. Figure 1.10 shows this type of geotextile.

Figure 1.10: Geotextiles for drainage.

The main advantages of the different types of GTX are:

- Saving on the project
- Reliability and durability of the structure
- Adaptation to project specificities
- Permanent separation between the base floor and the filler material. This allows the latter to be recovered if necessary

1.5.5 Uses of Geotextile in Construction

Geotextile have diverse uses in construction, including soil stabilization, drainage systems, and reinforcement of soil structures. They prevent soil erosion, improve drainage capacity, and enhance the load-bearing capacity of soil. Geotextiles are essential for ensuring durability and stability in construction projects.

1.5.5.1 Road Work

Figure 1.11 shows a type of geotextile commonly used for road work. It strengthens the soil by giving it traction resistance.

Figure 1.11: Geotextiles for road work.

1.5.5.2 Agriculture

Geotextile is a material widely employed in field of in agriculture. it is used to protect the soil and improve its quality. And it works to prevent soil erosion, water leakage and harmful substances. It can be used to promote plant growth and improve water management in agricultural land thanks to its porous properties and flexibility, it promotes more efficient use of resources and contributes to increased productivity and sustainability in agriculture.

1.5.5.3 Railway Works

Geotextile is used in this case to enhance soil and improve its ability to withstand pressure from train traffic. In addition, helps prevent soil deformations and ripples caused by movement effects and vibrations, as well promotes good water discharge and reduces the effects of wet soil on the railway. The stability of the rail can be improved and the incidence of disruptions and continuous maintenance is reduced (figure 1.12).

Figure1.12: Geotextiles for railway works.

1.5.5.4 Drainage

Geotextiles perform filtering mechanism for draining in earth dams, in roads and highways, in tanks, behind retaining walls, deep drainage trenches, and agriculture. (figure1.13).

Figure 1.13: Geotextiles Drainage.

1.6 CONCLUSION

The road project is not just about getting a good road and a good longitudinal profile. Once completed, the road will have to resist external aggressions (thermal gradients, rain, snow, ice, etc.).

This chapter presents some general characteristics regarding the types and methods of roads design. the Internationally adopted approaches to road infrastructure design are reflected in two basic methods: empirical and theoretical, so that each method depends on its own approach.

The geotextile product incorporated into geotextile/dune sand compound was used during the tests conducted in this study on the subject of research as well as its composition and areas of use in public works.

CHAPTER 2: MATERIALS AND METHODS

2.1 INTRODUCTION

This chapter aims to clarify the physical and chemical properties of dune sand. In addition to the mechanical properties of the compound DS/GTX.

The specific experiments are carried out on each of the materials geotextile and dune sand. The main experiment conducted is the plate test. The experiment was chosen to evaluate the geotechnical properties of the soil and allows the determination of several important geotechnical parameters. This information is necessary to design the appropriate pavement and to assess soil stability in various geotechnical works.

2.2 CHARACTERISTICS OF THE MATERIALS USED

2.2.1 Sources of materials used

The geotextile used is provided by the AFITEX-ALGERIE company within the framework of university cooperation with public sector.

Dune sands vary from region to region. The sand used in this project (end of studies) is the sand found in Ghardaïa region.

2.2.2 The Geotextile

Table 2.1 shows the mean technical information of the geotextile product obtained from its technical data sheet.

Table 2.1: Characteristics of the used Geotextile

<table>
<tr><td colspan="2">Nomination</td><td>AS15</td></tr>
<tr><td colspan="2">Surface mass</td><td>150 g/m^2</td></tr>
<tr><td colspan="2">Thickness under 2kPa</td><td>0.8 mm</td></tr>
<tr><td rowspan="2">Tensile strength</td><td>Machine direction</td><td>10 kN/mm</td></tr>
<tr><td>Cross-machine direction</td><td>12 kN/mm</td></tr>
<tr><td colspan="2">CBR puncture resistance</td><td>1.7 kN</td></tr>
</table>

2.2.3 The dune sand

The dune sand is the result of erosion and sedimentation of various rocks followed by wind transport. Most of the sandy formations are generally quartz. It is characterized by almost the same size of particles as shown in table 2.2.

In another meaning the sand of dune which imposes itself because of its abundance in nature (Sahara), it's almost zero extraction cost, and its apparent cleanliness, is the solution to the problem of depletion of natural resources and presents itself as a material of the future.

Table 2.2: Usual characteristics of dune sand

Sampling location	Ghardaïa
Sand equivalent (SE)	87
Dry unit weight (γ_d)	14kN/m^3
Cohesion (C)	0 kPa
Friction angle (φ)	29 °
Natural water content (ω_{nat})	2.5 %
Uniformity coefficient (Cu)	2.13
Apparent density	1644 kg/m^3
Absolute density	2627 kg/m^3

2.3 EXPERIMENTAL PROTOCOL

The approved test to assess the bearing capacity of the sand/geotextile compound (DS/GTX) is the so-called plate loading test, which allows determining the soil's ability to withstand loads and load overhead structures.

This test is usually performed on relatively soft soil, such as clayey soils or tuff material.

This test was chosen because it can be used as a quality control measure during project completion to check soil suitability for the proposed basic design and to ensure compliance with project specifications.

Plate testing is commonly used in construction projects to assess soil endurance and to design the right foundations for slab structures. Figure 2.1 shows the organs of the testing device.

The tests performed as part of this memory are conducted according to NF P 94-117-1 standard and are referred to as the plate experiment.

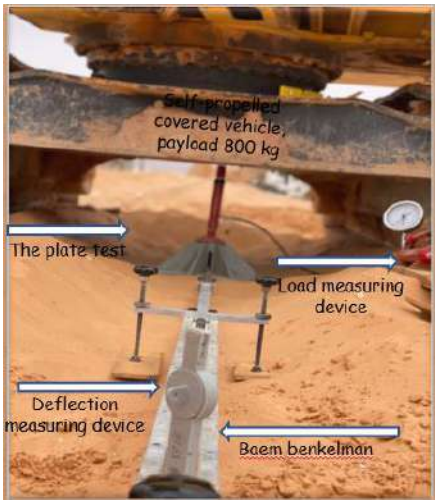

Figure 2.1: Parts of the apparatus and devices used in the test.

2.4 PLATE LOADING TEST

2.4.1 Preparation of the site and equipment of tests

After the test location is prepared and filled with dune sand, the test begins by applying the first experiment directly to the sandy soil, then it is repeated by placing geotextile on the soil surface, A series of tests are conducted depending on the geotextile pattern of perforation. However, the depth at which geotextile is added to the dune sand varies from the soil surface to the depth of 20 cm: z = 0 cm, z = 5 cm, z = 10 cm, z = 15 cm and z = 20 cm.

The difference in the substance of geotextile used in this study lies in the diameter (□) and spacing (SP) between holes in each type of geotextile so that they are referred to as follows (GTX unperforated, GTX4-9, GTX4-15, GTX 8-11 and GTX8-15).

2.4.2 Principle of the test

The plate loading tests are carried out using two loading cycles at constant speed (70 daN/s) on a rigid plate having a diameter of 60cm.

The results are recorded on site, then taken back to an office in order to properly draw all the representations necessary for a good understanding and interpretation of these results.

Hydraulic compression machine, of 200 kN capacity, lifts the massive reaction, following two successive loading cycles:

2.4.2.1 First loading cycle

The lift pressure is increased from 0 to 0.25 MPa and is maintained until deformation stabilizes (becomes less than 0.02 mm per 15 seconds). The deflexion of soil (**Z_0**) is measured, then the pressure is lowered until deleted (0MPa).

2.4.2.2 Second loading cycle

The lifting pressure is resumed until it reaches 0.20 MPa and so maintained until the stabilization of the deformation (< 0.02 mm per 15 sec.) The deflexion of soil (Z_2) is measured. Then the pressure is lowered until deleted (0MPa).

2.4.3 Analysis of the results

The formula used to get the soil stiffness coefficient (k) is: $K = \frac{EV_2}{EV_1}$

EV_2 (MPa): Deformation corresponding to the second load cycle = $\frac{90}{Z_2}$

The deformation corresponding to the first load cycle (at 0.25MPa) can be used to calculate **EV_1**.

The following formula is used: **EV_1** (MPa) = $\frac{112.5}{Z_1}$

In this formula Z_1 and Z_2 are is expressed in mm:

The EV_2/EV_1 ratio allows to appreciate the compaction quality.

$1.2 \leq \frac{EV_2}{EV_1} < 2$ = good compaction. $\frac{EV_2}{EV_1} < 1.2$ = very good compaction.

2.5 CONCLUSION

In this chapter, the characteristics of the two materials constituting the compound DS/GTX have been presented.

The dune sand is defined as a non-cohesive material that is difficult to handle. Accordingly, the compound material DS/GTX is tested in order to assess its suitability for improving the bearing capacity of pavement.

CHAPTER 3: PRESENTATION OF THE RESULTS

3.1. INTRODUCTION

This chapter presents mainly the results of the experiments conducted on the materials presented in chapter 2: dune sand (DS), geotextile (GTX) and the composite material (DS/GTX). This chapter also presents some interpretations of the results obtained in the light of the author's opinions. The small experience of the authors is based on their scientific knowledge acquired during their Master's training course, as well as their practical internships and this end-of-study project.

3.2. TEST RESULTS

The results obtained from the various tests performed on the DS/GTX compound are shown in the following forms. Figure 3.1 is the graphic representation of the results shown in table 3.1 for soil stiffness coefficient of DS and DS/GTX.

Table 3.1: Soil stiffness coefficient of DS and DS/GTX

Z (cm)	0	5	10	15	20
Sand alone	4.07				
Healthy GTX	4.23	3.39	4.09	5.15	3.55
GTX 4-9	4.15	6.12	7.22	7.58	6.07
GTX 4-15	3.06	4.32	5.62	5.97	4.03
GTX 8-11	3.47	5.66	7.01	6.77	4.49
GTX 8-15	2.26	4.3	4.99	3.96	3.38

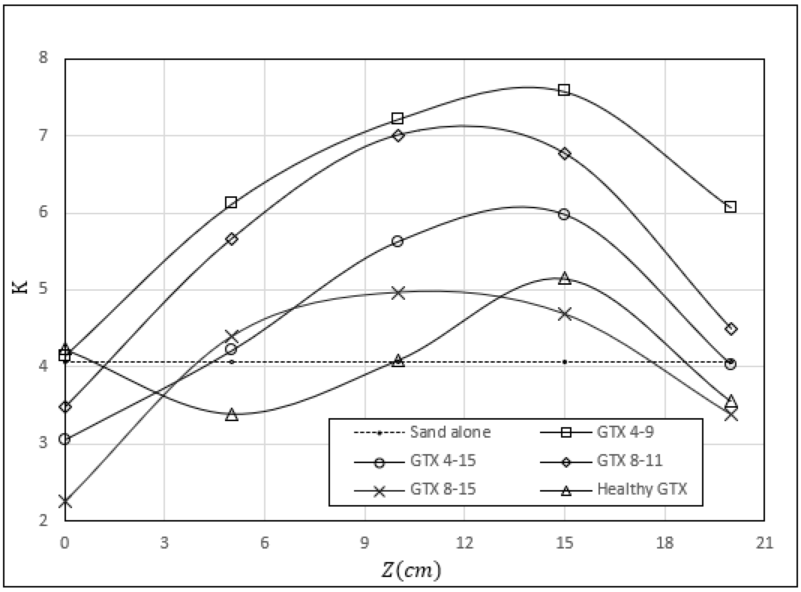

Figure 3.1 Soil stiffness coefficient versusGTX anchorage depth

Table 3.2 collects all static distortion coefficient values of DS and DS/GTX in the conducted tests and figure 3.2 shows the graphic representation of the values obtained in table 3.2.

Table 3.2: Static distortion coefficient of DS and DS/GTX

Z (cm)	0	5	10	15	20
Sand alone	59.88				
Healthy GTX	80.16	75	69.29	64.31	56.26
GTX 4-9	91.83	60.1	55.55	54.59	55.17
GTX 4-15	87.75	80.43	64.28	60	49.45
GTX 8-11	92.41	81.95	54.28	47.87	43.5
GTX 8-15	65.4	80.15	72.85	50.43	51.7

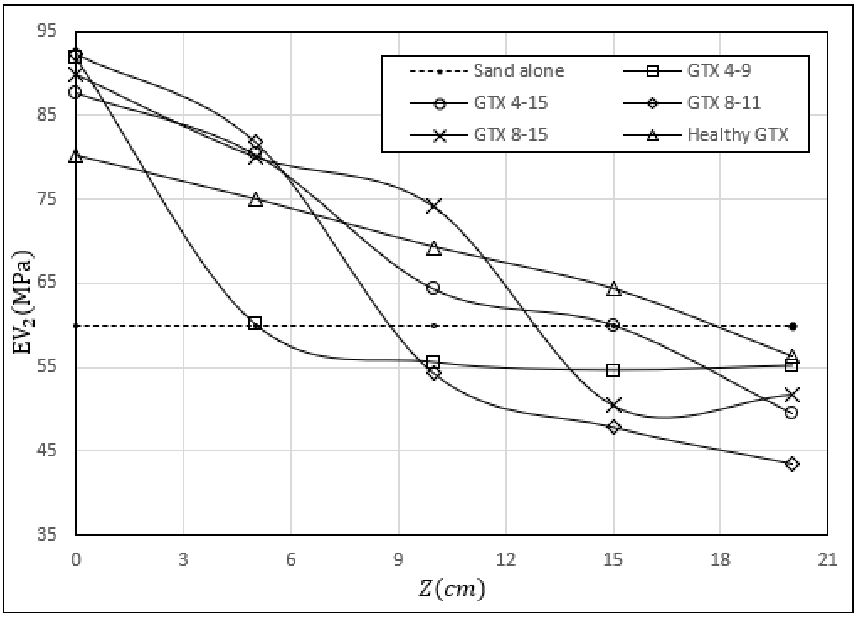

Figure 3.2: Static deformation modulus versus anchorage depth

Figures 3.3 and 3.4 reflect the results of the test on the DS and perforated GTX compound, where the diameter is respectively 4 mm and 8 mm but the spacing between the perforations is the same 15 mm.

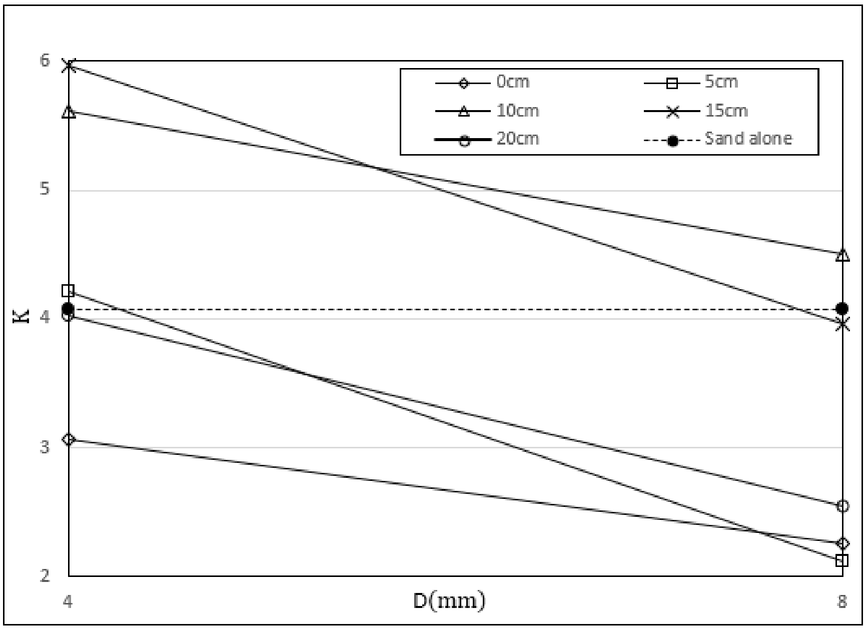

Figure 3.3 Soil stiffness coefficient versus diameter of the perforations

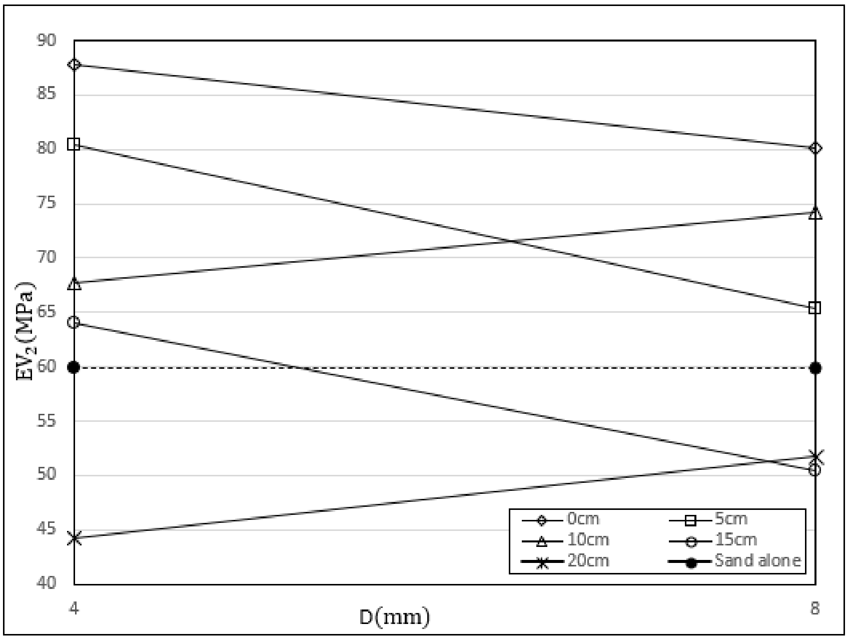

Figure 3.4 Static deformation modulus versus diameter of the perforations

3.3. INTERPRITATION

Figure 3.1 represents the soil stiffness coefficient (k) versus the GTX anchorage depth. Globally, it shows the same trend of the curves that represent the results obtained. The value of the coefficient (k) relative to the sand alone is indicated through the dashed line. It is an independent representation of the X axis. The curve corresponding to the healthy geotextile presents an irregularity compared to the rest of the curves.

Overall, the curves are bell-shaped. They start from values less than that of sand alone and increase somewhat, then converge towards the same starting value when the anchorage depth increases beyond 20 cm.

The significant increase in the coefficient (k), when GTX is installed as deep as 15 cm, attests of the latter's lack of contribution to soil hardening. It appears that the approximate depth of 0 cm (soil surface) to put GTX gave the best value in order to improve soil stability.

The curves shapes are acknowledged to be approximate given the differences in the results of the tests, even repeated under the same conditions. This observation affects the shape to be retained for each curve, as well as the arrangement of the curves in relation to each other. The ideal expected would have been very harmonic bell-shaped curves.

The tests are repeated in the same central point. At each test, the soil is removed and put back in place, which constitutes an uncontrollable reshuffle.

Thus, the same physical and mechanical properties of the soil cannot be obtained every time the experiment is conducted.

These factors do not allow for a strict judgement on the identity of the parameter that most affects the values of the results obtained in respect of the compound DS/GTX.

Figure 3.2 represents the variation of the static deformation coefficient of the soil (EV_2) versus the depth (z) of the GTX anchoring.

The results obtained of the EV_2 module start with a value slightly higher than that of sand alone (59.88MPa) and all decrease when the anchoring depth increases from 0cm to 20cm. The values of EV_2, recorded for all perforation patterns, decrease below the characteristic value of sand alone (59.88MPa) when the depth reaches 20cm.

The curves in figure 3.3 represent the variation of the coefficient (k) depending on whether the perforation pattern of the GTX is (4-15) or (8-15). The only difference between the GTXs reported on the X axis is the diameter of the perforations made. All the curves in this figure show a decrease in the coefficient (k) when the diameter of the holes made is increased. This variation makes sense because an increase in the diameter of the perforations means moving from GTX-reinforced sand to sand-only. Soil redness must therefore decrease.

The more diameter the holes in geotextile, the better the soil hardening coefficient, due to increased area in geotextile and increased entanglement between the compound (DS/GTX).

The curves in figure 3.4 represent the contrast of the EV_2 unit depending on whether the puncture pattern in GTX is (4-15) or (8-15). The only difference between GTX reported on the X-axis is the diameter of the holes made. Curves show a significant difference.

In this shape the curves related to the depths of 10 cm and 20 cm .The rise in the value of the EV2 coefficient is seen when the diameter of the manufactured holes is increased. By contrast, the curves at depths 0cm, 5cm and 15cm show a decrease in the EV_2 value.

The decrease in the EV_2 makes sense because the impact of plate pressure in the first cycle on the soil is lower at the second cycle.

It appears in curves. Difference in the value of the EV2 coefficient in depth 10 cm and 20 cm compared to the rest of the depths. This is partly due to the lack of control over the mechanical state of the sand during the test, which is to impact on the values of the test results. Besides the conditions that are not suitable for the test.

3.4. CONCLUSION

This chapter summarizes the experimental results obtained from the panel loading tests conducted on the sand alone and the (DS/GTX) compound. The geotextile inserted into the sand was either perforated or non-perforated. The aim of these differences in experimental parameters is to assess GTX's contribution to the impact on soil sustainability and the quality of stacking.

Particular attention should be paid to How to do geotextile perforation, and the way the test place is prepared must convenably be taken into account.

The obtained results show that the soil stiffness coefficient (k) of the DS/GTX compound is better when geotextile product on surface of the dune sand

The decrease in the value of the k coefficient is likely due to the diameter of the perforations. In addition, the perforations diameter and the spacing between them somehow affects the effect of geotextile on the dune sand.

CHAPTER 04: TECHNICAL AND ECONOMIC STUDY

4.1 INTRODUCTION

The speed and quality of completion of the project is one of the most important decisions the contracting company can take into account during the completion period. In order to achieve this economic aspect, several technical and functional criteria must be observed.

This purpose of this chapter is to provide a comparison of quantitative and estimated of the cost of achieving of the foundation layer of the road using composite materials DS/GTX, with the cost of accomplishing the same layer using currently used materials tuff**.**

4.2 QUANTITATIVE AND ESTIMATED ASSESSMENT

The section concerned with this study is the foundation layer of the road body. The cost of supplying used materials in that layer and the source of supply are highlighted considered**.**

The project taken is 5500 meters long and 5.80 meters width. This length needs the amount of GTX material which can be loaded and transported by semi-trailer truck. The main criterion for progress of work and evaluation of the geotextile supply is the semi-trailer truck. which is regarded as a reference unit for the work to be done.

Tables 4.1 and 4.2 relate to the prices of used materials, for the completion of the foundation layer in the road section, in accordance with the current market regulations. The supply distance of the material tuff is estimated to be 30 km from the work site.

Table 4.1: Quantities and estimates of achievement of 5500 metres of base layer using tuff material

DESIGNATION	U	QTY	U.P (DA)	T.P (DA)	Duration	Number of workers
Supply and put the foundation layer 20 cm thick of tuff including transport, brushing, spraying, mixing and stacking by up to 98% OPM Ensuring the inclination rate is not less than 2% and all the necessities of good execution.	m^3	6380	650	4 147 000.00	24days	• Four truck drivers for transporting and unloading tuff. • Driver grader for spreading tuff. • Driver for the Vibratory compressor for crushing large tuff stones. • For soft cylindrical compressor to compact the tuff. • Driver for the water tank to spray the layer, until reaching the cohesion. • Four workers to provide various services
	Total amount (E.T.)			**4 147 000.00**		
	T.A.V. 19%			**787 930.00**		
	Total A.T.I.			**4 934 930.00**		

Table 4.2: Quantities and estimates of achievement of 5500 metres of base layer using DS/GTX

DESIGNATION	U	QTY	U.P (DA)	T.P (DA)	Duration	Observation
Supplying of DS	m^3	6380	300	1 914 000	/	• The load of sand in a truck with a capacity of $16m^3$, the payment is estimated at 5000 DA.
Spreading the DS	km	5.5	4000	22 000	6 days	• The sand is spread by the machine by 1 km/day, at a price of 2000 DA/day. • Two workers, by hand, adjust the effects of the machine, the payment of each worker 1000 DA/day.
Purchase of GTX	m^2	31900	100	3 190 000	/	• Generally, from Algiers.
Transport of GTX rollers	U	22	(forfeit)	40 000	/	• According to AFITEX ALGERIA company, a truck can carry 22 rolls.
Unloading and setting up (deploying)	U	22	600	13 200	6 days	• Set in place by machine, 3 rolls per day.
Backfilling GTX with DS layer	km	5.5	30000	165 000	6 days	• The GTX is backfilled with a layer of sand to avoid its movement due to wind or other factors.
		Total amount (E.T.)		**5 344 200.00**		
		T.A.V. 19%		**1 015 398.00**		
		Total A.T.I.		**6 359 598.00**		

4.3 COMPARATIF ASPECTS

The comparison of the amounts shown in the two tables (4.1 and 4.2) shows the quantitative and estimated of the road foundation achieving process using DS/GTX is higher than the usual method. The relative difference in cost between the two methods is estimated to be 28.87 %. The increase in cost between the two methods can be attributed to several factors, including:

Materials used for completion are available near the project site. This clearly contributes to the lower cost of the project's implementation using tuff material, compared to the use of geotextile materials and the higher cost of their transportation during the completion of the project.

The second method of achievement using the DS/GTX compound is much faster than the first method. So that the climate factor and physical and mechanical conditions cannot affect the compound DS/GTX during achievement, unlike tuff which can be affected by climatic factors and lead to delays at the time of achievement.

Secondly, the first method directly depends on high-precision techniques in achievement. Therefore, this method depends on skilled and experienced laboratory commensurate with the working style, especially for machine drivers**.** In addition, all machines must be available at the project place to ensure normal or ready completion**.**

Unlike the second method that does not require highly experienced workers and a large number of machines. Only a few workers can rely on (4 to 5) workers as well as a crane machine**.**

Although the first method is less expensive than the second, in some cases it is depending on the conditions of availability of materials in the region. It can directly rely on compound DS/GTX to provide dune sand material at project site and easy acquisition of geotextile material.

4.4 CONCLUSION

A quantitative estimate is prepared to compare the use of compound DS/GTX and tuff during the achievement of a foundation layer pavement with an estimated distance of 5500 meters. This quantity will be performed according to semi-trailer truck carrying capacity for geotextile materials

The comparison between the achievement of the foundation layer using the two methods tuff and (DS/GTX) shows that the first method has a lower cost than the second one. This is due to the availability of basic materials used in at a lower cost but with difficulty applying them. Conversely, the second method requires the use of more expensive materials but an easy application process.

There is difficulty in using the method currently adopted in some regions. Because of the difficulty of availability of tuff material near the project place. It is indeed a prerequisite for governing this issue. Similarly, many constructions machinery and equipment should be moved to the achievement site. All these conditions can be negatively reflected on the cost and the time of the pavement achievement.

Finally, the quality and specialization of workers also lead to a major difference between the two techniques. Worker’s experience and the number of machines is not required when implementing the (DS/GTX) compound. This makes it an ideal way to accomplish in outlying areas.

GENERAL CONCLUSION

The study carried out, as part of the preparation for the Master's degree in civil engineering, focuses on the experimental testing of a composite material (dune sand + geotextile).

In this study, dune sand material is selected given its availability and low price. This is the main advantage of the approach adopted. Geotextile materials are also selected from among the least efficient in order to evaluate the economic aspect of the compound (DS/GTX).

The properties of the materials used (DS and GTX) significantly influence the choice of the tests performed in order to determine their performance. The technical performance of the latter depends significantly on the physical and mechanical characteristics of the base materials used (whether natural or synthetic).

The plate load test under this study was relied on as one of the most advanced mechanical tests, the main purpose of the plate test is:

- Determination of soil sustainability
- Assessment of the pressure force of soil
- Control the pressure of the soil layer

It also allows the measurement of many mechanical factors of soil compression quality: Ev_1, Ev_2, K..,

The wide variety of road types requires consideration of the methods of implementation of the road project, and varies between theoretical and experimental methods.

The added value of geotextile associated to the dune sand, had a clear impact on the results obtained during the application of the plate experiment to the DS/GTX compound. It gaves good values compared to the use of dune sand alone. So that the addition of perforated geotextile provides the compound DS/GTX with good stacking value against the applicable forces of the plate with a diameter of 8 mm.

It may be considered that some factors may, in some way, affect the validity of the test results, including:

- The difficulty of emulating the experimental protocol of testing, due to the lack of sufficient time and the necessary possibilities to ascertain each time the mechanical condition of the used materials (sand), after re-tilling the soil before re-testing each time. This leads to a lack of understanding of the factor(s) most affect of values among materials (sand and geotextiles
- The difficulty of providing the device to conduct the test in complete comfort
- Difficulty in supplying the equipment needed to perform the test properly
- Difficulty applying the test to a test piece that is fairly reality-simulated in accordance with internationally applicable standards

Through this study there is a clear difference in the operational value of the materials used, so that there is a difference in the cost of achievement between the use of tuff and the use of compound DS/GTX. During the achieving of the foundation layer of the road project.

This difference does not underestimate the value and importance of using the DS/GTX in project delivery because of its advantages:

- Speed of achievement
- Limiting the use of human and material potential
- DS/GTX can be used in most desert areas if tuff materials are not available or to reduce equipment transportation costs to the project site. By taking advantage of the abundance of sand dunes in the region and the rapid execution of works.
- Give added value to the mechanical property of the road sub-base layer and strengthen its resistance to loads resulting from other layers

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ملخص

رمال الكثبان الرملية (المعروفة أيضًا باسم رمال الرياح) وفيرة في جنوب الجزائر، وعمومًا في جميع أنحاء شمال الصحراء. ومع ذلك، فإن استخدامات المادة قليلة جدًا (إن وجدت) في مجال الهندسة المدنية والأشغال العامة، وحتى أقل في الهياكل الخطية مثل الطرق. ويرجع ذلك إلى افتقارها إلى التماسك والقدرة على الضغط.

يهدف مشروع الدراسات الدقيقة قيد الإعداد إلى تصحيح بعض العيوب الجوهرية الأساسية لرمال الكثبان الرملية من خلال ارتباطها مع **Geotextile** المثقب **(GTX).** لتحسين خصائص الرمال من أجل مقاومة القص وزيادة عدم اتساق التربة. للاستخدام في العديد من مشاريع الهندسة المدنية والأشغال العامة. يرتكز البحث الحالي على تجربة الصفيحة لمعرفة أداء المركب رمل/جيوتكستيل. بحيث تعتبر التجربة شائعة الاستعمال في مجال الجيوتقنية، وهذا بغرض إعطاء قيمة مضافة لدراسات سابقة ذات الصلة بالموضوع

الكلمات المفتاحية : رمال الكثبان الرملية ، جيونسيج، الأشغال العامة، طبقة الأساس.

ABSTRACT

Dune sand (also known as wind sand) is abundant in southern Algeria, and generally throughout the northern Sahara. However, the substance's uses are very little (if any) in the field of civil engineering and public works, and even less in linear structures such as roads. This is due to its lack of cohesion and pressure ability.

The project of fine studies in preparation aims to correct some fundamental intrinsic defects of dune sand through its association with perforated Geotextile (GTX). to improve the characteristics of the sand for shear resistance and to increase the inconsistency of the soil. For use in many civil engineering and public works projects. The current research is based on the plate loading test to see the DS/GTX compound's performance. The experience is so commonly used in the field of geotechnical that is to add value to previous relevant studies.

Keywords: sand dunes, geotextile, public works, foundation layer.

RÉSUMÉ

Mots clés : Dune sand, Géotextile, public works, foundation layer.

Le projet d’études fines en préparation vise à corriger certains défauts intrinsèques fondamentaux du sable de dunes par son association avec le géotextile perforé (GTX). Améliorer les caractéristiques du sable pour la résistance au cisaillement et augmenter l’incohérence du sol. Pour de nombreux projets de génie civil et de travaux publics.

Le sable des dunes (également connu sous le nom de sable du vent) est abondant dans le sud de l’Algérie, et généralement dans tout le nord du Sahara. Cependant, les utilisations de la substance sont très limitées (voire inexistantes) dans le domaine du génie civil et des travaux publics, et encore moins dans les structures linéaires telles que les routes. Cela est dû à son manque de cohésion et de capacité de pression. La recherche actuelle est basée sur le test de chargement des plaques pour voir les performances du composé DS/GTX. L’expérience est si couramment utilisée dans le domaine de la géotechnique qui est d’ajouter de la valeur aux études pertinentes antérieures

Mots clés : Sable de dunes, Géotextile, travaux publics, couche de fondation.