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THEME

INFLUENCE OF THE INCLUSION OF A PERFORATED GEOTEXTILE ON THE BEARING CAPACITY OF DUNE SAND

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Dedication

Praise to God almighty first for all the many blessings such as patience and the ability to accomplish our work.

To the one who supported me with her prayer, to the source of kindness and tenderness, to the most wonderful woman in existence: my dear mother, and to the one who taught me that the world is a struggle and a quest for my comfort and success, to the greatest and dearest man in the universe, my dear father, to my beloved sisters and brothers: Lina, Ibrahim, Mohammed al-Arabi, and Ammat al-Rahman, to all the Mehiri and Belkhira family.

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♡ MEHIRI Hadil

Dedication

With determination come wills

To my heart beating, for the symbol of love and the balm of life for my dear mother

To Sindh, my beloved, my dear father.

To my life partner and the soul mate of my fiancé, GUERGOUR Azzeddine.

To my dear role model and family

To my classmate Hadil Mehiri

To my dear masters, religion has not been stingy with knowledge and knowledge

To the person who stood by me despite situations and despite adversity

My sister MESSAOUDI Asma

I dedicate the outcome of my hard work and effort and the outcome of the journey to all of you.

♡ **MESSOUDI Fatma**

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MAIN RATING

GTX: GEOTEXTIL

DS: DUNE SAND

CBR: CALIFORNIA BEARING RATIO

Greek letters

ϕ: Dimeter

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GENERAL INTRODUCTION

Roads are one of the most important infrastructures in the modern world. They are built for social, strategic, and economic purposes: development of trade, urban comfort, and connection of isolated localities.

They exist in various forms: roadway, track, secondary road, main road, highway, and airstrips. The administrations and companies responsible for the road networks must ensure the best operation, maintenance, and development of the roads.

The economy in a road project involves optimal use of local materials and natural resources existing in the vicinity of the site under consideration. Thereby, it is necessary to direct the research toward dune sand, which is known to be abundant in the northern Sahara, which includes a large part of Algeria. This can constitute an alternative to the use of dune sand in the construction of roads.

The present study proposes to test a material composed of dune sand associated with a geotextile (DS/GTX) as a pavement body. The original idea, at the base of this approach, is the use of sand dunes recognized everywhere abundant, therefore almost free.

The main objectives are:

- Improvement of the mechanical behavior of dune sand.
- Contribution to solving the challenge of the scarcity of noble materials for the construction of road surfaces.
- Use of a material already harmonized and compatible with the arid geoenvironmental conditions.
- Contribution to the development of rural areas.

The assumed technical approach is expected to solve the problems indicated above. The idea is to use local sand with a perforated geotextile fabric, in order to determine the optimal layout in terms of toughness. The key parameter investigated is the bearing capacity of the compound through the California Bearing Ratio (CBR) test.

The test procedure being well standardized, the current study foresees a modification in the tested material. The soil compacted according to Proctor procedure is replaced by the dune sand/geotextile (DS/GTX) compound. All other aspects of the test are kept the same. The layout and placement of the GTX strips are considered the input variables.

The structure of the thesis is based on four main chapters:

- The first chapter is a bibliographic review. It consists of the concepts related to the materials used in road construction in southern Algeria as well as summarizing the general information about the tests used on the roads. Also, it is a brief explanation of pavement structure.
- The second chapter is an explanation of the used material properties as well as a brief presentation of the used tests.
- The third chapter presents the obtained results, This is done by tables and means of graphs. Additionally, it contains the analysis and interpretation of the results.
- The fourth chapter shows the comparison of used methods, according to duration, workforce, technical means, and final costs.
- The last chapter is a reminder of the relevant results mentioned in this study. On occasion, recommendations are indicated, as well as proposals for the continuation of the work carried out.

Chapter 1: CONSTRUCTION MATERIALS IN SOUTHERN ALGER

1.1 INTRODUCTION

In the south of Algeria, and to a lesser degree in the north, the roads are recognized to be degraded to the point of being barely usable. This state is due to several factors including, in particular, their old age and their previous construction techniques which were adopted in the 1950s. Also, the climatic and geo-environmental conditions have contributed to the degradation of these structures called roads: sunshine, winds, and silting up. , intense daily and annual temperature gradient. Other potential factors are considered for the same contribution to the poor quality of built roads. The scarcity of good quality (so-called noble) materials is required for the sustainable construction of such structures. Heavy traffic, even if not intense, is also a feared parameter in view of a road's firmness.

This study aims to use dune sand in the face of all the constraints mentioned. This is in spite of the recognized mechanical defects of this one.

this chapter is a review of general notions on geosynthetic materials and their uses. It is based on a type of perforated geotextile to highlight the importance and applied technique of using these materials.

1.2 VARIOUS MATERIALS USED IN ROAD CONSTRUCTION

When constructing roads, the method is to use a lot of different materials like stones and pebbles of all kinds and sizes. And it's a priority to ensure these materials live up to the construct requirements and standardized quality. Because of that, this sheet will mention the important qualities of the resources that play a part in road structure:

Table 1.1 summarizes the main information about the usual materials used in road construction.

Number	Nomination	ingredients	Mixing method	Experiments	Layer thickness	Dimensions of gravel
1	Surface layer	Asphaltic concrete: • asphalte • Gravel	- Cold mixture: 40-50 cold-open asphalt - Hot mixture: (150-190) Asphaltic concrete surface coating	Experiments on asphalt: • Penetration • Density Experiments on gravel: • Particle size analysis • Los Angeles • Purity Experiments on sand: • Sand equivalent • Stability (concrete) Experiment on concrete: • Marshall • Thickness measurement	From 5 to 7 cm	0/3 3/8 8/15 15/25

2	Base class	Light asphalt mixture	Lightweight concrete mix	• Marshall • Duriez	From 7 to 12 cm	0/3 3/8 8/15 15/25
		• Crushed pebble stones • Treated crushed pebble stones (cement, teff…) • teff	• Gravel mixture	• Compaction (Proctor)	From 20 to 30 cm	0/3 3/8
3	Base layer	• Crushed pebble stones • Treated crushed pebble stones (cement, teff…) • teff	• Gravel mixture	/	20 cm	0/3 3/8 8/15
4	Earth layer	• Original soil • Treated soil • Replace soil	Soil	• Compaction (Proctor)		

1.3 Common Road tests

1.3.1 California Bearing Ratio

California Bearing Ratio (CBR) aims to give the relative resistance of the soil after being compacted according to the Proctor procedure test procedure This test consists of pushing a piston placed on the surface of a compacted sample until the depression of 10mm is exceeded. The bearing index is a comparative ratio of the resistance strength of the tested soil to that of a California reference soil. The comparison ratio is the maximum value of the force recorded, identified at the depressions at 25mm and at 5.0mm. The CBR test is carried out in particular to evaluate the workability of the soil composing the base layer of a roadway, as well as the backfilling layers.

Application domain: Road geotechnics - pavement design

1.3.2 Particle size analysis

The particle size analysis of soil progress is as follows: We bring a weight of sand of: 1.5 kg, then bring a series of sieves on top of each other, where the sieve with a smaller diameter is from the bottom to the sieve with a large diameter from the top. After that We empty the weighed sample over the upper sieve. We operate the device (electric vibrator) for an estimated period of 10 minutes. we take each sieve separately and make sure that each sieve only keeps what is the largest in diameter. Weigh the remaining grains from each sieve Weigh the remaining pass-throughs in the base container less than 0.08 mm in diameter. It allows a standard nomenclature of the tested soil and its classification.

Application domains: classification, Predict, roughly, the mechanical behavior of the soil.

1.3.3 Specific weight

The specific weight of the solid grains is defined as their unit weight reported to that of water. The unit weight of the solids is their own weight reported to their volume.

Application domain: needed for large grain soils. the grains need to be at the maximum dimension of fine sand and present an already important cohesion.

Moisture content

The water content of a soil is the ratio between the mass of water contained in this soil and the mass of the solid grains composing this soil. Water content is often expressed in percent (%).

Application domains: Almost all areas of geotechnics

- Prediction of soil behavior

- Correlation to other physical and mechanical soil parameters

1.3.4 Direct shear test

The shear resistance of a soil is defined as being the greatest resistance that this soil can develop against applied tangential stress.

Application domains:

Used in Geotechnical calculations

1.3.5 Sand equivalent

The sand equivalent test is carried out on the fraction of grains with a size of less than 5mm. The test in question gives an estimate of the fine elements existing within the soil. These fine elements are considered impurities.

Application domains:

The test applies in many fields, Such as:

- Choice and control of soils usable in mechanical stabilization
- Control of soils used in chemical stabilization
- Choice and control of aggregates for bituminous mixes
- The equivalent of sand and granulometric analysis of soil, are two methods to classify the soil the solid grains. And this makes it possible to know the properties of this soil. thus to know which is valid or not for the construction.

Proctor test

Proctor experiment is one of the most used tests in road geotechnics, Its goal is to determine (in the laboratory) the maximum dry density of the soil material and the optimum water content related to certain compaction energy.

Application domains:

Evaluation and control of compaction of backfill materials.

The following table summarizes these tests:

Table 1.2: Summarized information about the most utilized experiments

	Designation	Standards	Principle	Unit
01	Particle size analysis	NF P8-540 ASTM-D 422-63	Weight arrangement of different aggregate particles according to their dimensions	Curve
02	Specific weight	EN 1097-6	Measuring weight of a specific volume	kN/m³
03	Volumic mass	EN 1097	Measuring mass of a specific volume	g/cm^3
04	Chemical composition	NF P 15-461	Measuring the proportions of certain components such as (SiO,CaCO3).	%
05	California bearing ratio	P 94-078 ASTM D 1883 BS 1377-4	Measuring the bearing strength of the soil compared to a referential value.	%
06	Proctor •standard test •Modified test	P 94-093 ASTM D 558, D 698 BS 1377-4	Finding the relationship between the water content and the dry density of the soil according to specific compaction energy.	Curve
07	Direct shear	ASTM-D3080-90	Obtaining the ultimate shear strength, internal friction angle, cohesion, and shear stress deformation properties.	
08	Sand equivalent	EN 933-8 ASTM-D 2419-74	Determination of the percentage of fine materials (clays and impurities) present in the sand.	%
09	Simple pressure	NF P 94-077	Measuring the soil resistance against compression.	kN/m²
10	Water content	NF P 18-554 ASTM D 2216 BS 1377-2	Determination of moisture content of soil.	%

1.4 OVERVIEW OF PAVEMENT SIZING

Designing pavement structures is an important step in the road project study. This includes a special selection of the necessary materials that include the required properties and the determination of the thicknesses of the different layers of the paving structure. Well technically diagnosed materials must be selected to ensure good mechanical properties that allow the pavement to withstand all loads throughout its life. This goes according to the following basic considerations:

- The traffic: All vehicles using the roadway (weight, frequency, speed, etc.)
- The road environment (primarily the climate)
- The supporting soil

1.4.1 Definition of the roads

- In the geometric sense: the developed surface of the road on which vehicles travel.
- In the structural sense: all the layers of combined materials which allow the absorption of loads.

1.4.2 Different pavement types

From the construction point of view, pavements can be grouped into three main categories:

- Flexible pavement: most used type, consists of two construction elements soil and stony materials with spread or tight grain size and hydrocarbon binders which provide cohesion by establishing flexible bonds between the grains of stony materials.
- Rigid pavement: consists of a Portland cement slab that flexes elastically under loads, resting on compacted soil, or on a thin foundation of crushed stone or gravel, or on a stabilized foundation.
- Semi-rigid pavement: intermediate case between flexible pavements and rigid pavements.

Figure 1.1 shows a diagram of the usual materials utilized in the road domain.

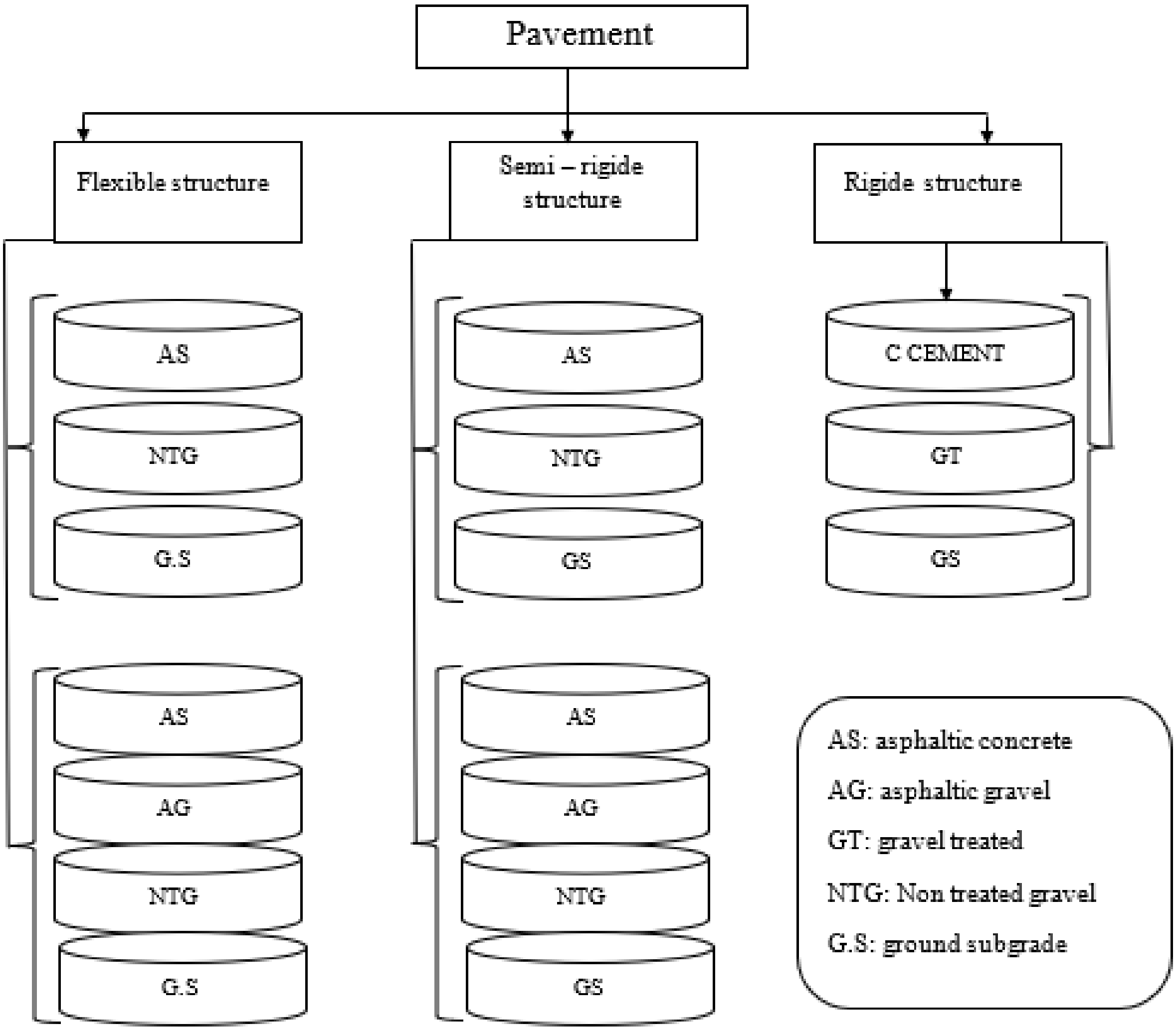

Figure 1.1 the usual materials utilized in the road domain

1.4.3 Main design method

There are two main family methods for designing a road:

- The empirical methods derived from experimental studies on pavement performance.
- The so-called "rational" methods based on the theoretical behavior study of pavements,

The most widely used methods of dimensioning pavement structures are:

- CBR (California -Bearing Ratio) method
- Method taken from the catalog for the dimensioning of new pavements.

1.4.4 CBR method

The CBR method is a semi-empirical method which is based on a punching test applied on a sample of the supporting soil. The latter is prepared by compaction at 90% to 100% of the modified Proctor optimum.

According to BOUSSINESQ's theory for the pavement to hold the distributed vertical stress must be less than a limit stress which is proportional to the CBR index. The pavement thickness is given by the following formula:

$$t = \frac{100\sqrt{p}(75 + 50\log\frac{N}{10})}{I_{cbr} + 5}$$

With:

t: equivalent thickness

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 (axle 13 t).

Log: decimal logarithm.

1.4.5 New pavement sizing catalogue method

The use of a design catalog adopts the same settings used in other pavement design methods (traffic, materials, subgrade). These parameters often constitute input data for the dimensioning and the choice of a given pavement structure.

The new pavement design catalog method is a rational method based on two theoretical approaches.

- Empirical approach.
- Theoretical approach.

Figure 1.2 shows a summarize diagram of the new pavement sizing catalogue method

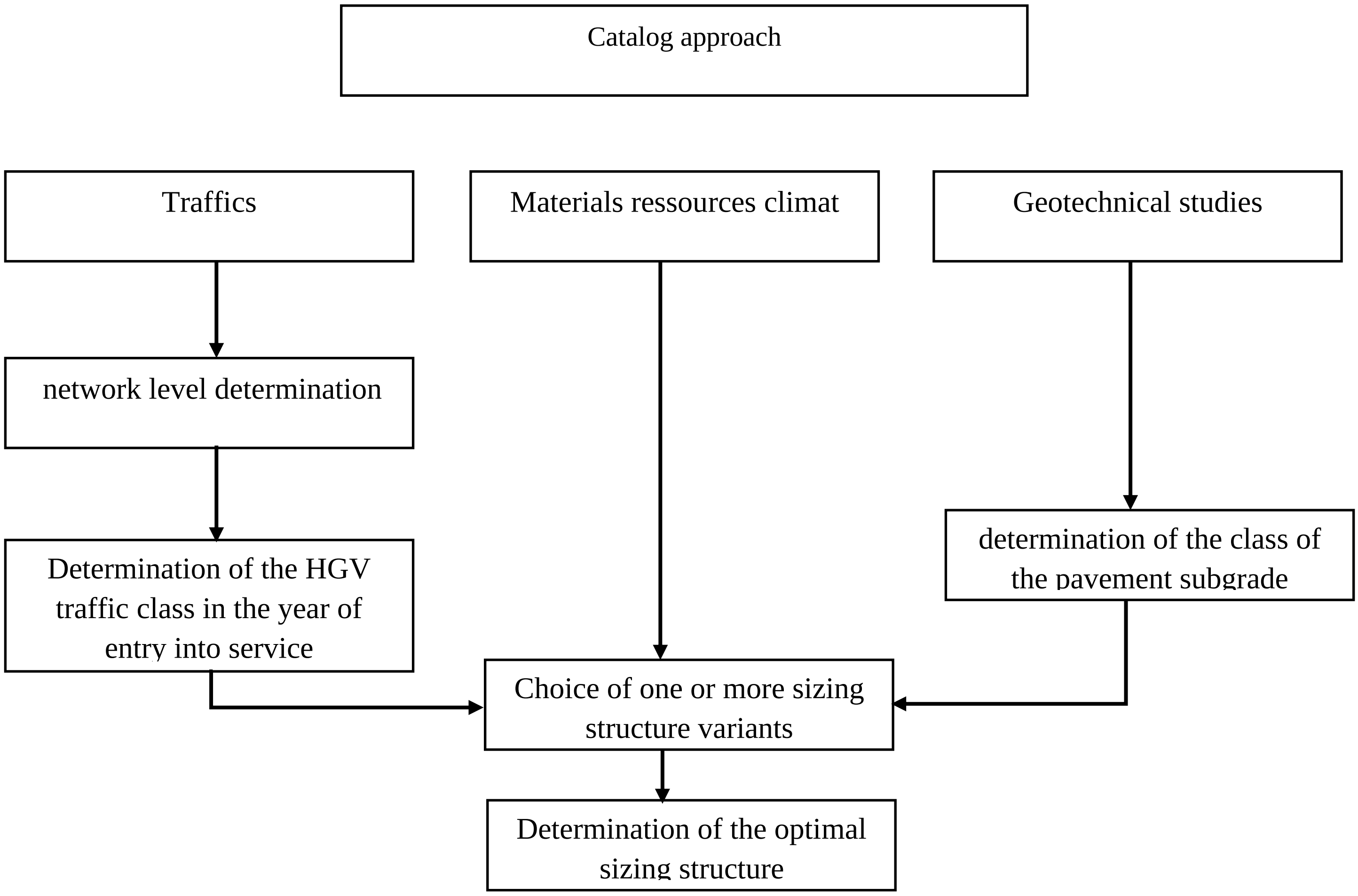

Figure 1.2 New pavement sizing catalogue method

1.5. Conclusion

This chapter is a review of general concepts about materials used in road construction, which are lacking in quality materials.

The materials to be used must be technically diagnosed. They meet the requirements of construction and standard quality, as each material has its own intrinsic properties. The diagnosis varies according to the material.For the optimal diagnosis of the materials used, it is recommended to diversify the applicable experiments (physical - chemical - mechanical).

Pavement structure design is an important step in the road project study. The design of the road depends on 3 criteria: traffic, climate, and the choice of materials used.

Chapter 2: EXPERIMENTATION ON THE USED MATERIALS

2.1 INTRODUCTION

The purpose of this chapter is to assess the characteristics of the materials used: dune sand (DS) and the geotextile (GTX). The composite material is designated by the abbreviation (DS/GTX).

This characterization is, in fact, required for the identification of these materials. The results of the tests carried out on the DS/GTX material will obviously depend on those relating to the individual materials and also on the methodology adopted for the performed tests.

The scheduled tests are carried out on each elementary material (DS and GTX), then on the DS/GTX compound. The main test carried out is the one named ‘California Bearing Ratio’ (CBR). This test is selected considering its suitability for the evaluation of the soil bearing capacity, and also the availability of the test devices within the soil mechanics laboratory of the University of Ouargla. The dune sand used in this study comes from the region of Ouargla. The GTX is chosen on the basis of its availability in Algeria and its (deliberate) worst-performing targeted type. This is to consider the most economical conditions of the product.

2.2 CHARACTERISTIC OF USED MATERIALS

The usual physical and mechanical characteristics of the two elementary materials (DS and GTX) are reported in table 2.1. The parameters relating to the sand are measured in the laboratory, and those relating to the GTX are copied from the technical sheet of the product. Indeed, the measurement of the characteristics of the GTX is not possible because of the absence of specific devices.

Table 2.1: Characteristics of Sand and GTX [1]

	Physical characteristics of the sand				
	Volume mass (g/cm³)			Sand equivalent (%)	Friction angle (°)
	Loose state	Dense state	Natural state	SE	φ
sp.1	1.52	1.75	1.63	79.17	28.44
sp.2	1.52	1.80	1.59	70.73	29.48
sp.3	1.53	1.76	1.57	73.08	31.33
sp.4	1.53	1.76	1.57	----	----
sp.5	1.66	1.72	1.59	----	----

Features of the GTX (AS10)			
		Standards	Results
		Physical characteristics	
Surface mass		EN IOS 9864	100 g/m²
Thickness under 20 kPa		EN IOS	0.5 mm
		Mechanical characteristic	
Tensile strength	SP*	EN ISO 10319	6 kN/mm
	ST*		7 kN/mm
CBR puncture resistance		EN ISO 12236	1.0 kN
Resistance to pyramidal punching		EN 14574	0.7 kN

Table 2.2: Geometric designing of the used geotextile

Holes diameter (mm)	Spacing (mm)	Number of circles
2	5.7.9.11	16
4	7.9.11.13	16
8	11.13.15.17	16
10	13.15.17.19	16
12	15.17.19.21	16

Table 2.2 shows the geometric characteristics of the geotextile used in this study: diameter and spacing of each specimen.

2.3 EXPERIMENTAL PROTOCOL

The main test adopted to assess the bearing capacity of the dune sand/geotextile (DS/GTX) product is the so-called CBR. This test is chosen because of its ease of execution compared to other load-bearing tests lands (Plate test, pressure meter, triaxial) .The limited means of experimentation and the short duration of time allocated for the realization of this 'end-of-study project' (ESP) also contributed to the choice of this type of test (the CBR).The tests in question are carried out in accordance with standard NF P 94-078 and referred to as CBR despite being carried out on a compound material: soil + geotextile. These tests are carried out on dry dune sand filled in a CBR mold and interspersed with layers of GTX.

Figures 2.1 and 2.2 show the mean material used in the CBR test.

Figure 2.1: CBR mold mounted on the compression machine

Figure 2.2: CBR test accessories.

1. Annular surcharge for plated steel.
2. Split surcharge weight for plated steel.
3. Cutting edge for plated steel
4. Filter paper ϕ150mm (pack of 100)
5. Modified compaction hammer (ϕ= 51 mm and H= 457.2 mm).
6. Spacer disc for plated steel, 25.4 mm.
7. Split NF CBR mold for same as T0089/NF, split longitudinally on one side
8. NF CBR mold for complete with collar and perforated base plated steel.152 mm diameter ×152 mm body height.

2.4 EXECUTION OF THE TEST

2.4.1 Preparation of Specimens

In the common case, the CBR test is carried out on the basis of the results of the modified Proctor test. Specimens are prepared according to the maximum dry density and optimum water content obtained from the compaction test. As for the case of the modified Proctor test, the elements larger than 20mm are eliminated.

The number of materials needed to carry out the tests must be guaranteed to be sufficient to fill a mold: usually 5.5kg for the immediate CBR and IBI tests, and 7kg for the soaked CBR test.

If the test is to be carried out on the soaked sample (Immersed CBR), the water content after immersion is measured:

- either by weighing the entire mold including the soil
- or on a sample placed under the same conditions

The mold containing the specimen is then detached from its base plate, and turned over so that the upper face of the specimen comes in contact with the base. Then, it is again assembled into the mold. Proceed with the extraction of the spacer disk, then with the execution of the punching or the immersion depending on the targeted objective.

2.4.2 Execution of Punching

The punching execution methods differ depending on whether the IBI, the immediate CBR, or the immersion CBR are sought.

2.4.2.1 IBI test

Place the assembly (compacted soil in the mold, including its base) on the press centered under the piston, then proceed as follows:

- Bring the upper surface of the specimen into contact with the piston.
- Initialize the force and sinking sensors.
- Perform punching by maintaining the penetration speed at 1.27 mm/min ± 0.1 mm/min.
- Establish the force-deformation curve corresponding, at least, to punching of 1.25mm, 2mm, 2.5mm, 5mm, 7.5mm, and 10mm.
- Measure the water content of the soil specimen after performing the puncture punchtest.

2.4.2.2 Immediate CBR test

The immediate CBR test is carried out in the same way as that of IBI, with the only difference of the application of an overload on the tested sample. The load in question represents that applied on the site. It generally corresponds to stress around 50 kPa. The operator is free to adjust this load as appropriate.

2.4.2.3 Immersion CBR test

- Position the swelling disc on the specimen before fitting the overloads as indicated above.
- Set up and initialize the swelling measurement device.
- Immerse the assembly so that the specimen is covered by a depth of water of, at least, 20 mm.
- Note the swelling reached after 4 days (± 2h) of immersion.
- Remove the mold and the test piece from the immersion tank and after draining, carry out the punching as indicated above.

2.5. CALCULATIONS AND RESULTS

The index measured (whether IBI, CBR immediate, or immersed) is retained as being the highest value between the following two results:

$$\frac{Penetration\ \ effort\ \ at\ \ 2.5\ mm\ \ punching\ (kN)}{13.35}\ x\ 100(\%)$$

$$\frac{Penetration\ \ effort\ \ at\ \ 5.0\ mm\ \ punching\ (kN)}{19.93}\ x\ 100(\%)$$

2.6 CONCLUSION

In this chapter, the main characteristics of the materials used (Geotextile, DuneSand) are presented in a brief manner.

The dune sand is characterized as a loose material difficult to deal with. To accommodate this, the geotextile and the dune sand combination is implemented in order to improve the performance of sand in terms of mechanical properties and thus make it usable in projects. Devices and tools have been adapted to study the feasibility of sand for each type of material.

The technology of including GTX in the road base layer is designed with inspiration from the technologies of GTX usage in general. Thus, practical investigation is mandatory for the estimation of the behavior of any new designed material.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 INTRODUCTION

The present chapter is dedicated to the experimental part of the study carried out. It announces, in particular, the results of the various achieved tests. The tested materials are those mentioned in the previous chapter. These tests are performed on the same materials (DS and GTX) but considered as a combination. The test results are interpreted according to the scientific opinion of the authors, on the basis of the all knowledge acquired during the course of the master's and the realization of this end-of-study project. Detailed results of the conducted tests are presented in the appendices.

3.2 RESULTS AND DISCUSSION

3.2.1 Presentation

The results obtained from the various tests carried out are presented in this section. Figure 3.1 is the graphical representation of the results shown in Table 3.1 and relating to sand alone. The expressions denoted by formula 1 and formula 2 are respectively:

Formula (1) $$\frac{Penetration\ \ effort\ \ at\ \ 2.5\,mm\ \ punching\,(kN)}{13.35}\ x\,100(\%)$$

Formula (2) $$\frac{Penetration\ \ effort\ \ at\ \ 5.0\,mm\ \ punching\,(kN)}{19.93}\ x\,100(\%)$$

Figures 3.2 to 3.6 express the results obtained for the GTX perforated with 2mm diameter holes and stored in the soil specimen at (respectively): the surface of the soil specimen, at anchorage of 1cm, 2cm, 3cm and 4cm.

The same test program was repeated for a GTX perforated with a ϕ=2mm and spacing of 7mm. The results obtained being numerous, they have been placed in the appendix of this memory figures 3.2 to 3.6 for respectively z=0, z=1cm, z=2cm, z=3cm and z=4cm).

After noting that the bearing capacity of the soil specimens is always high for the case of the GTX placed on the surface, this arrangement was retained: i.e., no more carrying out of tests with anchored GTX. Therefore, for z=0, the figures A.6 to A.9 shown in the appendix, represent the results of the tests relating to the reinforced sand of GTX with the holes perforated and spaced respectively of

- ϕ2 (S9 and S11)
- ϕ 4 (S7, S9, S11 and S13)
- ϕ 8 (S9, S11, S13 and S15)
- ϕ 10 (S11, S13, S15, S17 and S19)

Table 3.2 in the appendix groups together all the calculated values of the CBR indices obtained at the end of all the tests carried out.

Finally, table 3.3 and figures 3.7 and 3.8 are shown, grouping together all the calculated CBR indices. The figures 3.9 and 3.10 are derived from the same CBR results obtained after analytical examination.

Table 3.1: CBR values for sand alone

	Test 01	Test 02	Test 03
F(kN)	1.531	1.436	1.598
CBR(%)	7.68	7.21	8.02
Mean value of the CBR (%)	7.64		

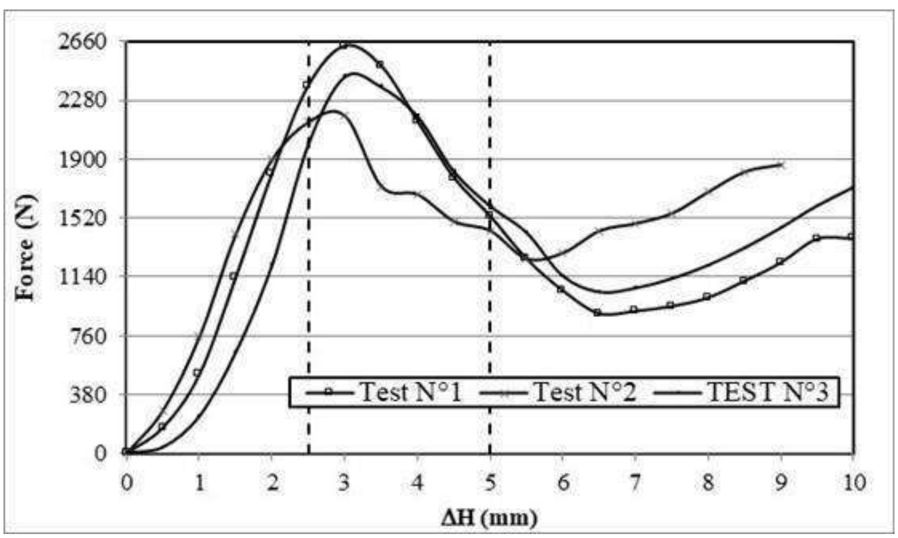

Figure 3.1: Punching force versus penetration (Dune Sand alone)

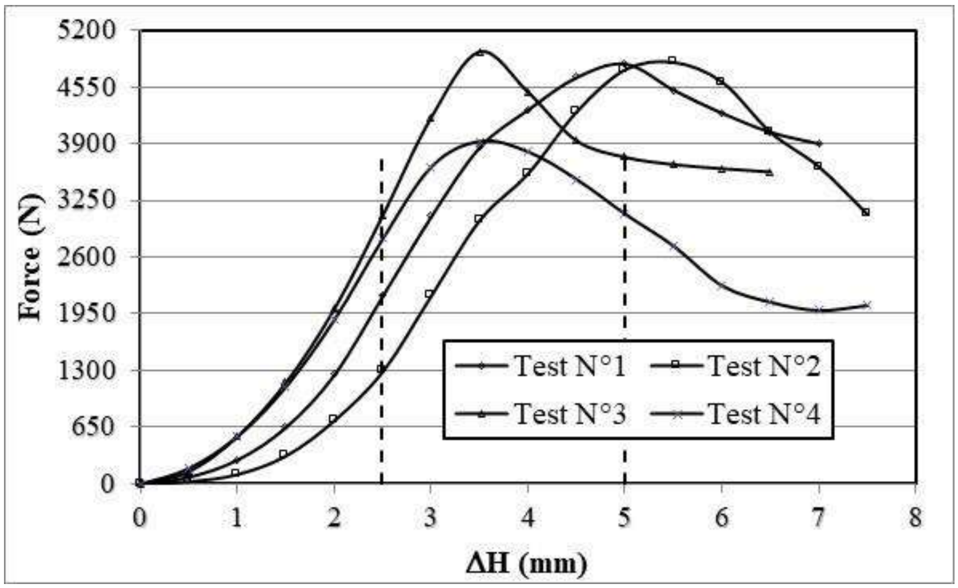

Figure 3.2: Punching force versus penetration (DS/GTX ϕ 2 Sp 5 at the surface)

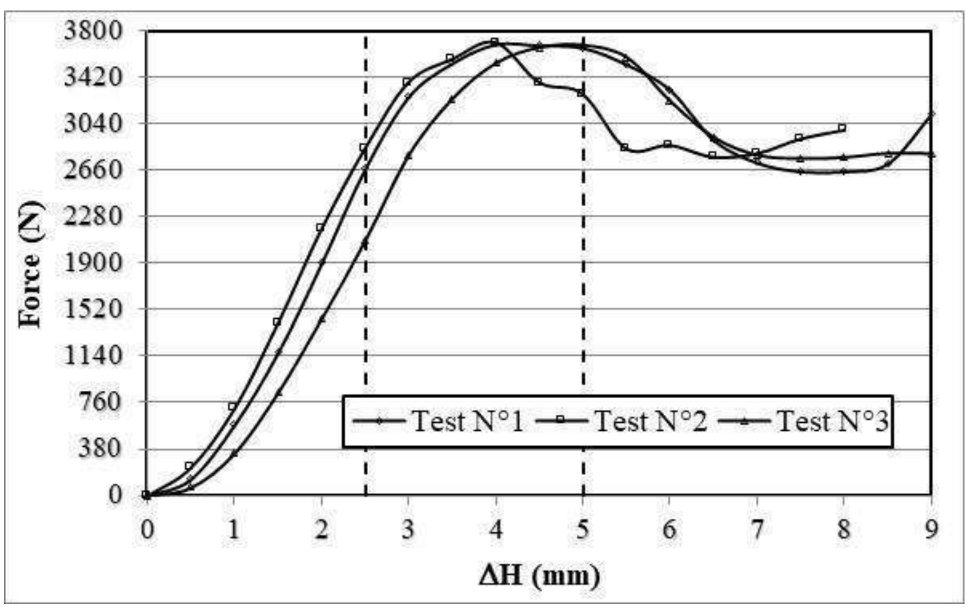

Figure 3.3: Punching force versus penetration (DS/GTX ϕ 2 Sp 5 at 1cm)

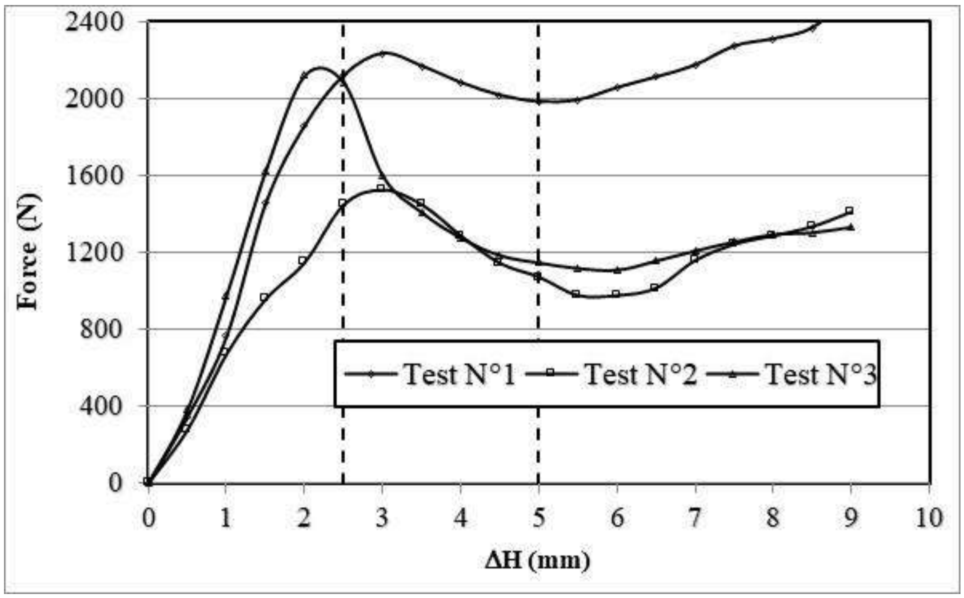

Figure 3.4: Punching force versus penetration (DS/GTX ϕ 2 Sp 5 at 2cm)

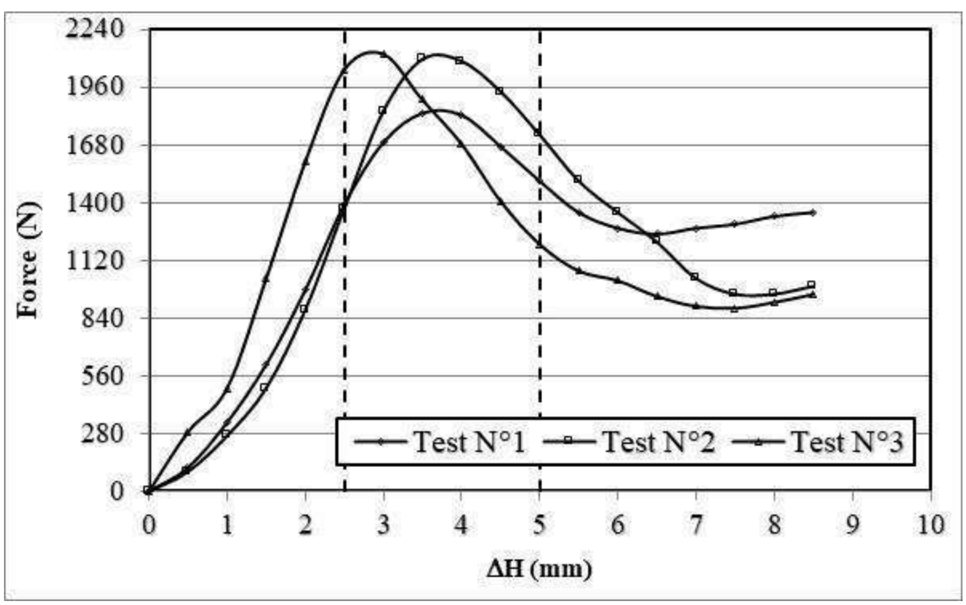

Figure 3.5: Punching force versus penetration (DS/GTX ϕ 2 Sp 5 at 3cm)

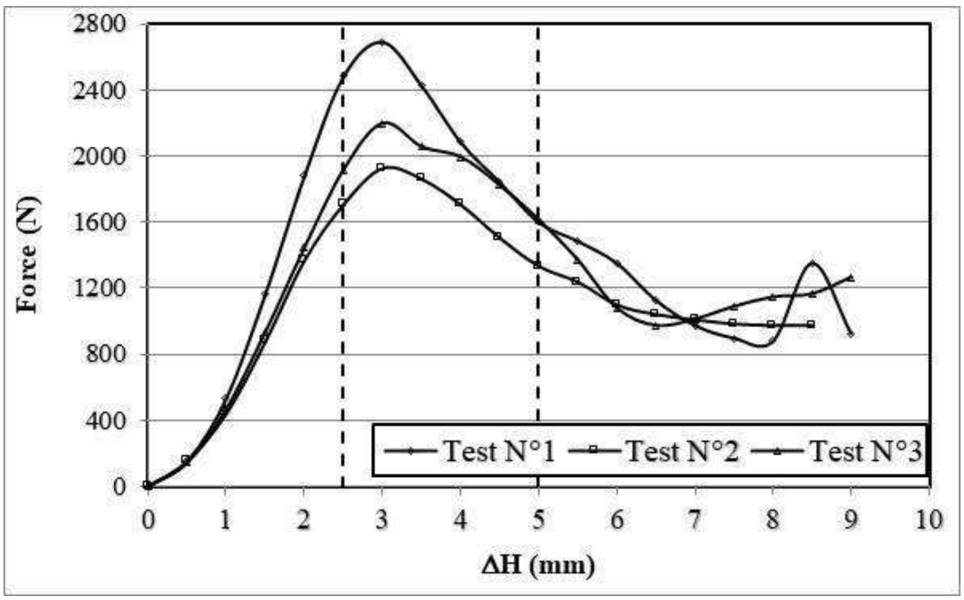

Figure 3.6: Punching force versus penetration (DS/GTX ϕ 2 Sp 5 at 4cm)

Table 3.3: Summary of the obtained CBR results

		Spacing (mm)							
		5	7	9	11	13	15	17	19
Ø (mm)	2	12.47	14.86	16.09	13.67	---	---	---	---
	4	---	7.88	12.27	12.27	19.36	---	---	---
	8	---	---	---	11.43	13.91	13.77	15.61	---
	10	---	---	---	---	12.04	17.57	15.68	17.81

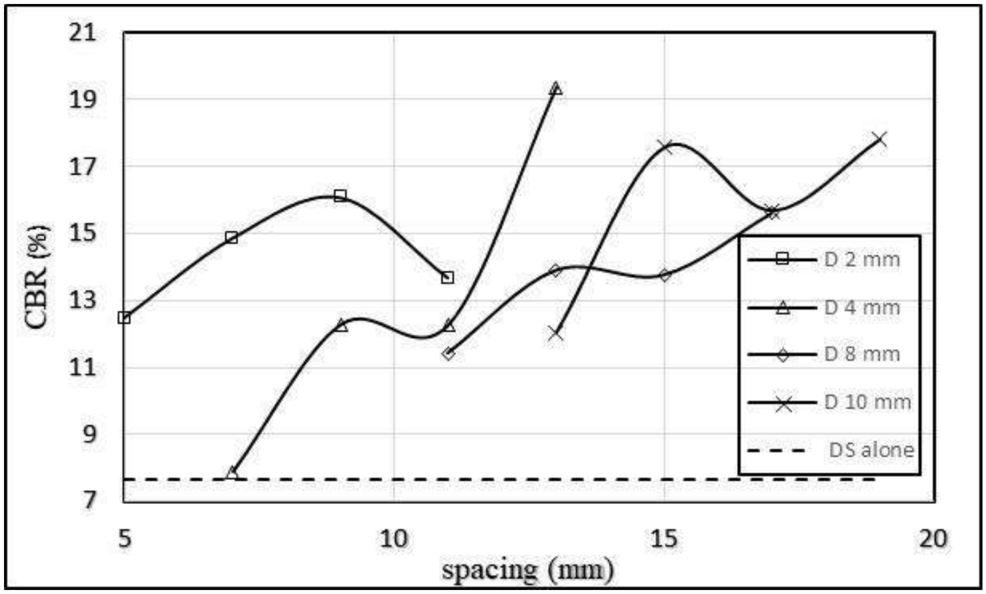

Figure 3.7: CBR versus spacing between the holes (different hole diameters)

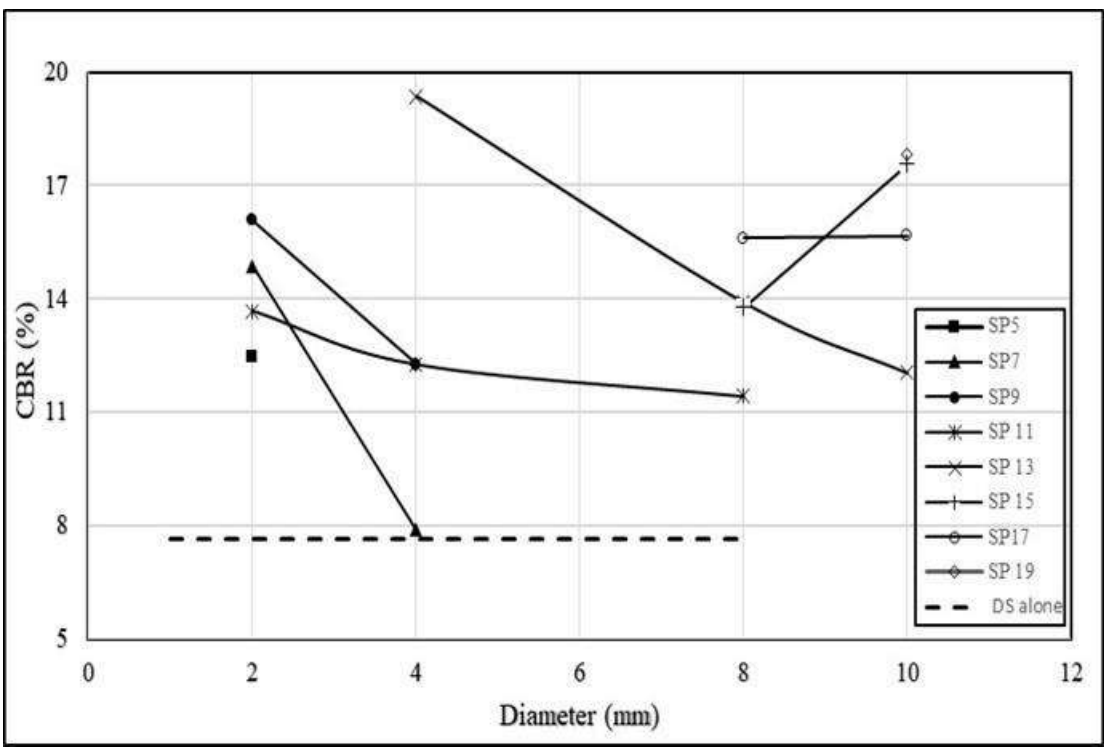

Figure 3.8: CBR versus diameter of the holes (different spaces)

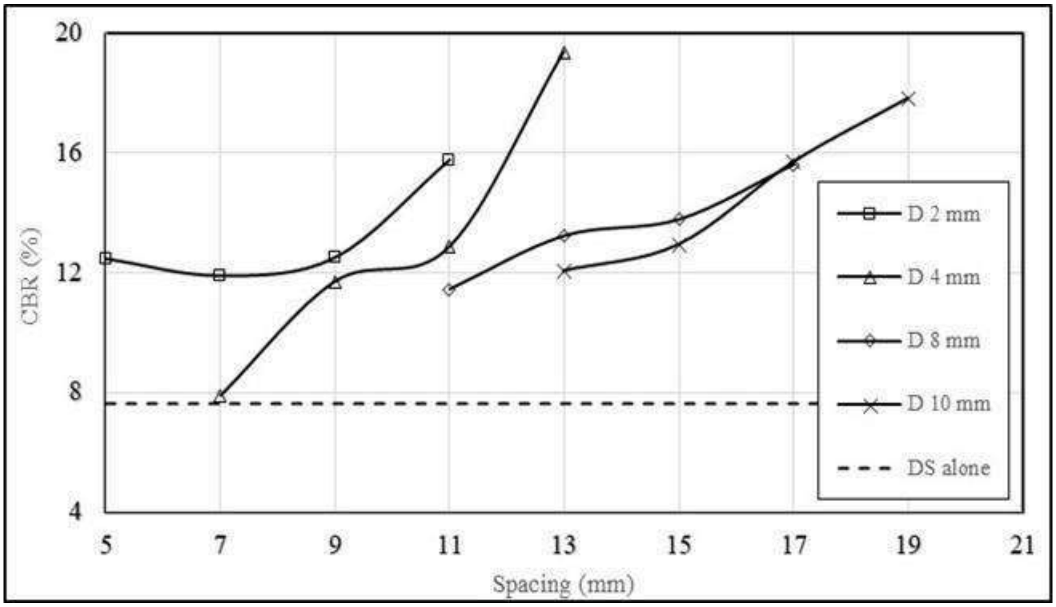

Figure 3.9: CBR / spacing / diameter relationships (corrected results)

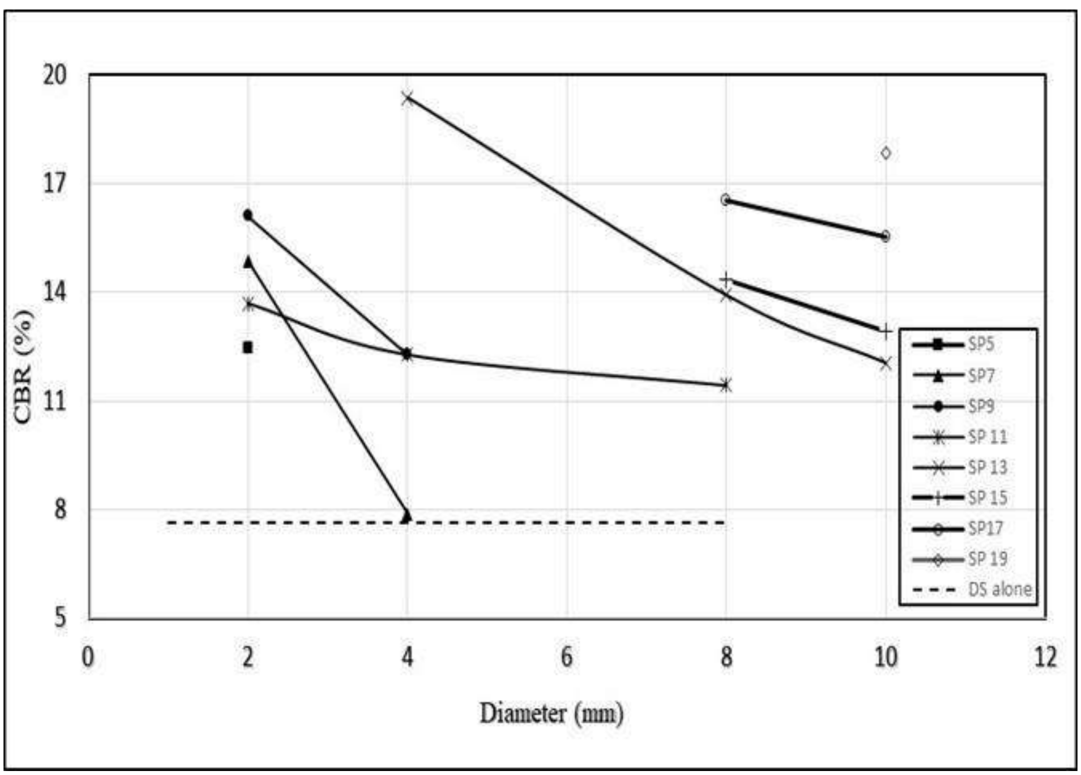

Figure 3.10: CBR / diameter / spacing relationships (corrected results)

3.2.2 Description

Figure 3.1 relating to sand alone shows a certain similarity between the curves representative of the results. The brittle aspect of the sand is highlighted (peak followed by a drop in puncture resistance). A resumption of resistance is clearly observable on the three curves shown. The stability of the soil resistance is not achieved beyond a depression of 10mm.

The forces recorded at the 2.5mm depression are visibly greater than those relating to the 5.0mm depression.

The curves in Figure 3.2 show distinctive differences. No curve seems harmonic to another. The only common observation highlighted is the superiority of the forces recorded at the 5.0mm penetration compared to those at 2.5mm.

The curves in Figure 3.3 are very close to each other. This is a sign of confirmation of the results obtained. Those in Figure 3.4 are relatively distinct. The forces recorded at 2.5mm and 5.0mm strains are occasionally comparable. The same remarks can be extended for the case of the curves in figure 3.5. Figure 3.6 shows close curves at the start and end of the imposed punching. At the peaks of the forces recorded, some dispersions are noted.

In Figures 3.7 to 3.10, the dotted curve represents the CBR value of sand alone. This representation is adopted despite the independence of the latter from the parameter mentioned on the abscissa axis (diameter or spacing). Figures 3.7 and 3.8 are obtained on the basis of the results considered in the first appreciation. Figures 3.9 and 3.10 are obtained after an analytical processing of all the test results.

3.2.3 INTERPRETATION

The results obtained from all the CBR tests carried out are interpreted as a whole. These results were first processed statistically, then all represented in Figures 3.7 and 3.8.

At first sight of figure 3.7, the results seem disordered, but all superior to the CBR index of the sand alone. It was predictable to see an increase in the CBR index as a function of the spacing between the perforations. This is because the greater the spacing, the more existing the GTX, which gives more reinforcement to the soil.

Similarly, for the case of figure 3.8, the bearing capacity of the ground in terms of CBR index decreases when the diameter of the holes increases. This is logically interpreted from the fact that when the diameter increases, the compound tends to become an ordinary sand, ie of low bearing capacity. The curve representative of the 15mm spacing is an exception to the variation shown. It is possible that the values considered are marred by errors or not treated statistically.

The curves in Figures 3.9 and 3.10 come from the same database used for (respectively) Figures 3.7 and 3.8 taking into account the primary results that best fit the overall trend of CBR variation. The shape of the experimental curves shown in Figures 3.9 and 3.10 then becomes quite understandable.

3.3 CONCLUSION

This chapter brings together all the results obtained from the CBR tests carried out. The sand was tested alone, then with the inclusion of GTX layers. The layers of GTX associated with the sand are prepared by having made holes of various diameters and various spaces.

The results obtained show that the bearing capacity of the DS/GTX compound is better when the GTX is placed on the surface of the ground. Similarly, the soil bearing capacity is proportional to the spacing between the perforations made on the GTX, and is inversely proportional to the diameter of the holes. Finally, the same value of the Californian bearing index can be obtained for various combinations between the diameter of the holes and the spacing between them.

Chapter 04: ECONOMIC STUDY

4.1. INTRODUCTION

The economic estimating or appraisal is an important aspect in the study of any construction project. It enables the project owner to make decisions regarding the costs necessary to complete the project. This estimating depends on many technical, social and functional parameters. This assessment is closely linked to the specificities of the project under consideration. It can even change from one period to another for the same project.

The present chapter aims a presentation of an application example. This relates to a stretch of road of a given length. The cost price of a layer of the compound (DS / GTX) is evaluated in comparison with the same layer made using conventional techniques according to current market rules. Also, the means and techniques implemented, and the temporal aspects are highlighted.

4.2. QUANTITATIVE AND ESTIMATIVE VALUATING

In this part of the study, the sub-base of a road section is considered. This part of the road structure is evaluated (on the one hand) by being constructed with the ordinary materials currently in use, and (on the other hand) made in DS/GTX compound. The two quotes are presented (respectively) in tables 4.1 and 4.2.

The foundation section length taken into account is 6960m. This length is dictated by the quantity of GTX materials that can be transported by a semi-trailer type truck. The loading capacity of such a truck is retained as the reference unit for the work to be performed. This is because it is a key parameter for the progress of work and the evaluation of funding. In table 4.1, the unit prices mentioned relate to the supply of materials from a deposit in the vicinity of the project (distance less than 20 km).

Table 4.1: Quantitative and estimated detection of 6960 m of road carried outby the habitual method

DESIGNATION	U	Qty	U.P. (DA)	T.P. (DA)	Duration	Number of workers
Supply, transport, implementation, and execution of the tuff foundation layer 20 cm thick including extraction, loading, Transport to the place of deposit, leveling of the subgrade, watering and compacting with repair all networks damaged due to excavation work and all constraints of good performance.	m^3	6960	600	4.176.000	The period required to complete this layer of the road is illustrated by planning GANTT. It is estimated at 26 days.	▪ Four truck drivers for transporting and unloading tuff. ▪ Driver grader for spreading tuff. ▪ Driver for the Vibratory compressor for crushing large tuff stones. ▪ Driver 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.)			**4.176.000**		
	TAV 19%			**793.440**		
	Total A.T.I.			**4.969.440**		

Table 4.2: Quantities and estimations of 6960 m of foundation layer made by DS/GTX compound

DESIGNATION	**U**	**QTY**	**U.P (DA)**	**T.P (DA)**	**Duration**	**Observation**
Supplying of DS	m^3	6960	31.25	217.500	/	▪ The load of sand in a truck with a capacity of $16m^3$, the payment is estimated at 5000 DA.
Spreading the DS	km	6.96	30.000	208.800	7 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	48720	100	4.782.000	/	▪ Generally, from Algiers
Transport of GTX rollers	U	28	(Forfeit)	40.000	/	▪ According to AFITEX ALGERIA company, a truck can carry 28 rolls.
Unloading and setting up (deploying)	U	28	600	16.800	7 days	▪ Set in place by machine, 3 rolls per day.
Backfilling GTX with DS layer	km	6.96	30.000	208.800	7 days	▪ The GTX is backfilled with a layer of sand to avoid its movement due to wind or other factors.
		Total amount (E.T.)		**5.545.900**		
		T.A.V. 19%		**1.053.721**		
		Total A.T.I.		**6.599.621**		

4.3. COMPARISON ASPECTS

The comparative analysis of the two tables (4.1 and 4.2) shows some relevant aspects.

1) The amount of road construction with the composite (DS/GTX) is higher compared to the usual method. The percentage increase between the two methods is estimated at 32.8%. The main reasons can be the ones below:

- The first method is based on using tuff material, which is of low cost, considering its availability in the vicinity of the construction project. This contributes, visibly, to the low cost of carrying out the project.
- The second method is based on the implementation of the GTX material. The purchase price of this material is recognized to be the major reason for the high cost of constructing the road. Its purchase price alone constitutes 75% of the total amount of the project.

2) Another potential parameter making the difference between the two implementation techniques is the time factor. In fact, the method based on compound (DS/GTX) is three times faster than the usual method. This is because the two used materials (DS and GTX) are considered ready for immediate implementation.

3) Labor is one of the most important elements in construction projects. It is an indispensable resource in any construction project.

4) A simplistic comparison between the human resources required in the two cases shows, among others, the following aspects:

- The nature of the tuff material generally used in roads construction requires leveling with certain techniques of high accuracy. Therefore, this method depends on skilled and experienced labor commensurate with the work style, especially for machine drivers.
- The second method using (DS/GTX) is a method that does not require special skills or the intervention of a large number of workers. Four to five workers can be enough to run a construction site.

5) The use of machines for carrying out the work also shows distinctive aspects:

- In the usual method (using tuff), each operation is carried out with special machines and each machine has a specific task.
- The ‘DS/GTX’ method does not depend too much on machinery. It only needs a crane and a motor grader.

6) The purchase price of the GTX may be negotiated and, somewhat, reduced or compensated by another service, like any commercial transaction. This is supported by the diversity of suppliers and the competition between them. Also, the means of transport can be diversified given the handy nature of the GTX lots.

7) Unlike the technique based on classical materials, the one using DS/GTX can be implemented anywhere due to the availability of raw materials. This constitutes a key parameter in the socio-economic development policy based on the extension of the road network.

4.4. CONCLUSION

A quantitative estimation is prepared to compare the variables (DS/GTX) and (tuff) for a road of about 6960 m. This amount is governed by the truck's packing capacity of the geotextiles.

The study in question shows that the second method (DS/GTX) is more expensive compared to the first method (tuff). This is due to the higher purchase price of the main component (GTX) that really affects the balance of benefits.

The second method is characterized by the speed of implementation compared to the classic method, the fact that it does not require a lot of effort and equipment. And it can be implemented anywhere for the availability of ready-made raw materials.

The current technique cannot be used in just any region. The availability of compliant materials is, indeed, a primary condition governing this issue. Similarly, many constructions machinery and equipment must be moved to the construction site. All these conditions can be against a road construction project.

Finally, the quality and specialization of the workers also make a main difference between the two techniques. Neither the number nor the performance of the workers is required when the compound (DS/GTX) is implemented.

GENERAL CONCLUSION

The developed study falls within the context of evaluating the performance of a mixture consisting of dune sand and geotextile.

As part of the end-of-study project, some topics seem quite relevant and deserve to be mentioned. Moreover, some small proposals and suggestions related to the topic are required for the continuity of the conducted study.

The technical material covered in this study consists of a review of some specific concepts related to road materials. A first conclusion, which can be highlighted, concerns the characterization of the materials that can be used in road construction. Indeed, the technical performance of the latter depends significantly on the physical and mechanical characteristics of the base materials used (whether natural or synthetic).

In the present study, dune sand is chosen on the basis of its abundant availability and its free nature. The geotextile material is also chosen among the least efficient in order to evaluate the economic aspect of the compound (DS/GTX). The geotechnical characterization of the two materials is mainly based on the CBR test, representative of the bearing capacity of the material (sand alone or reinforced sand). The GTX embedded in the sand was pierced with regularly spaced circular holes.

The results obtained indicate a better bearing capacity of the DS/GTX compound when the geotextile is placed on the ground surface. Also, the CBR index is all the higher as the perforations are small and the spacing increased.

The comparative study of quotes for two variants (usual materials and DS/GTX) shows that the GTX technique is 30% more expensive than the usual one. In the opposite, the DS/GTX technique is much faster and does not require large number of workers nor high qualification.

Besides, the occasion of the conducted study uncovers some other aspects. These can be reported as recommendations:

- The used ring for measuring the punching force during the CBR test must be chosen appropriately in order to be adapted to the consistency of the soil tested (soft, firm, friable, compressible, hard, ...)
- The preparation of the test specimens is an operation to be considered with care. The results obtained risk being dispersed due to a lack of standardization in the preparation of these specimens. The preparation of the test specimens is an operation to be considered with care. The results obtained risk being dispersed due to a lack of standardization in the preparation of these specimens.

Several aspects of the study proved to be relevant and deserving of full scientific study. They can be developed in the form of end-of-study projects or research projects.

- Resume the same test protocol with changing the quality of the main material from geotextile to Geogrid, Geomembrane, or Geonets.
- Resume the same test protocol with a change in the diameters of the holes and the spacing between them
- Test the effect of saturation on the bearing capacity of the DS/GTX compound.

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Tab A.1: Forces and CBR results obtained for all the tests carried out (DS/GTX).

Diameter	2 (mm)											
Spacing	5 (mm)			7 (mm)			9 (mm)			11 (mm)		
Force (kN)	1.49	2.41	0.61	0.82	1.40	0.82	1.23	1.57	2.54	1.65	1.23	1.93
Formula (1)	11.13	18.08	4.59	6.11	10.49	6.11	9.23	11.76	19.03	12.39	9.23	14.44
Force (kN)	2.63	2.41	2.41	2.37	3.74	2.96	3.20	4.26	1.78	2.75	3.14	2.7
Formula (2)	13.21	12.11	12.11	11.90	18.74	14.86	16.09	21.35	8.93	13.80	15.76	13.55
CBR (%)	12.48			`14.86			16.09			13.68		
Diameter	4 (mm)											
Spacing	7 (mm)			9 (mm)			11 (mm)			13 (mm)		
Force (kN)	0.49	1.15	0.73	1.40	1.04	0.90	1.54	1.04	0.90	1.53	0.82	1.49
Formula (1)	3.67	8.60	5.50	10.49	7.81	6.73	11.57	7.81	6.73	11.44	6.11	11.13
Force (kN)	1.57	1.53	1.61	2.56	2.33	1.40	2.56	2.33	1.40	4.32	3.07	3.86
Formula (2)	7.88	7.66	8.09	12.85	11.69	7.03	12.85	11.69	7.03	21.67	15.38	19.36
CBR (%)	7.88			12.27			12.27			19.36		
Diameter	8 (mm)											
Spacing	11 (mm)			13 (mm)			15 (mm)			17 (mm)		
Force (kN)	1.93	1.82	1.11	0.65	0.69	0.73	1.49	1.49	0.78	1.65	0.86	3.04
Formula (1)	14.44	13.65	8.28	4.89	5.20	5.44	11.13	11.13	5.81	12.39	6.42	22.81
Force (kN)	2.39	2.22	2.22	1.70	3.57	3.04	2.86	2.69	2.69	3.23	3.00	3.65
Formula (2)	12.00	11.11	11.16	8.51	17.93	15.28	14.33	13.49	13.49	16.19	15.03	18.34
CBR (%)	11.43			13.91			13.77			15.61		
Diameter	10 (mm)											
Spacing	13 (mm)			15 (mm)			17 (mm)			19 (mm)		
Force (kN)	1.79	0.87	1.93	2.05	2.84	1.19	1.89	1.17	2.46	2.29	1.02	1.13
Formula (1)	13.40	6.51	14.44	15.39	21.30	8.91	14.13	8.75	18.39	17.13	7.65	8.44
Force (kN)	2.33	2.03	2.84	3.67	1.82	3.33	3.13	3.45	2.71	3.09	3.70	3.40
Formula (2)	11.69	10.20	14.23	18.44	9.15	16.70	15.68	17.32	13.59	15.48	18.54	17.07
CBR (%)	12.04			17.57			15.68			17.81		

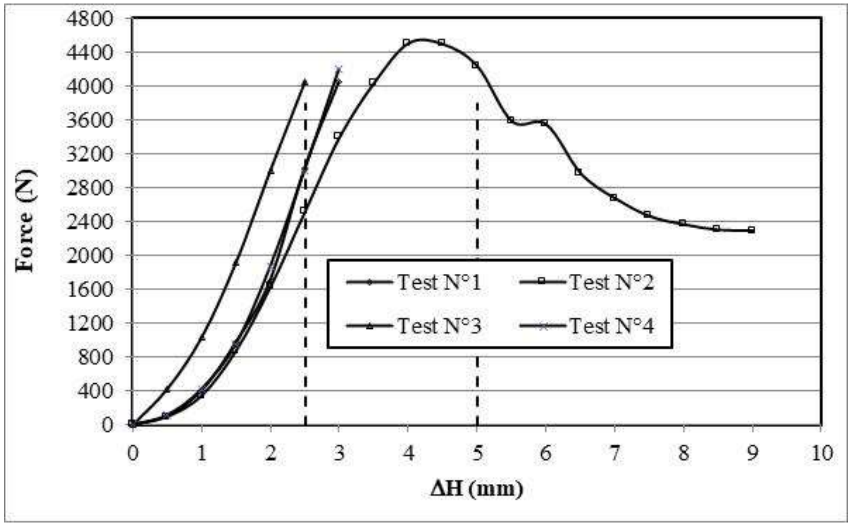


Figure A.1: Force vs penetration (Ø 2mm / SP 7mm / z= 0 cm)

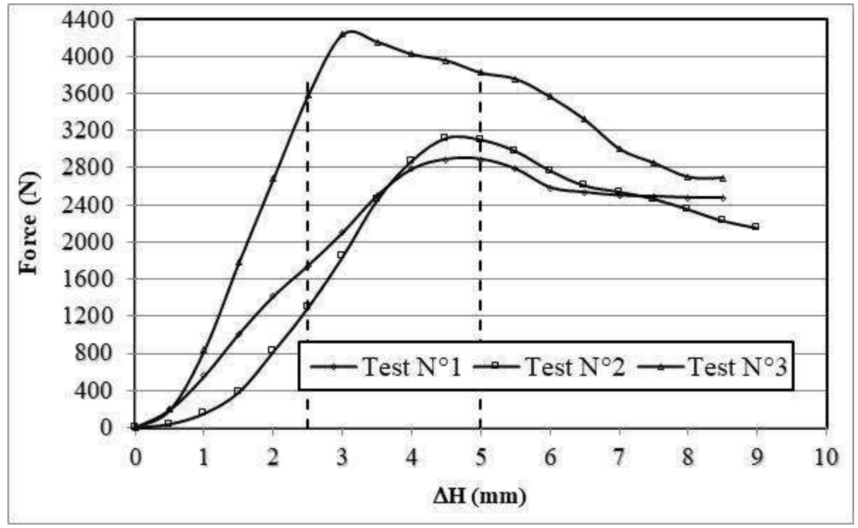


Figure A.2: Force vs penetration (Ø 2mm / SP 7mm / z= 1 cm)

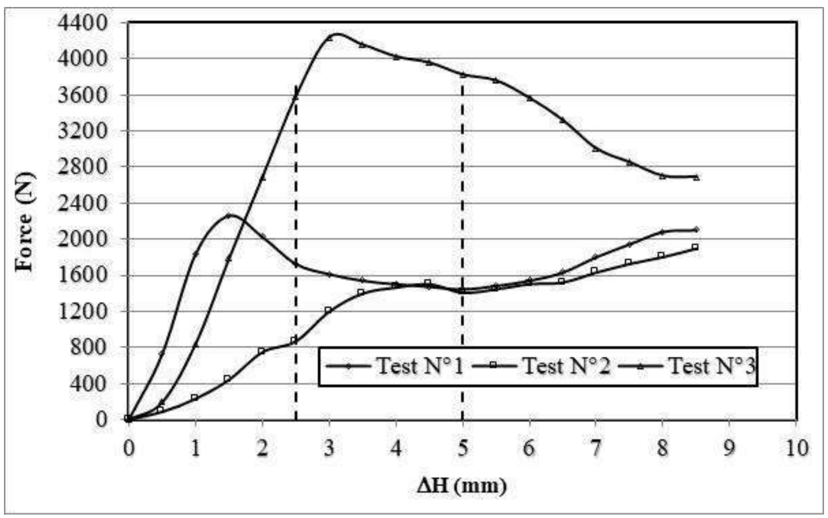


Figure A.3: Force vs penetration (Ø 2mm / SP 7mm / z= 2 cm)

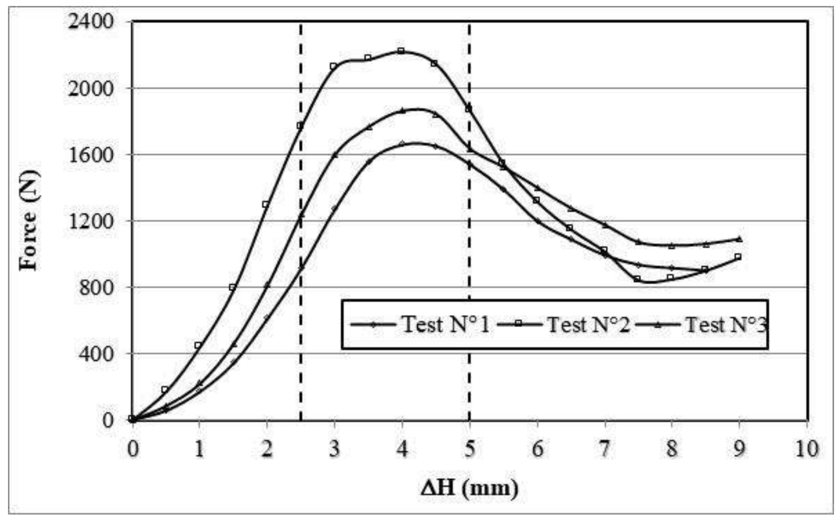
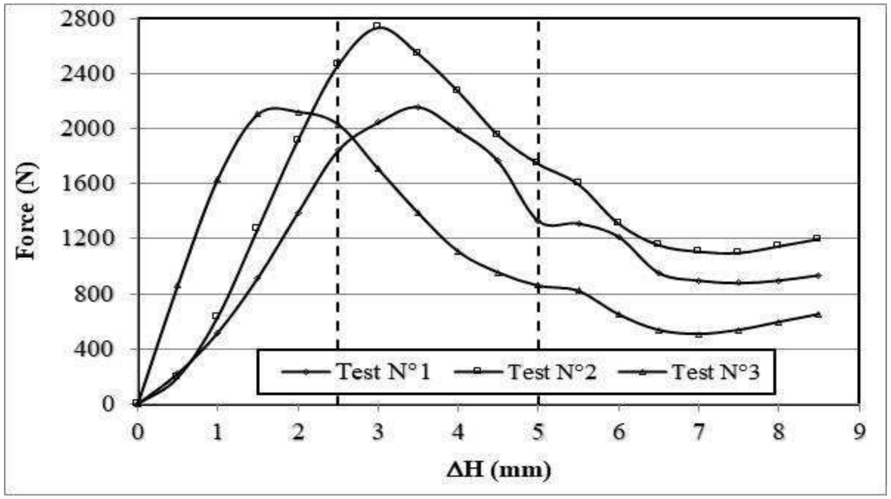


Figure A.4: Force vs penetration (Ø 2mm / SP 7mm / z= 3 cm)



A.5: : Force vs penetration (Ø 2mm / SP 7mm / z= 4 cm)

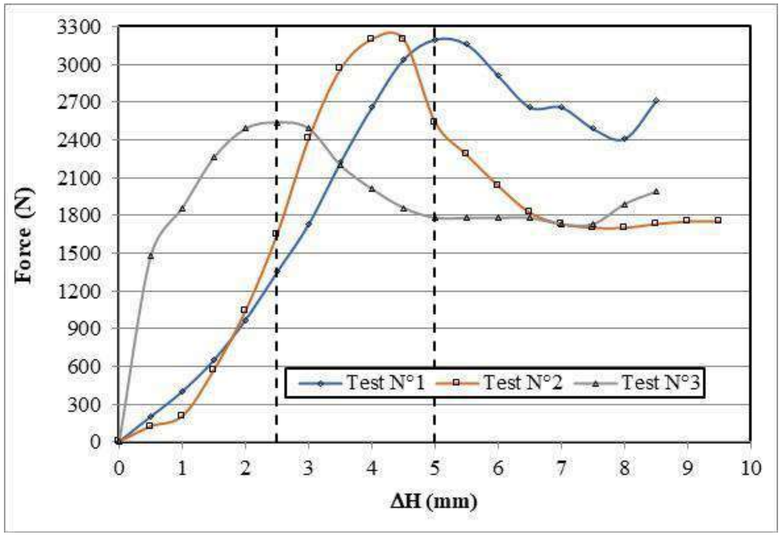


Figure A.6: Force vs penetration at the surface (Ø 2/ SP 9)

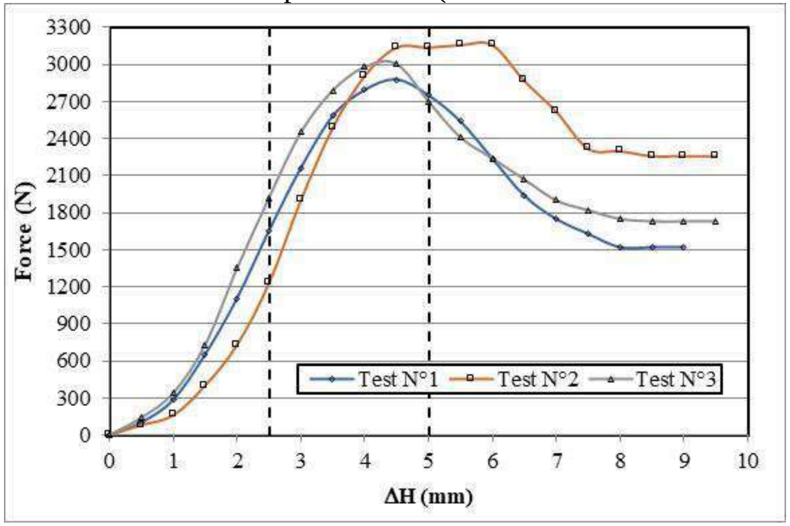


Figure A.7: Force vs penetration at the surface (Ø 2/ SP 11)

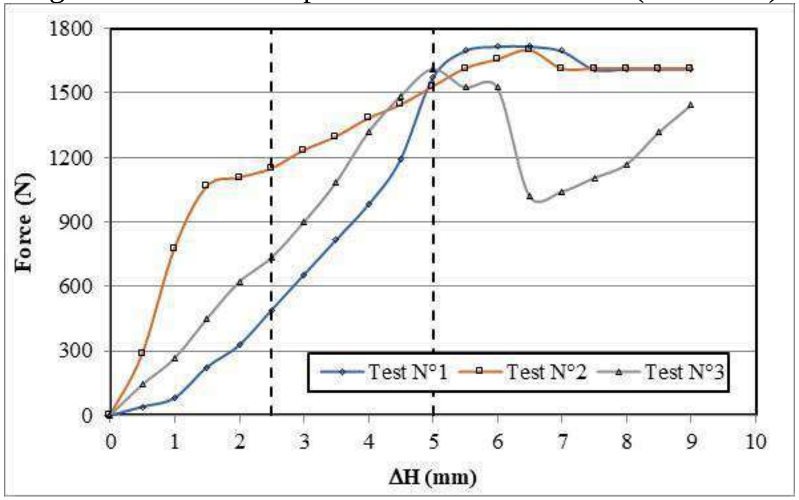


Figure A.8: Force vs penetration at the surface (Ø 4/ SP 7)

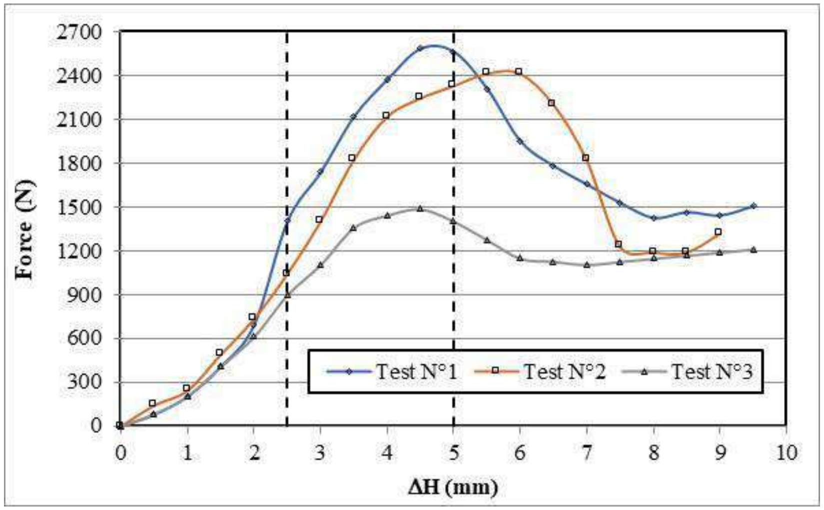


Figure A.9: Force vs penetration at the surface (Ø 4/ SP 9)

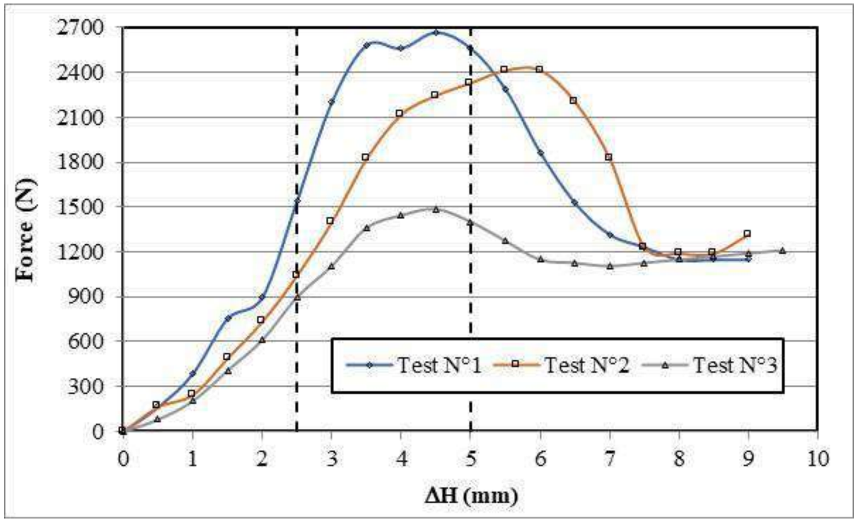


Figure A.10: Force vs penetration at the surface (Ø 4/ SP 11)

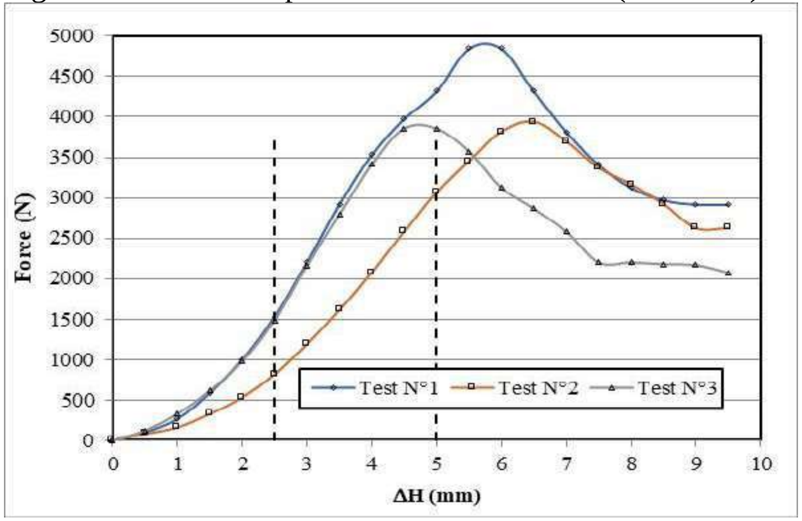


Figure A.11: Force vs penetration at the surface (Ø 4/ SP 13)

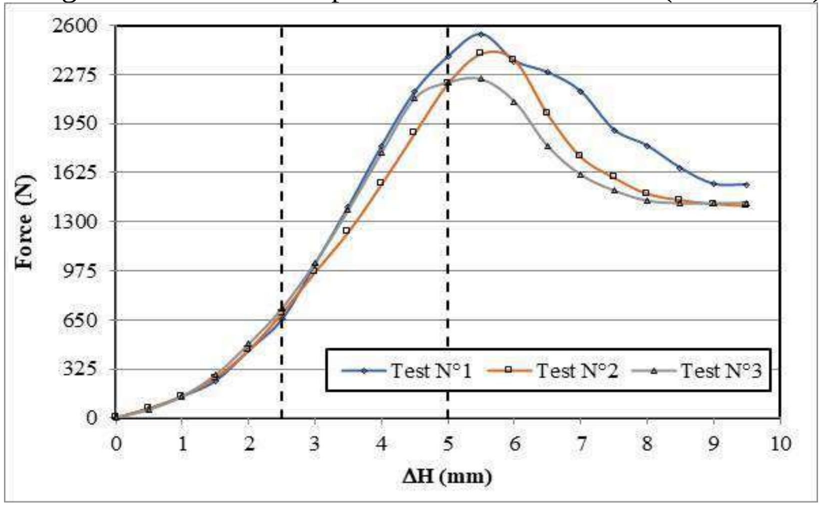


Figure A.12: Force vs penetration at the surface (Ø 8/ SP 11)

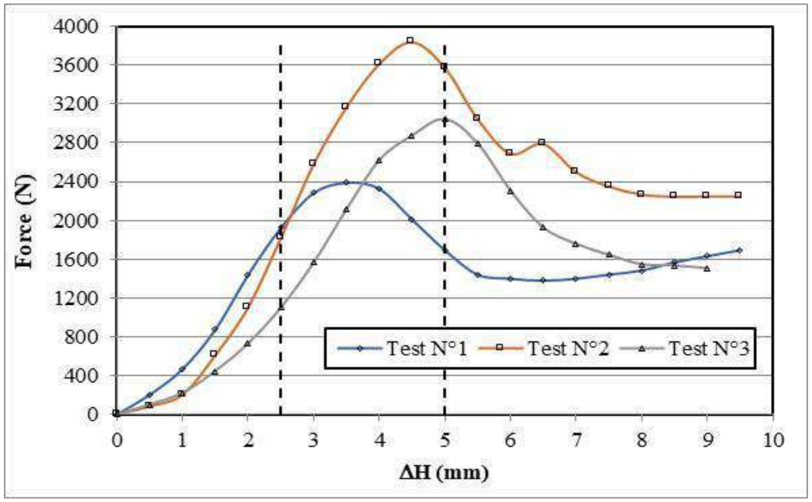


Figure A.13: Force vs penetration at the surface (Ø 8/ SP 13)

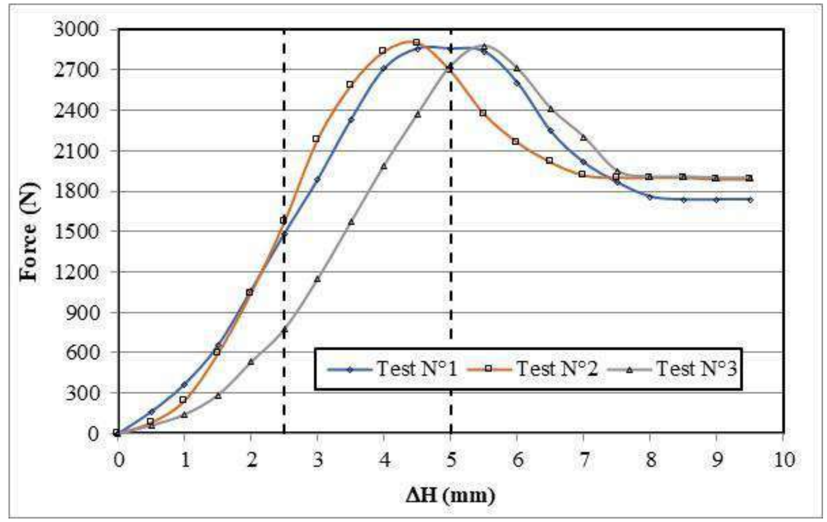


Figure A.14: Force vs penetration at the surface (Ø 8/ SP 15)

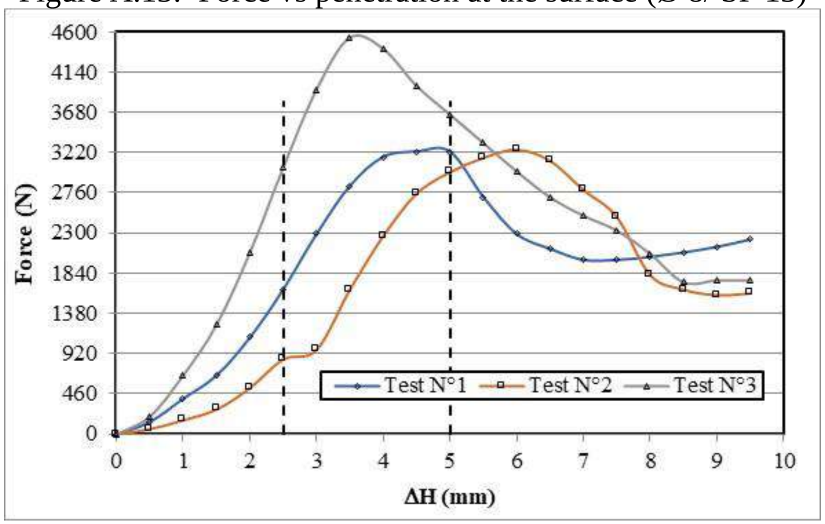


Figure A.15: Force vs penetration at the surface (Ø 8/ SP 17)

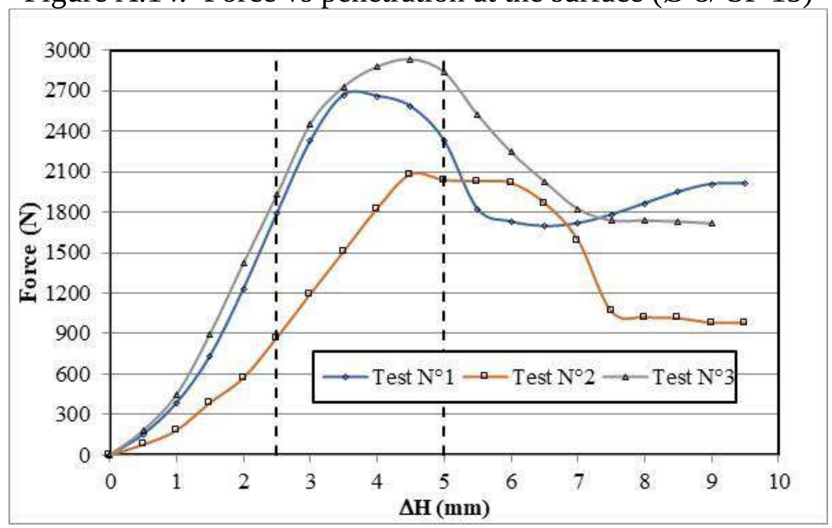


Figure A.16: Force vs penetration at the surface (Ø 10/ SP13)

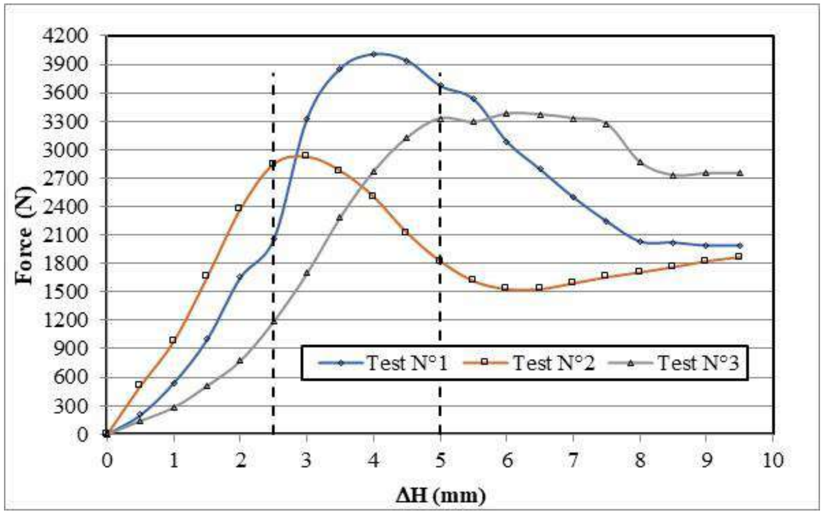


Figure A.17: Force vs penetration at the surface (Ø 10/ SP15)

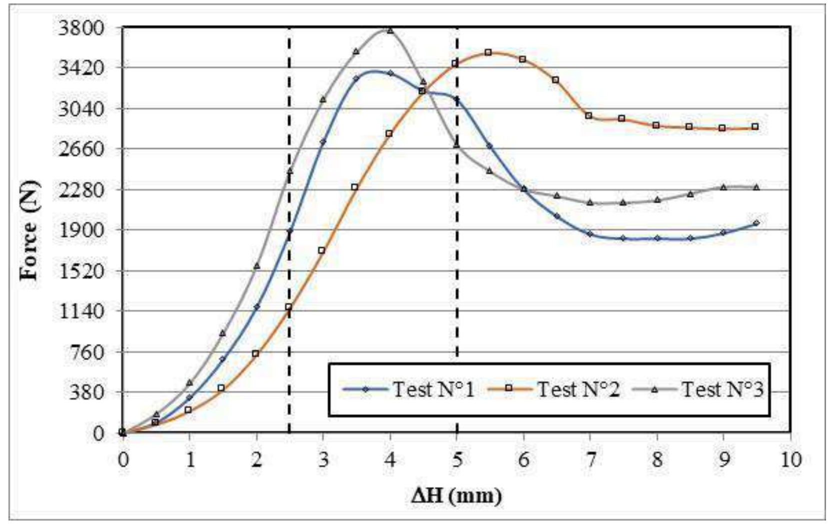


Figure A.18: Force vs penetration at the surface (Ø 10/ SP17)

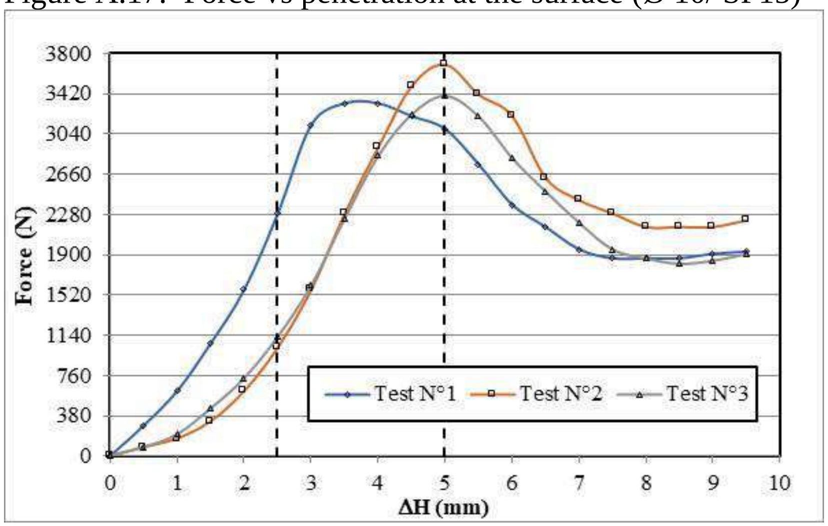


Figure A.19: Force vs penetration at the surface (Ø 10/ SP19)

ملخص

يعاني الجنوب الجزائري، كبقية المناطق الصحراوية من ندرة المواد المستخدمة في إنجاز الطرق مقارنة بالمعايير الدولية المعتمدة. لذا فإن الاتجاه الحالي هو تكييف التقنيات المستعملة في إنجاز الطرق على استخدام المواد المحلية ومن ضمنها رمال الكثبان. تتميز هذه الرمال بوفرتها ومجانيتها وقد تشكل بديلا للمواد المستعملة.

تهتم الدراسة المنجزة بتدعيم رمل الكثبان بمادة جيونسيجية بغرض تحسين التلاصقية بها. تعتمد الدراسة على تجربة دليل الحمولة الكاليفورني على الرمل الطبيعي، ثم عند تدعيمه بالمادة الجيونسيجية. تم تغيير بعض الخصائص الهندسية للمادة الجيونسيجية باعتماد ثقوب منجزة بها، مع تبديل منهجي لأقطار تلك الثقوب وكذا البعد بينها.

تظهر الدراسة المنجزة نتائج ملفتة للانتباه، قابلة للتطبيق الميداني لمشاهدة مدى صلاحيتها واقعيا.

الكلمات المفتاحية: جيونسيج، رمل الكثبان، دليل الحمولة الكاليفورني.

Abstract

As for the desert regions, southern Algeria faces a scarcity of road materials recommended in international standards. The current trend is therefore to adapt road construction techniques to the specificities of local materials, including sand dunes. The latter is, in fact, abundant and free, and can be an alternative to the materials used.

The study carried out concerns the reinforcement of dune sand with a geotextile product, in order to improve its cohesion. The study relates to the Californian bearing test applied to sand alone, then reinforced by the geotextile material. Some geometric properties of the geotextile are modified by applying regularly spaced holes with variation of their diameter and their spacing.

The study carried out shows quite interesting results, and is applicable in practice in order to appreciate its suitability.

Keywords: geotextile, dune sand, California Bearing Ratio.

Résumé

A l'image des régions désertiques, le Sud Algérien confronte une rareté des matériaux routiers recommandés dans les normes internationales. La tendance actuelle est donc d'adapter les techniques de construction des routes aux spécificités des matériaux locaux dont fait partie le sable de dunes. Ce dernier est, en effet, abondant et gratuit, et peut être une alternative aux matériaux utilisés.

L'étude réalisée porte sur le renforcement du sable de dunes par un produit géotextile, en vue d'améliorer sa cohésion. L'étude porte du l'essai de portance Californien appliqué au sable seul, puis renforcé par le matériau géotextile. Quelques propriétés géométriques du géotextile sont modifiées par application de trous régulièrement espacés avec variation de leur diamètre et de leur espacement.

L'étude réalisée montre des résultats assez intéressants, et est applicable dans la pratique en vue d'apprécier sa convenance.

Mots-clés : géotextile, sable des dunes, Indice portant Californien