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Soil reinforcement by treated natural fiber (halfa, date palm fibers)

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Dedication

We thank God the Almighty for giving us the privilege and the chance to study and follow the path of science.

To my dear parents: my mom and my dad

To all my brothers and my dear sister

To the whole family from the biggest to the smallest

To whom I owe all my recognition of moral help To my very dear friend SERBAH KHALED

To all those who are dear to me

I dedicate this modest work

Abderrezzaq

Dedication

I dedicate this modest work to
My dear father

My dear mother

My brothers and sisters

All my family

All my friends especially my best friend
***BOUNEDJAR Abderrezzaq**, for whom I*
deeply respect and appreciate

TO all who know me

Ali

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ملخص

ان حركة النقل التي صارة أكثر كثافة وتركيزا بالإضافة الى وجود عوامل كثيرة تضعف خصائص التربة التي تعد أحد الاسباب الرئيسية للتشوهات التي تحدث لطبقات الطرق هده العوامل قادت الى استغلال مواد جديدة لتغطية القصور المسجل على مستوى الطريق. الدراسة الحالية تهدف الى ايجاد الخصائص الميكانيكية للتربة محصل عليها من خلال اضافة الياف نباتية مستخلصة من اشجار النخيل ونبات الحلفاء. تم انجاز عدة تجارب بتراكيز مختلفة على نفس التربة (تربة مأخوذة من بلدية تجلابين ولاية بومرداس) بليفين من نوع مختلف بغرض تتبع تغير الخصائص الميكانيكية ومقارنة الدور الحقيقي لكل من الليفين المضافين.وقد اضهرت التجارب ان اضافة الالياف النباتية لديه تأثير على اداء التربة المدعمة حيث انه ادى الى ارتفاع ملحوظ في الخصائص الميكانيكية.

الكلمات المفتاحية: طبقات الطرق، الخصائص الميكانيكية، الياف نباتية، اشجار النخيل، نبات الحلفاء، التربة المدعمة.

Abstract

The transport movement, which has become more intense and concentrated, in addition to the presence of many factors that weaken the soil properties, which is one of the main causes of the distortions that occur to road layers, these factors led to the exploitation of new materials to cover the shortcomings recorded at the road level.The current study aims to find the mechanical properties of the soil obtained through the addition of plant fibers extracted from palm trees and halfa plants.Several experiments were conducted with different concentrations on the same soil (Soil taken from the municipality of Tjellabine, Boumerdes) with different type of fibers in order to track the change of mechanical properties and compare the actual role of each of the added fibers.Experiments have shown that the addition of plant fibers has an effect on the performance of the reinforced soil as it led to a significant increase in the mechanical properties.

Keywords: road layers, mechanical properties, plant fibers, palm trees, halfa plants, reinforced soil.

Résumé

Le mouvement de transport, devenu plus dense et concentré, s'ajoute à la présence de nombreux facteurs qui affaiblissent les propriétés du sol, qui est l'une des principales causes des distorsions qui se produisent sur les couches routières, ces facteurs ont conduit à l'exploitation de nouveaux matériaux pour combler les carences constatées au niveau de la route.La présente étude vise à trouver les propriétés mécaniques du sol obtenues par l'ajout des fibres végétales extraites de palmiers et de plantes de l’halfa.Plusieurs expériences ont été réalisées avec des concentrations différentes sur le même sol (Sol prélevé sur la commune de Tjellabine, Boumerdes) avec différent type de fibres afin de suivre l'évolution des propriétés mécaniques et de comparer le rôle réel de chacune des fibres ajoutées.Des expériences ont montré que l'ajout de fibres végétales à un effet sur les performances du sol renforcé car il conduit à une augmentation remarquable des propriétés mécaniques.

Mots clés: couches de route, propriétés mécaniques, fibres végétales, palmiers, plante de l’halfa, sol renforcé.

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Notations and abbreviation list

PI: plasticity index (percentage %).

PL: water content at soil plastic limit (percentage %).

LL: water content at soil liquidity limit (percentage %).

CI: consistency index (percentage %).

IPI: immediate bearing index (without unit).

W_{nat}: natural water content of the soil (percentage %).

MBV: The methylene blue value expressed in grams.

SE: The sand equivalent test.

CL: capping layer.

D_t: direct tensile strength (N/m^2 , pa, kpa, Mpa)

ρd: dry mass volume (kg/m^3).

γd: dry density (kg/m^3).

PVC: polyvinyl choride colloquil (synthetic plastic polymer)

PE: polyethene

PP: polypropylene (thermoplastic polymer)

LNHC: National Laboratory for Housing and Construction

LCTP: Central Public Works Laboratory

V : acceleration volume

LA : Los Angeles coefficient

MDE : micro Deval coefficient in the presence of water

FS : sand friability coefficient

FR : fragmentability coefficient

DG : degradability coefficient

φ : soil friction angle (drained conditions)

C : cohesion

E : oedometric modulus of the material

ε : strain

σ : stress

Z : vertical displacement

EV2 : reversible deformation modulus measured with plate test

Rt : direct tensile strength

Pc : pre-consolidation constraint

Cc : consolidation coefficient

Cg: swelling index

Cu : uniformité coefficient

H : initial height

ΔH : the difference between the final height and the initial height

σv0 : the initial effective stress value

General Introduction

General Introduction

The application of the reinforced soil method in geotechnical engineering has a long history, including in construction,roadways, railways, dikes, stabilization of soil slope [1], and improvement of soft soil.certain desired properties such as load bearing capacity, shear strength, and permeability of soil can be improved by various techniques. one of the most commonly used techniques is the use of fibers to reinforce the soil it has been a solution to stabilizethin soil and localized repair of failed slopes by using natural or synthetic fibers [26].

Algeria is among the countries, which have extraordinary plant fiber resources

(palm, Hemp,halfa, Cotton…) [49], unfortunately, their valuation in practical fields, among others, in building materials is still little exploited [57].

The objective of this work is to make our contribution to the development of local resources, in this case the plant fibers of the date palm and halfa at low cost coming from a renewable source and to integrate it in a rational way in the field of road works [53], in order to try to develop the techniques of soil treatments and the valuation of natural fibers, we proposed a treatment of the capping layer material of the road pavement from the region of "Tidjellabine city of boumerdes" based on biomaterials at different percentages (3%, 5%, and 7%). so the treatment we have chosen for these fibers is alkaline based on NAOH[65] ,[66]. all with the aim of obtaining a capping layer material that is both resistant of good bearing capacity and economical, without forgetting the preservation of the environment.

The present work is therefore interested in the study of the influence of the addition of plant fibers such as date palm and halfa on weak soil to improve the geotechnical properties for safe and stable reuse [67] .

Does this research answer the question if these natural fibers able to pass a series of tests to prove their effectiveness in supporting the soil in a safe and stable way more than other methods?

- **Workplan**

The present work consists of four chapters:

The **first chapter** represents an introduction to the road and the layers that form it, especially capping layer, while respecting the various tests that must be done before establishing the project according to the applicable standards from the French technical road guide.

Followed by **the second chapter** that presents a general information on fibers, natural and artificial fibers and their structure that allows them to be used in several fields, especially plant fibers, halfa and date palm, and the need to benefit from a cheap local product with high quality.

then **the third chapter** presents the location of soil samples and the program of experiments to work with, in addition to the results of testes to identify the soil, followed by the chemical treatment of the used fibers, and finally the testes s applied to soil samples supported by fibers.

The **fourth chapter** consists in a comparative study of the true role of each of the halfa and date palm fibers supporting the soil, using the CBR and DS tests.

Finally, this work ends with a **general conclusion**, which summarizes all of the results obtained.

Chapter I Generality on roads and pavements

I.1. Introduction

Roads are an essential asset for any nation; however, the creation of these assets alone is not enough we have to carefully planned, as pavement that is not well-designed and constructed quickly collapse.

There are various types of pavement structures that differ in their suitability in different environments like Flexible pavements that occupies most of the Algerian roads, Pavement structure is part of the road with the traffic flow, and serves to provide a safe, comfortable and economical movement of vehicles within the foreseen period of exploitation.

In order to accomplish this, it is necessary to pavement structure meets the following requirements :

-it is sufficiently resistant to the impact of moving load and to provide load transfer on the placenta and the groundbasis (subsoil).

- it is usable for traffic in all weather conditions.

-the pavement surface characteristics, especially evenness and roughness, provide a comfortable and safe driving.

-to ensure the designed service life (or estimated number of passages of standard axle), with easy maintenance and reasonable cos.

It must guarantee good conditions of safety comfort for users.

I.2.Definition of pavement

Road surface or pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic [1] .

I.3. Functional description of the pavement layers

The pavements composition in multi-layer structures built on top of what we refer to as a pavement foundation consisting of the natural ground (called the subgrade) generally overlaid with a capping layer. The rally of the layers forming the pavement:

(Capping layer, Base layer, Surface course, wearing course)

Capping layer:

This transitional layer belween subgrade and rood foundation has a dual function :

-during the works phase, it protects the subgrade,establishing a level surface of good qualify to enable vehicules and equipment to circulate in order to deliver materials and build the pavement layers,

-with respect to the mechanical performance of the pavement, it improves the homogeneity of the materials and possibly the variable characteristics of the backfill or the natural ground and also protects them from frost.

The rale of the layers forming the pavement:

-the base layers : road base and sub-base

-the surface course

Differ in how'they contribute to the functions provided by the pavement.

Base layers:

The pavement base usually consists of two layers, the sub-base surmounted by the road base. These made-up materials (usually treated, in high-traffic layers of pavements) provide the pavement with the mechanical strength to withstand the vertical leads induced by traffic. They distribute the pressures across the pavement foundation below to ensure that any deformations at this level remain within allowable limits.

For low traffic pavements, the role of sub-base can in some cases be achieved by stabilization of the natural ground

Surface course:

The surface course consists of :

The wearing course, which is the top layer of the pavement structure on which the combined aggression of traffic and climate are exerted.
-and possibly a binder course between the base layers and the wearing course.

Any devices intended to slow reflection cracking from base layers treated with hydraulic binders are located at the interface between the surface course and the road base.

The characteristics of the wearing course surface depend greatly part on the wearability of the pavement.the surface course also contributes to the perenniality of the pavement structure , particularly due to its function of waterproofing the base layer [2].

I.4 Geotechnical parameters of soils and compaction

I.4.1 Classification GTR 92 and standard NF P 11-300

The soils in place are natural materials, consisting of granular elements, which easily separated by simple crushing or, probably, by the action of a stream of water [3].

According to **NFP11-300** of the laboratory, tests and this classification generally referred to as **GTR** (Technical Road Guide),(SETRA/LCPC) **[**2]. The tables from NFP11-300 norm describe the classification of soils divided into four classes: **class A**: soils; **B:** sandy and gravel soils, **C:** soils with broad and fine elements, **D:** soils insensitive to water [4].

I.4.2 Nature parameters

They do not vary or change little over time they are intrinsic characteristics.

• The grain size (standards NFP 94-056 and NFP 94-057) [5]**and** [6]**:**
The granularity is a parameter which makes it possible to distinguish soils thanks to the size of their grains. a first analysis consists in measuring the distribution of the quantities according to the size of the grains. the two complementary methods are sieving forcoarse (or grainy) soils and sedimentometry for fine soils. this involves measuring the percentage of soil grains passing through a given sieve (passing or sieve).

The classic expression of this analysis is the grain size curve characterized by the following indices (d60 is the diameter corresponding to a loop of 60%):

- the uniformity coefficient (of Hazen): CU = d60 / d10 (CU <2 uniform,CU> 2 spread)

- the curvature coefficient:Cc = d (30) ^{2} / d60 x d10 (well graduated if CC between 1 an and 3)

Dmax : Maximum dimension of the largest elements contained in the soil. It determines the earthmoving workshop (the equipment used), the thickness of the layers and the mixing conditions. the threshold used is 50mm,as this makes it possible to distinguish fine, sandy or gravelly soils from boulder soil. it is also the current limit value for mixing soil with a binder for a quality CDF.

80µm sieve : Percentage of soil fines. fines are sensitive to water , according to their proportion they will there fore influence the behavior of the soil. thresholds retained by (GTR) : > 35% : behavior of the soil totally governed by the fine fraction <12 % : conventional threshold for saying whether a soil is poor or rich in fines

2mm sieve: distinction between sandy and gravelly soils threshold retained by(GTR):70%> 70%:sandy tendency soil <70%:gravelly tendency soil.

• **The argillosity** : Consistency states 3 Atterberg limits (standard NF P 94-051) the Atterberg limits are determined only for the fine elements of a soil (<400µm),because they are the only elements on which the water works by changing the consistency of the soil.the test there fore consists in varying the water content of this fraction of soil and in observing its consistency. depending on the water content, the soil will behave like a solid, a plastic material (able to deform a lot without breaking) or a liquid .

• **The plasticity index PI:** Characterizes the width of the soil studied has a plastic behavior.

$$PI = LL - PL$$

PL → water content at soil plastic limit (%)

LL → water content at soil liquidity limit (%) Threshold retained by (GTR):

- 12 :Upper limit of weakly clayey soils
- 25 :Upper limit of soil moderately clayey
- 40 :Upper limit between clayey and very clayey soils

• The methylene blue value MBV (standard NF P 94-068):

Parameter representing the absorption of the specific surface of the soil.the VBS is expressed in g of blue absorbed per 100 g of soil. the specific surface of the soil is determined by the surface of the particles of the clay fraction, an indirect evaluation of the quantity and the nature of the clay contained in the soil.

Threshold selected by (GTR):

- 0.1: soil insensitive to water
- 0.2 : appearance of a slight sensitivity to water (sandy soils)
- 1.5 : distinction between sandy-loamy soils and sandy-clay soils
- 2.5 : distinction between low plastic loamy soils with medium plasticity
- 6 :distinction between loamy soils and clayey soils
- 8 :distinction between clayey soils and very clayey soils [8].

• The sand equivalent test SE:

This test characterizes the pollution of a sand by clay or silt by measuring the quantity of colloidal particles that are made to flocculate . the test makes it possible to determine in a soil the relative proportion of fine soil and grainy soil. the sand equivalent is expressed as a percentage,this corresponds to the proportion of the fine soil flocculate (h2) compared to the solid deposit (h1) , both being measured on a test tube containing the soil sample and a standardized solution for disperse soil particles.

$$Es = [h1 / (h1 + h2)] \times 10$$

- ES = 0 Pure clay - ES = 20 Plastic soil

- ES = 40 Non-plastic soil

- ES = 100 Pure and clean sand

Certain minerals have a particular influence on the treatment of soil because, like clays , they are sensitive to the presence of water. Particular chemical constituents (organic matter , phosphates and nitrates, chlorides , sulfates and sulfides) also interfere with the hydraulic intake[9].

I.4.3. the parameters of mechanical behavior

These parameters are taken in to account to judge the possible land use as capping layer.

They distinguish materials whose granular fraction is likely to resist traffic and are therefore usable in CDF, and materials which are likely to fragment and will require special treatment provisions. The following parameters used for the classification of rock materials [10].

I.4.4 State parameters

The water state is particularly important for loose soils sensitive to water.

There are five different hydric states: - very humid **vh** - humid **h** - average humidity **ah** (optimum) - dry **d** -very dry **VD** the hydric state of a material makes it possible to define its classification of PST, because the bearing capacity of the soil is strongly linked this state.

• The natural water content:

W_{Nat} compared to the Optimum Proctor Normal W_{OPN}. W_{Nat} / W_{OPN}.

• **The consistency index CI (NF P 94-051):** Comparison of the natural water content W of a soil and the Atterberg limits; this gives you an idea of the state of a clay CI =LL−W_{Nat} /LL−PL.

• **The immediate bearing index (IBI):** It expresses the value of the CBR punch measured without overloading or immersion of a test piece of soil compacted with normal Proctor energy.

• **Dry density γd and dry mass volume ρd (γd = ρd x g)** the state of compactness in place is determined by measuring the apparent density of a dehydrated soil sample [11].

I.4.5 Compaction

Compacting the soil designed to reduce its volume by applying a mechanical process.

Such volume reduction happens only by eliminating air-filled voids that remain in the soil in its initial state, Compaction used to prevent subsequent deformation:
(backfill settlement, ground deformation etc...), improved mechanical characteristics (increase bearing power; allow materials to withstand road traffic) and used to ensure impermeability.

Bearing capacity : The bearing capacity of a soil is characterized by its resistance to compaction as a function of cohesion and internal frictio,the measurement of this lift determined by the CBR or IbI index or by the EV2 module of the plate test.

The CBR index (standard NF P 94-078)

The Californian Bearing Ratio (CBR) test is carried out both on the foundation soil of a pavement structure and on the materials that constitute it.

From this test,we define an empirical index called "Californianlift index",for two states : immersed CBR index (= ICBR after 4 days of immersion)and immediate CBR index
This index is used for the dimensioning of a pavement structure,is thus calculated by the ratio between the driving pressure of the ground and that of a referenced type material (in%):

• Pressure at 2.5mm depth /0.7

• Pressure at 5.0 mm depth / 1.05

The higher of the 2 values which is retained.

The submerged CBR index differs from the IbI by I mmersion of the mold for 4 days.

The EV2 module :

This test is intended to measure the deformability of the earthworks platform made up of materials ,the largest elements of which donot exceed 200 mm.

The test consists of measuring , using a defined device , the vertical displacement of the point on the ground surface located directly above the center of gravity of a loaded rigid plate , this displacement is called deflection (W) , this measurement gives the bearing capacity of the support and indicates whether the compaction is correct and makes it possible to verify whether the planned mechanical performance objectives are achieved.

The loads defined conventionally by LCPC are 20 kN for the 1st load and 25 kN for the 2nd load

EV2 is the module for deformation of the soil on the plate during the second loading cycle , EV1 is the module for deformation of the soil on the first loading.

K= EV2 / EV1 is the ratio of the modules to the plate of the two successive loads to determine if the compaction is sufficient ,we speak of better compaction when we have a low K ratio.

I.5 The capping layer

I.5.1 Definition and nature of the capping layer

The capping layer is the transition layer between the supporting soil and the body of the roadway. Therefore, it must have certain qualities [12], with mechanical, geometric, hydraulic and thermal characteristics taken as hypotheses in the design of the pavement [4].

I.5.2 the objectives and design of the capping layer

The capping layer is a transition element allowing the characteristics of the embankments material or the ground in place to the essential functions of a pavement support platform.

- **In the short term** (with regard to *pavement* construction) leveling, port once, protection of the supporting soil, traffic ability.

- **In the long term** (the structure in service): homogenization, maintenance of the time for a minimum port once, contribution to drainage [1].

I.5.3. Capping layer materials

Some materials used as a layer in the state, others made suitable by modifying their nature and/or their state in order to satisfy criteria concerning:

- Insensitivity to water.
- The size of the largest elements.
- The resistance under circulation of construction equipment.
- Insensitivity to frost [1] .

I.5.4. Techniques for preparing and protecting materials for use in a capping layer

These techniques mentioned and encoded in (Table VII page55-60) [10], this table is identical to one referring to the conditions of use of the embankments soils but does not have a section on compaction conditions.

- **Procedure to fix the thickness**

The thickness of the capping layer is determined at the end of the following procedure.

The geotechnical classification of soils and the water conditions affecting the upper meter supporting the capping layer, an area called "Upper Part of Earthworks" (PST) , make it possible to distinguish 7 cases .

Each PST is associated with one or two class (s) of long-term lift of the earthwork level , denoted ARi .

For each PST case and for the different shape layer materials,it is then recommended a shape layer thickness .

- **The different cases of Upper earthworks (UE) (PST)**

According to the nature of the materials and the water environment,7 categories of Upper earthworks noted from PST n ° 0 to PST n ° 6 ,The case of PST n ° 0 corresponds to a situation unfit for creation of a platform.

The classes of lift of the earthwork level introduced for each case of PST are associated with the characteristics of the soil called long-term support soil ,that is to say representative of the unfavorable water conditions that the platform may experience, during the duration of pavement service (with the exception of the freeze-that problem deal with it separately).

❖ Thickness recommended for the capping layer

The thickness recommended for capping layer is fixed so that it:

- satisfies the various resistance criteria allowing correct implementation of the road layers,

- ensures the sustainability of a minimum long-term lift value of the platform.

This recommended thickness depends on:

- the case of PST and the long-term lift at the level of the earthworks level,

- the characteristics of the material constituting the capping layer [3].

The techniques considered fall under four headings:

- **Heading G:** Actions on granularity

The elimination of the fine fraction sensitive to water 0/d by screening in the natural state or with washing settling, they often used value of d is a round 10mm.

- **Heading W:** Actions on the water state

Significantly higher values tolerated in some cases of construction sites with materials that can be broken by very powerful mixers. The normal Proctor optimum of the material-binder mixture is necessary to achieve the required high mechanical efficiency.

- **Heading T:** Treatment

This section brings together the actions consisting of mixing different products such as lime, hydraulic binders (cement, fly ash, slag ...), or grain size correctors, to give the material mechanical performance higher than those it has in its natural state, and durable throughout the life of the structure.

- **Heading S:** Surface protection

Untreated granular materials used as a capping layer, often need surface protection to provide adequate resistance to the tangential forces generated by the machines tires (accelerations, braking, turns), or to guarantee the leveling requirements.

I.6. Mechanical classification of the treated CL

The mechanical class of the capping layer material is determined by:

-CL mechanical type abacus according to D_t and E in [4] , which defines the zones according to 90-day values of the Young's modulus and the direct traction resistance determined on the test parts molded to the predicted compactness at the bottom of the layer (8 cm lower) [13].

I.7 Conclusion

In this chapter we provide an overview of the different components of the pavement (complex mechanical assembly of layers of aggregates and binders), and the capping layer, its structure, and the geotechnical parameters used to study the characteristics of the latter.

It is therefore essential to know the different methods for choosing the support soil structure, or for treating the poor soil qualities, and this is what we will look at in the second chapter on different types of fibers especially natural ones, used in different fields (road Construction, buildings, and other domains).

Chapter II Types and properties of fibers and their application

II.1 Introduction

The reinforcing fibers give the composites their mechanical characteristics such as rigidity, breaking strength and hardness; they can also improve some of their physical properties such as thermal behavior, fire resistance and abrasion resistance.

The desired qualities of the fibers are their high mechanical characteristics, their low density, the ease of their implementation and their low cost [14].

Plant fiber is one of the most important fibers because of its distinctive characteristics, diversity, easy to use and its positive impact on nature, such as the Lhalfa and Palm leafs, especially in our country with its diverse climate that helps in its growth as it can be used in various fields.

We will also show you in this research some ways that can be applied and obtain satisfactory results.

The fibers are classified according to their origin (natural or artificial), their shape (straight, wavy, needle, etc.), their size (macro or microfibers) and their mechanical properties, there are:

II .2 Artificial fibers

The most used in the construction field are glass fibers, metallic fibers and synthetic fibers.

In massive form, the glass is characterized by a very great brittleness due to its high sensitivity to cracking, but in the form of fibers of small diameter, it has good mechanical strengths with a silica content ranging from 50 to 70%. The major disadvantage of glass fibers is their sensitivity.

Metallic fibers are among the most used artificial fibers in the reinforcement of mortars and concretes and are the subject of many research studies to date. This fibers includes steel fibers and amorphous cast iron fibers, they are classified into two categories:

- Flat fibers with a large specific surface, they are not very ductile and works by adhesion, their main role is to limit the opening of the cracks.
- The cylindrical drawn steel fibers having a ductile behavior, It works by anchoring provided by hooks at the fiber ends or by the wavy shape of the fiber, They give good ductility to concrete.

The low cost of petroleum products after the Second World War meant that synthetic fibers such as nylon, polyester, acrylic and polypropylene invaded the textile market and replaced natural fibers.

At the end of the 19th century , world production of synthetic fibers exceeded that of natural fibers and the gap did not stop widening until the 2000s [15], [16],These petrochemical-based fibers are produced in masses with diversity in the lengths and colors of the fiber according to consumer demand and uniformity in quality and mechanical performance.

Polypropylene fibers are obtained by extrusion of polypropylene and are in bundles or in the form of individual filaments; they are added to the concrete during mixing and are distributed in a multidirectional manner in the concrete.

Polypropylene fibers allow better control of plastic shrinkage of concrete and improve its handling and cohesion; they are flexible, chemically insensitive but not very resistant to fire (melting temperature between 140 and 170 ° C).

The major advantage of polypropylene fiber concrete is their resistance to cracking due to "first shrinkage" as well as their impact resistance.

II. 3. Natural fibers

Almost 35 million tonnes of natural fibers are harvested each year , This quantity represents almost a third of world production of textile fibers , These fibers are of animal origin such as fibers of sheep , goats , or alpacas [17]or of vegetable origin such as fibers of hemp , flax , halfa, jute stalks, sisal and cotton.

All of these fibers are used to make fabrics, ropes and twines and play a very important role in the socio-economic life of the local population.

Natural fibers are generally harvested by seasonal workers and mainly harvested by hand.

After the surge in the price of oil and the taking into account of environmental constraints and the use of local, biodegradable and recyclable materials, industrialists are returning to the use of natural and particularly vegetable fibers in textiles, construction, plastics and the automobile.

They work to strengthen local production and economic in dependence from imported products for reasons of cost and respect for the environment [18].

Many natural fiber resources have been explored over time for the textile and craft industries, depending on the f ineness, strength and longevity of the fibers produced, these different resources are used for the production of clothing, fabrics, carpets, ropes or handling bags.

Competed in these sectors by artificial and synthetic textile fibers, they sometimes find new outlets in the paper industry or in construction, particularly for their good mechanical performance, their biodegrade ability and their low cost [19].

Plant fibers are used in place of synthetic fibers as in the case of glass or carbon fibers in the field of civil engineering or as polymer , PVC , PE or PP reinforcements in industry in general [20], [21]

Research studies [22], [23] have shown that the use of polymers and plant fibers extends to the field of bioplastics and the manufacture of certain automotive accessories.

Hemp, l inen, sisal and even abaca reinforce the armrests, the rear shelves, the seat backs or the engine shields.

In Europe, their use in the automobile industry was estimated at 100,000 tonnes in 2010, In Germany, the BMW company uses up to 24 kg of sisal or flax fibers in the manufacture of certain series [22].

In the field of construction, hemp is incorporated into concrete for the production of insulating slabs or the mounting of walls.

Hemp and hemp wool from the stems crushed hemp are an alternative for glass wool As Dallel M. [18] specifies natural insulators have many environmental advantages: thermo-acoustic insulation performance, hygrometric regulation capacity and low gray energy for their manufacture, recyclability and carbon capture of the air for vegetable fibers.

The use of vegetable fibers is very varied, they represent materials with technical and mechanical performance, which sometimes exceed those of traditional materials; this use has increased over the last decade to the point of being insufficient to meet the increasing demand from manufacturers [24] and [25].

The natural fibers of vegetable origin most used in industry and particularly in the field of construction are the fibers of cotton, linen, hemp, date palm, diss, straw, sisal, jute, kenaf, coconut or alfa.

Natural fibers are divided into two categories according to their origin: fibers of animal origin and those of vegetable origin.

II. 3. 1. Animal fibers

Natural fibers come from animals and are divided into three main groups: wool, hair, natural silk.

Wool is a material made up of keratin fibers from sheep, it is one of the main fibers used in the world, and the structure of its proteins gives it qualities that synthetic fibers cannot match, such as exceptional resilience and elasticity.

It is also a good thermal insulator and with a high absorbing power of the order of 16 to 18% [16], Sheep was one of the first domesticated animals and woolen fabrics are probably among the first clothes to be worn by humans.

Figure II.1 represents three different animal fibers; from left to right we have a silkworm cocoon, angora fibers and alpaca fibers [18].

Figure II.1 Photos of some animal fibers in [18].

II. 3. 2. Plant fibers

Plant fibers are extracted from plants, either from the stem like flax and hemp, or from the leaf like date palm fibers or even from the fruit itself such as coconut. They are part of the biomass; they are characterized by low density, thermal insulation power, high tensile strengths, and biodegradability, which constitutes a major advantage for ecology [19].

Their main components are cellulose, hemicellulose, lignin and pectins.

Their proportions determine the overall fiber properties.

- **Cellulose** is the main component of almost all vegetable fibers.
  It represents more than 50% of the biomass on earth, It is a carbohydrate of molecular formula $(C_6H_{10}O_5)_n$, where n represents the degree of polymerization ; its value can vary from a few hundred to a few tens of thousands[18]
  It is responsible for the cohesion properties and the hydrophilic appearance of natural fibers; it is hardly soluble and can only be melted from 320 ° C.

- **Lignin** represents the second main component after cellulose in biomass in terms of abundance by weight on the surface of the earth. It participates in the structural rigidity of cell walls and protects plants against attack by pathogenic organisms [26]; Lignin gives the plant impermeability to water and great resistance to decomposition.
  Lignin also stores toxic phenolic in the free form, which the plant has to neutralize.
  It therefore also plays a role in storing plant waste.
  Its natural production is estimated at nearly one billion tonnes per year.

- **Hemicellulose** is the third main component after cellulose and lignin and constitutes almost a quarter by weight of biomass.
  Hemicellulose forms the support matrix for cellulose micro fibrils.
  Unlike cellulose, it is composed of neutral sugars and is very hydrophilic, soluble in an alkaline medium and easily hydrolyzable in acids [26].

- **Pectins** are present in smaller quantities than cellulose and ling in but remain an important element in plant biomass.
  They play the role of a cement between the cells of plant tissues, which make them more rigid and maintain cohesion between them.

Table II.1 gives the chemical composition and the percentages of the main components of the vegetable fibers most used in industry in [18], according to [27] and [28].

Table II.1 Chemical composition (in% by mass) of the most used vegetable fibers

Fibres	Cellulose	Hémicelluloses	Lignin	Pectin	Wax
Cotton	85 - 90	5,7	0,7 – 1,6	0 - 1	0,6
Linen	71	18,6 – 20,6	2.2	2,3	1,7
Hemp	70 - 74	17,9 – 22,4	3,7 – 5,7	0,9	0,8
Jute	61,1- 71,3	13,6 – 20,4	12 - 13	0,2	0,5
Ramie	68,6 – 76,2	13,1 – 16,7	0,6 – 0,7	1.9	0,3
Sisal	66 - 78	10 - 14	10 - 14	10	2
Coconut	32 - 43	0,15 – 0,25	40 - 45	3 - 4	-
Alfa	45	24	24	5	2

II. 3. 3. Properties of plant fibers

The physico-chemical properties of the various fibers allow their use as a substitute for synthetic fibers in textiles and composites according to the characteristics to be developed in the material.

The cellulose fibrils are oriented in a helix at an angle called the micro fibrillary angle.

The percentage of cellulose, the micro fibrillary angle, the diameter d of the fiber, its length L and the ratio L / d constitute the main physical properties of these fibers (Table II.2).

Table II.2 Physical properties of different plant fibers in [18], from [29]and [30].

Fibres	Microfibrillary angle (°)	Diameter (µm)	Length (mm)	Ratio L / d
Cotton	33	19	35	1842
Linen	10	5 - 76	4 - 77	1687
Hemp	6.2	10 - 51	5 - 55	960
Jute	8	25 - 200	9 - 70	110
Ramie	7.5	16 - 126	40 - 250	3500
Sisal	20	7 - 47	0.8 - 8	100
Coconut	45	12 - 24	0,3 - 1	35
Alfa	33	5 - 95	5 - 50	1964

Their mechanical tensile properties, main characteristics of the fibers, are given in Table II.3 for the most widely used vegetable fibers [18], [31], and [32].

Despite the fact that plant fibers have certain limits to their use , such as poor dimensional stability , low fire resistance (degradation from 200 ° C), variability in properties according to age, region, climate and even d " A fiber to the other belonging and a dependence on the harvest (quality and quantity) , they have several advantages such as their biodegradability , their low density , their renewableness, their mechanical and acoustic insulation properties , the low quantity of residues during incineration and the low carbon foot print [31].

Table II.3 mechanical property contraction of some fibers

Fibres	Module d'Young E (GPa)	Allongement (%)	Contrainte à la traction (MPa)	Densité
Coton	5,5 – 12,6	7 - 8	287 - 597	1 ,5 – 1,6
Lin	58	3,27	1339	1,53
Chanvre	35	1,6	389	1,07
Jute	26,5	1,5 – 1,8	393 – 773	1,44
Ramie	61,4 - 128	1,2 – 3,8	400 – 938	1,56
Sisal	9 – 21	3 – 7	350 – 700	1,45
Coco	4 – 6	15 - 40	131 – 175	1,15
Alfa	12,7	1,6	75 – 154	1,51

II. 3. 4. Classification of plant fibers

Plant fibers are classified and 5 categories according to their origin (Figure II.2).

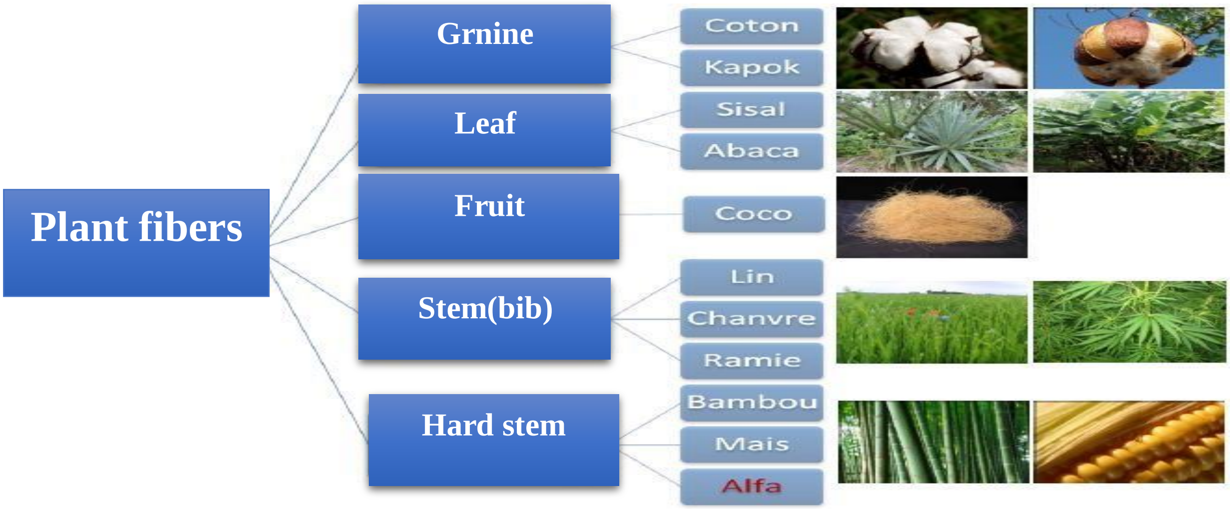


Figure II.2 Classification of vegetable fibers in [18] from [19]

II. 4. Alfa fibers

As the forest reserves are limited in Algeria, we turned instead to the use of recovered cellulose fibers such as old recycled paper and cardboard and those of endemic natural plants such as date palm, diss, halfa...

In this study, we were particularly interested in the effect of alfa and date palm fibers as natural fibers of plant origin on the mechanical performance and durability.

Halfa fiber was chosen for reasons of availability and economy; it is a renewable resource that can be rationally integrated in to the construction field.

The term "halfa" is an Arabic designation [33] formerly designating all steppe grasses with resistant and jonciform leaves in times of drought.

The Latin word “spartum”, which gave “sparto” or “esparto” [34], is the name used by the Spanish.

Currently, only one plant is called halfa, it is "Stipa tenacissima L".

The idea of the use of halfa fibers in human daily life is very old , it dates from antiquity [20],for the manufacture of carpets , wheat silos , ropes , mats and especially of antiquity [34], [35], [36].

As a reinforcement of traditional building materials, it was used in the manufacture of clay bricks or plasters.

II. 4. 1. Geographical distribution of Alfa

Alfa is an endemic wild plant, which grows in the form of tufts in the arid regions around the Mediterranean; its territorial distribution is given in Table II.4.

The roots of the alfa trap particles of the soil and thus fight against erosion and desertification, the aerial part consists of stems carrying sheaths nested one inside the other, the cobs protruding from its leaves which can reach 120 cm in length. The leaves and stems are composed of cellulosic filaments linked by lignin, pectins and hemicellulose.

It is of great ecological importance because its culture requires very little water, no insecticides or pesticides, it is a persistent plant that does not disappear during the winter and grows freely, and forming large sheets and halfa is eaten fresh for livestock.

Table II.4 The territorial distribution of halfa [37]

Country	Area of the alfa extension (ha)
Algeria	4.000.000
Morocco	3.186.000
Tunisia	600.000
Libya	350.000
Spain	300.000
Portugal	Little

The species of the genus Stipa are distinguished by their morphology and anatomy [38], they grow in the south of Europe like Spain and North Africa [39], in South Africa [40]and even in Eastern Europe [41] such as the former Czechoslovakia.

The Algerian steppes are located between the Tellian Atlas in the North and the Saharan Atlas in the South as shown in Figure II.3 [42]. The steppe regions constitute a bulwark between the coastal zones and the Sahara, which contributes ecologically to the limitation of the advance of the Sahara towards the north; they are part of the arid zones in the world (Figure II.4) buffer between coastal Algeria and Saharan Algeria, of which they limit the negative climatic influences on the former.

The alfa samples we brought come from the region of the town of Djelfa located 290 km south of Algiers

Figure II.3 Geographical distribution of the Algerian steppes

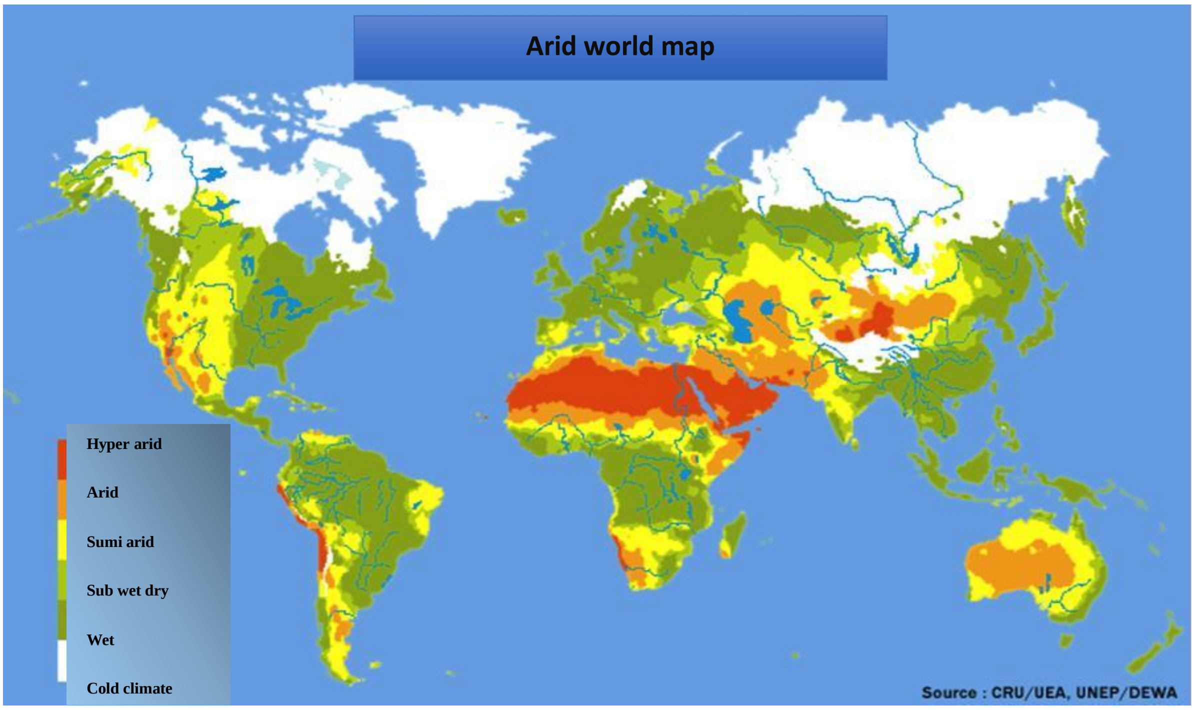


Figure II.4 Geographic location of the steppe region in Algeria

II. 4. 2. The morphology of the halfa

Seen from above, the stems grow in the form of a circle having for center a common root, as shown in Figure II. 5. The stems, which constitute the part aerial of the plant and the roots that make up the underground part of the plant can reach a depth of up to 1 m , which keeps it well anchored in the soil , and allows it to hold and grow, Between the two is the roots (Figure II. 6).

The alfa, thanks to its roots, stabilizes the sand and the soil well, which gives it the very important function of stopping desertification and avoiding wind erosion. Thanks to its presence, the wind hardly displaces the sand, In addition, the stems or leaves close to the ground are hairy and waxy, they limit desertification in a second way by capturing the particles of sand transported by the wind [42], [43].

Waxes limit evaporation, which gives the alfa resistance to large temperature differences (between -20 ° C at night and 40 ° C during the day) and low water consumption [44].

Figure II. 5 The alfa plant in the form of circular tufts

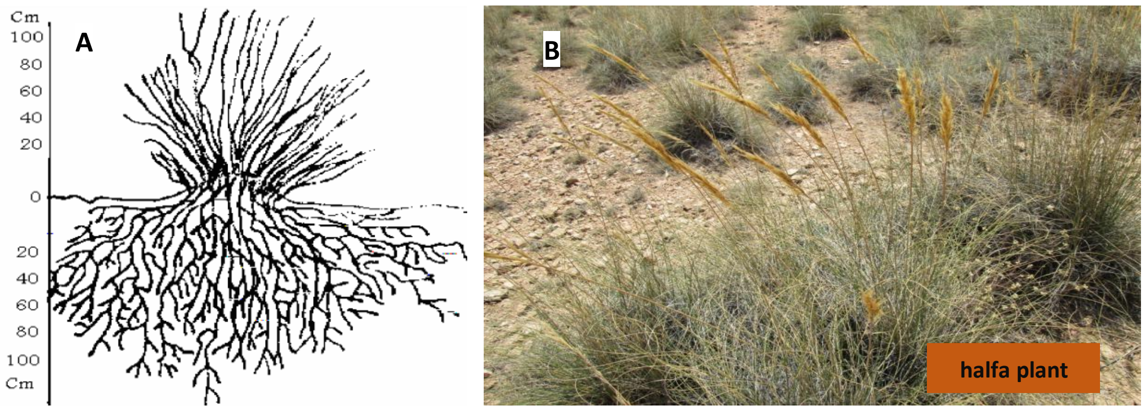


Figure II. 6 Morphology of the alfa plant, A. Upright highly developed roots and Aerial part, B. A tuft of alfa with leaves and stems carrying the grain spikes.

The alfa flowers from early May to late June. It is harvested manually from July to November and sometimes its harvest can go up to February.

II. 4. 3. The morphological structure of the halfa fiber

The structure of the alfa fibers is heterogeneous; the small microscopic fibers stuck to the leaves are called cellulosic filaments or fibrils. They have a length, which varies from 1 to 5 mm and a diameter which varies from 5 to 10 µm. These fibrils are linked together by hemicellulose and thus form fibers [28].

The chemical composition of alfa fibers can be summarized in Table II.1 and the physical and mechanical characteristics by Table II.2 [18].

II. 4.4. Alfa and its environment

The abundance and characteristics of alfa in the Mediterranean basin and more particularly in North Africa have interested man for a long time and pushed him to operate intensively. Indeed, the leaves of this plant are of major socio-economic interest due to the finesse, resistance and flexibility of its fibers. Its exploitation always requires a large workforce, which contributes greatly to the maintenance of employment for the local population and thus prevents rural exodus [45], [46] and contributes to the maintenance of the ecosystem by forming a barrier against desertification, which is advancing rapidly in the north of Africa

The usefulness of the alfa is no longer to be demonstrated. Its various fields of use in the rural world have earned it the name of "social grass" [47]. It is used in several fields such as:

- **Handicrafts:** the workers, mainly country folk from the region, tear off the halfa leaves by hand. They are intended for plaiting, that is to say the making of carpets, ropes, braids for the baskets, grain silos (figure II. 7).

- **Industry:** stipa tenacissima is a plant very rich in cellulose (45%). The alfatier countries use it in the high quality paper industry [48]. During the colonial era, special railway lines linked certain cities like Djelfa to the port of Algiers for the delivery of halfa to France for the production of high quality paper.

Figure II. 7 The Use of halfa in crafts

II. 5 The date palm

II.5.1 General Presentation

The date palm is a perennial dioecious fruit tree from arid, tropical or semi-tropical regions whose fruit or date is eaten. This tree seems to originate from the Persian Gulf, it has been cultivated since ancient times, and it was introduced on the eastern coasts of Africa in the 15th century.

It is a tree of great interest, for not only its high productivity and the quality of its fruits; but also thanks to its ability to adapt to the Saharan regions Also, the properties of the fiber used in several fields, such as building and improving soil resistance to roads .

Algeria is considered the sixth world producer of dates, with more than 468,000 tonnes / year, 48% of which is Deglet Nour [49].

II.5.2 Classification

According to (FAO) we can classify the date palm phoenix dactylifera:

- Phylum : spermaphytes
- Under branching : Angiosperms
- Class : monocots
- Order : palms
- Family : Palmaceous
- Sub family : Coryphoideaes
- Gender : Phoenix
- Species: Phoenix dactylifera L, 1747

II.5.3 Geographical distribution

- **In the world:** The date palm is encountered in regions where the temperature is high and the humidity is low and at neglected rainfall when fruiting occurs , it is encountered between latitudes 10' to 35 ° north and does not exceeds latitude 24 '44 ° North , So the distribution of date palm is in Mediterranean Europe , Africa, West Asia , America and Australia.

- **In Algeria :** The date palm culture is distributed in three essential zones

  1- Northern Sahara which is located between the two latitudes 30.5 ° and 35.5 ° that it is presented by : Ziban (Biskra, Tolga), Oued Souf, Oued Righ (Touggourt) , Ouargla , Metlili , Ghardaïa , Béchar in the Southeast and Berreane

  2- Southern Sahara which is located between the two latitudes 22 ° and 26 ° and which is presented by Ajjers (Tamanrasset), Djanet

  3- Central Sahara which is located between the two latitudes 26 and 30.5 and which is presented by El Goléa , Touat, Adrar , Timimoune, Gourara , Tidikelt , La Saoura, Béni Abbes in the south-east [50].

Figure II.8: Date palm and stem and trunk fibers.

II.5.4 Economic importance of the date palm

* Evolution of date production in recent years:

1- On a global scale:

Table II.5. Date production worldwide (tonnes) [51].

country	2004	2005	2006	2007
Egypte	1 166 182	1 170 000	1 328 720	1 313 696
Iran	989 626	996 770	1 000 000	1 000 000
AR. Saoudite	741 293	970 488	977 036	982 546
Irak	875 000	404 000	432 000	440 000
Emirat AU	760 000	750 000	757 600	755 000
Pakistan	622 404	496 576	426 281	557 524
Algérie	422 600	516 293	491 188	526 921
Soudan	336 000	328 200	332 000	332 000
Oman	231 000	247 331	258 738	255 871
Libye	150 000	150 000	170 000	175 000

2-on the national scale:

Table II.5 Date production in Algeria

The year	Production (tonnes)
2005	**516 293**
2006	**491 188**
2007	**526 921**
2008	**552765**

Regarding the current state of phoeniciculture, it was pointed out that the overall surface area of palm groves in Algeria is 160,000 hectares that the number of palm trees is 18 million including 12 million date palms and that Daglet Nour represents 40% of palm groves. In 2009, its national production of dates reached 6.3 million quintals (qx).

II.5.5 The Different Use of Date Palm

- The tree trunk, used in traditional cabinet making, as firewood and building frames.

- Dry palms, used as fences, breezes or in the making of baskets, hats, baskets...

- The lif for making soles of sandals, ropes, nets...

- Reinforcement of certain construction materials such as mortars and concretes [52].

Date palm samples were taken from the side of the road .

II.6 Conclusion:

In recent years, increasing attention has been paid to the use of low-cost renewable resources, particularly of plant origin in composite applications in industrialized countries

India, China and Brazil are the largest fiber producing countries in the world.

Algeria is a Maghreb country with a very rich flora in the mountainous regions, the high plateaus and Saharan: cork, alfa, Diss, Doum, date palm, Pine, Cotton, Lin, etc... , Algeria with an annual production of cork of around 6000 tonnes; it is the sixth largest producer of cork in the world. In addition, the alfa occupies about 4 million hectares in Algeria. It is also interesting to note that Algeria has 10 million date palms.

Therefor In order to improve the mechanical and physical properties of the soil, these locally sourced natural plant fibers may be one of the building blocks for building a new economy, especially in construction projects, which is the main goal of our graduation memo.

Chapter III Area of study and results of laboratory tests

III.1 Introduction

Knowing the soil, its characteristics and the nature of its behavior is one of the biggest challenges facing the geotechnical engineers, as it is a black point that must be uncovered to ensure the establishment and stability of the infrastructures (the road, buildings, etc.)

Geotechnical study allows specifying terrain parameters and measure deformations and resistance in order to suggest solutions and avoid problems if they occur.

In this chapter, we will show you a set of soil samples taken from a sites located in Boumerdès subjected to a series of physical and mechanical tests and chemical treatment protocol with different percentages of palm and Lhalfa fibers.

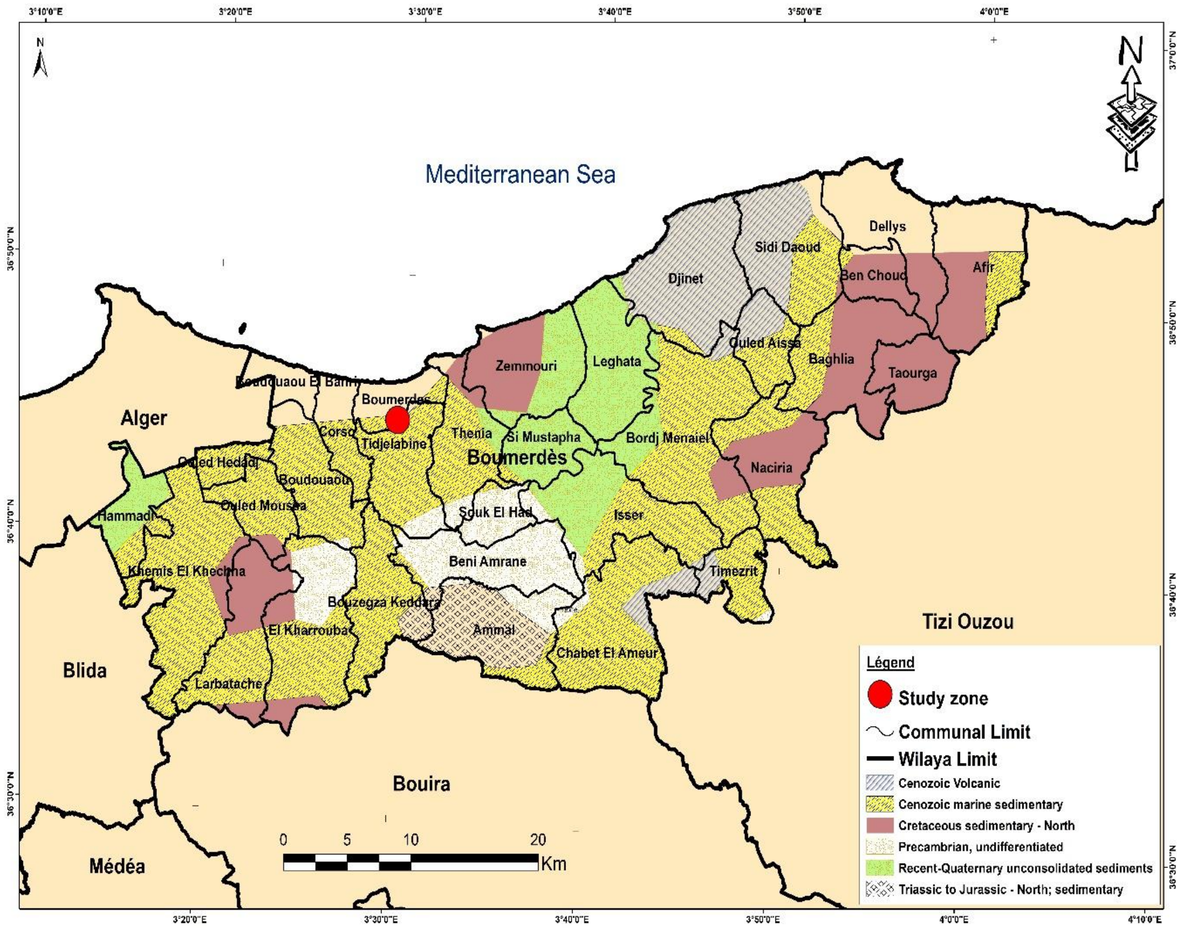
III.2 Location of the study area

The soil used in our research comes from excavated material extracted within the framework of the project located between Boumerdès city and Tidjelabine.

The same site and the same soil which were studied by (Moulla Hicham and ZAMOUM Loubna,2019)in their Masters degree, it was taken from the Tdjelabine region, it was chosen to see the possibility of its reuse for the construction of the layers backfill and CDF.

Tidjelabine is an Algerian city located in the provionce of Boumerdès, 45 km east of Algiers; it is 4 km from the city of Boumerdès.

Figure III.1: Material Storage area



Sourc: U.S. Géologec Sservice ;2002

Figure III.2 Location map (SIG) of studied zone

III.3 Laboratory test program

In order to identify the soil and know the geotechnical characteristics, we have a series of tests, which essentially relate to the following:

- Physical tests and identifications.

- Mechanical tests.

The physical and mechanical parameters were determined in:

- Central Public Works Laboratory, Bouira unit [52].

- National Laboratory for Housing and Construction (LNHC) oued semmar unit, Algiers [52] and [53].

III.4 Identification of tests

III.4.1 Identification tests

III.4.1.1 Sieve Analysis (Standard NF P 94-056)

In order to classify a soil for engineering purposes, one needs to know the distribution of the size of grains in a given soil mass [54]. Sieve analysis is a method used to determine the grainsize distribution of soils [55].

- **Objective of the test:**

The particle size analysis makes it possible to determine the size and the respective weight percentages of the different families of grains constituting the sample:

*Pebbles *gravel *coarse sand *fine sand *silt and clay [56].

We call:

• **REFUSAL on a sieve:** the quantity of material retained on the sieve.

• **SIEVE (or passing):** the quantity of material that passes through the sieve.

-The dimensional distribution by weight of the particles with a dimension greater than or equal to 80µ separate the agglomerated grains by mixing under water.

- **Equipment:**

1-series of sieves, bottom pan, and a cov 2- Electric balance.

3-Oven 4-Mechanical sieve shaker

- **PRINCIPLE OF THE TEST:**

• The test consists of fractionating, by means of a series of sieves, a material into several granular classes of decreasing size.

• The masses of the various rejects and sieves related to the initial mass of the material, the percentages thus obtained used in a graphical form [55].

- **GRANULOMETRIC CURVE:**

It is enough to carry the various percentages of the sifted cumulated on a semi logarithmic sheet:

• On the abscissa: the dimensions of the meshes, logarithmic scale

• On the ordinate: the percentages on an arithmetic scale.

• The curve is continuous.

Thanks to this curve, we can determine two coefficients, which are:

-Coefficient of uniformity Cu: - Coefficient of Curvature Cc:

$$\mathbf{Cu} = \frac{\mathbf{D_{60}}}{\boldsymbol{D_{10}}} \qquad \mathbf{Cc} = \frac{(\mathbf{D_{30}})^2}{\mathbf{D_{10}} \times \mathbf{D_{60}}}$$

III.4.1.2 Granulometric analysis by Sedimentation:

- **Objective:** quantify the φ of grains <80µm
- **Principle:**

based on the Stocks law which measures the speed (v) of settling of spherical particles , Function of the viscosity of the medium , Deflocculant to take off the sheets of clay , 5% sodium hexametaphosphate solution , Measurement of the density of the liquid , with a Hydrometer , At 0.5, 2, 5, 10, 20, 40, 80 minutes, 4 and 23 hours [57].

- **Description:**

The falling speed of a spherical particle falling freely in a fluid is proportional to the square of its radius and its density. The grains of different diameters, sediment in a liquid medium at rest at different speeds.

The sedimentometry completes the particle size curve obtained by sieving the particle size whose diameter between 80 and 0.2 microns [58].

The following relation gives Stokes law, which measures the speed:

$$v = \frac{\rho - \rho 0}{18\,\eta} \times g \times D^2$$

III.4.1.3 Atterberg limit test (Standard NF P 94-051)

A soil can be in the liquid, plastic or solid state. The Atterberg limits are the liquidity limit (WL) and the plasticity limit (WP) which are the values of the water content which separate these different states. These limits are used in the classification of soils and are used to estimate their mechanical properties. Their knowledge allows (by correlations) to presume the behavior of a given soil (according to the nature and the quantity of clay which it contains) when it is subjected to stresses [59].

- **Objective:**

Determine the water contents, which characterize the change of state [57]:

● Solid → Plastic: W_P

● Plastic → Liquid: W_L

● $PI = W_L - W_P$

● going up to 400µm

- **Equipment** [56] **:**

The equipment necessary to carry out this test includes:

- A tank,
- Casagrande apparatus
- A precision balance,
- Grooving tool,
- Glass plate 5cm wide and 10.5 cm long graduated every 1cm.
- A 400 square mesh sieve,
- A drying oven at
- Petri dishes
- A smooth marble plate,
- Spatula,

- **Principle**[58]

a) Liquidity limit L_L (WL):

-To determine the liquidity limit, made a groove in the middle of the sample contained in the Casagrande dish. The ground will have reached its liquidity limit when the cup falling on a height of 10mm will have closed the groove over a distance of 13mm at 25 shots. The test is repeated 3 to 5 times to be able to generate a straight line according to the values of the water content and the number of strokes corresponding. From this line, it is easy to determine the water content at 25 strokes.

b) The plastic limit P_L (W_P):

- The plastic limit is reached when a 3mm roll from the soil cracks when lifted 15 to 20mm. preforming four identical tests on the same material to consider their average as the plastic limit of the material in question .

C) The plasticity index pI:

The plasticity index (PI) is a percentage of the dry weight of the soil sample. It indicates the extent of the range of water contents between which the soil remains plastic. Obtained by the difference between the liquidity limit and the plasticity limit, using the plasticity index to classify a soil according to its degree of plasticity.

pI = WL- WP

Table III.1: Classification of the degree of plasticity according to the plastic index.

plasticity index	Degree of plasticity of the soil
0 à 5	Non-plastic soil
4 à15	Low plastic soil
14 à 40	Plastic soil
>40	Very plastic soil

Orders of values

- Clay PI >30
- Silty clay 20 <Ip >30
- Limon 10 <Ip >20
- Clay sand 5 <Ip >20
- Silty sand 5 <Ip >15

III.4.1.4 The methylene blue value [56]:

This test concerns soils and certain rocky materials. However, for the most clayey materials, we will favor the achievement of the Atterberg limits.

Objective:

The test consists of measuring the absorption capacity of methylene blue by the clay particles of a material.

➢ **Principle:**

- 0 / 5mm fraction of soil
- Determination of methylene blue
- fixes on clay particles
- Until saturation
- Value in g of blue for 100g of 0 / 50m soil

➢ **Equipment :**

The equipment necessary to carry out this test includes:

- Burette, - Filter paper,
- Glass rod, - Stirrer with fins,

- Balance, - Stopwatch,
- Spoon, - Distilled water,
- Non-absorbent support, - Beaker

➢ **Results and interpretations:**

● successively add doses of 5 cm3 of blue solution ● clear task ● No saturation ● Diffuse blue on the filter paper (blue halo) ● saturation

The VBS formula: VBS = B .C. 100 / Ms (in grams of blue per 100g of dry material).

B: mass of blue introduced (10g / l solution).

C: proportion of 0/5 mm (subjected to the test) in the 0/50 mm fraction of dry material. MS: dry mass of the test portion.

III.4.2 mechanical behavior

III.4.2.1 Proctor compaction test (standard NF P 94-093) [59].

➢ **Objective:**

Determination of the compaction references of a material: density and water content.

➢ **Principle of the test:**

The Proctor test, completely standardized, consists in placing in a mold of determined dimensions, a sample moistened in a homogeneous manner with a given water content, low at the beginning, and in compacting this sample in layers at means of standardized weight falling from a standardized height. For each of the water contents considered, the dry density of the soil is determined and the curve of the variations of this density established as a function of the water content.

❖ **Note :**

-If the rejection is ≤ 25%, the test must carried out in the CBR (Californian-Bearing-Ratio) mold, but without integrating the rejection (the sample clipped at 20 mm).

- If the refusal is> 25%, the PROCTOR test must not be carried out (hazardous compaction).

III.4.2.2 CBR test (Californian-Bearing-Ratio) (Standard NF P 94-078) [60]

- **Objective:**

This test gives a measure of the relative bearing capacity of soils compared to a typical soil, consisting of crushed and compacted stones, extracted from a quarry in California.

This test makes it possible: - Establish a classification of soils (GTR) - Evaluate thetrafficability of earth-moving machinery - Determine the thickness of the pavements (CBR increases → thickness decreases).

- **Principle of the test:**

The California bearing index CBR is the ratio, expressed as a% of the pressure producing a given depression by means of a standardized cylindrical punch (of section 19.32 cm²) moving at a determined speed (1.27 mm / min) and the pressure necessary to drive the same punch under the same conditions, in a standard material.

This index can be taken at different hydric state (ie at different level of compaction): • at the optimum: index relating to the optimal water content Wopm • to the natural water content (Immediate bearing index) at Wnat • after saturation: the mold is immersed for four days in water and the punch is pressed at constant speed.

The purpose of this test is to determine the impact resistance. It consists of measuring the quantity of fine elements produced by subjecting the aggregate to the impact of standardized balls in a machine called "Los Angeles" which is a laboratory crusher. Sieved on each of the sieves of the selected granular class, washed, dried and weighed (to the nearest 1 g), the test sample (5000 +/- 5 g) is placed in a drum with an appropriate ball load. Trained for 500 turns by steel shelf, these balls fall with the materials they fragment, then washed on a 1.6 mm sieve, dried and the loop is weighed (mass m).

$$\frac{PQ}{100} = \frac{R}{500}$$

III.4.2.3 Direct shear test (Standard NF P94-071-1) [61]

- **PURPOSE OF THE TEST:**

It is a question of determining experimentally the intrinsic curve of a pulverulent soil then of deducing the shear parameters, which make it possible to estimate for example the breaking stress under a surface foundation.

- **PRINCIPLE OF THE TEST:**

According to the French standard (NF P94-071-1) In the Casagrande box shear test, we seek to cause the sample to rupture along an imposed plane.

Placing the sample in a box made up of two parts, which can slide horizontally one over the other. A normal compression force N applied to the sample, vertically, by means of a piston and a shearing force T, horizontally, by moving the lower half-box. A comparator measures the variation in height of the sample.

III.4.2.4 Oedometric test (NF P94-090-1) [62].

Principle of this test: Consolidation and compressibility tests make it possible to assess the vertical deformation of soils.

An odometer test set therefore consists of:

- A loading frame: the odometer

- An odometer cell

- A settlement device

- Optional: a permeability cell and the burette device complete the basic set

- **Objective:**

Is to measure the settlement over time of a cylindrical (intact) wafer-type test piece placed in an enclosure without possible lateral deformation as and when different constant vertical loads are applied.

This test makes it possible to establish, for a given sample, two types of curves:

- Consolidation curves, which give the settlement of the sample as a function of time under application of a constant stress.

-the compressibility curve, which indicates the total settlement as a function of the logarithm of the applied stress.

III.4.2.5 Carbonate content [63]

- **Object**

Determination of the carbonate content by the volumetric method.

- **Application field**

Method for determining the carbonate content in soil samples (including sediment), materials used on or in soils and waste. This determination is systematic on amending matters but not on soils.

- **Principle**

Adding Hydrochloric acid to a sample to decompose all the carbonates present:

$MeCO_3 + 2H^+ \rightarrow Me^{2+} + H_2CO_3$

$H2CO_3 \rightarrow H_2O + CO_{2\ gas}$

Measuring the released volume of carbon dioxide using a Scheibler device and compare it to the volume of carbon dioxide produced by pure calcium carbonate. In order not to take correction in to account, all the tests are under the same conditions.

- **Equipment and materials used**

- Schreiber device
- Analytical balance
-Reaction vials
- Plastic containers
-Forceps: acid resistant;
-Watch glass.
-250 µm sieve (possibly)

- **Sample preparation**

In accordance with procedure S-I-1, the samples dried in air or in a ventilated oven at a temperature below 40 ° C. They crumble and sieved through a 2 mm mesh-opening sieve. Optionally, if the test portion is less than 2 g, part of the sample can be ground, without residue, to pass through a sieve with a 250-µm mesh opening.

- **Procedure**

After air drying, the sample is reduced to a fraction <2 mm. Assay: The assays of the samples, blank tests and calcium carbonate must be carried out simultaneously in a room where the temperature and the pressure do not vary too much during the duration of the assays. Include for each series 2 blank tests and 2 standards of 0.200 and 0.400 g of calcium carbonate respectively.

- **NB:**

As part of the determination of organic carbon by dry combustion, the carbonate content may need to be determined.

III.5 Results of laboratory tests

The results found are in the following table

Table III.2: Results of laboratory tests

Apparent nature of soil	Granulometry			Atterberg limits			MBV	Classification GTR
	D max (mm)	≤ 2 mm (%)	≤ 0.08 mm (%)	W_L (%)	W_P (%)	I_P (%)		
Gravelly, yellowish silty clay	31.5	71.28	44.47	40.07	20.10	19.97	3.5	A2

Modified proctor		CBR INDEX at 95% of the OPM	CD	
W OPM (%)	γd max (t/m^3)		C' (Kpa)	φ' (Deg)
10.3	1.87	11.78	6.93	29.3

Comments on results

Granulometry

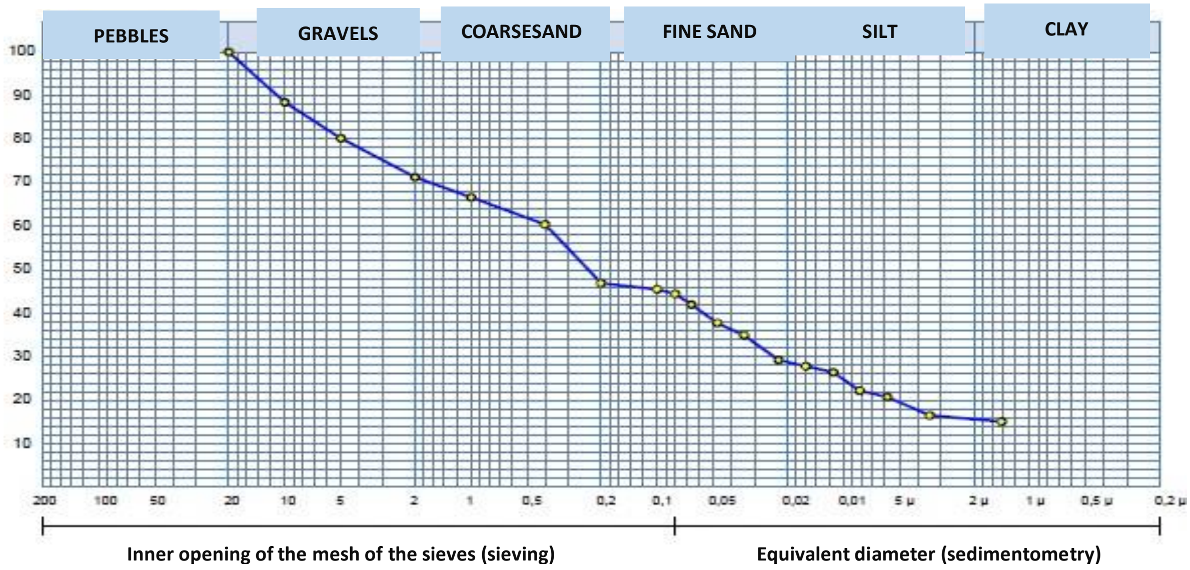


Figure III.3: The grain size curve

Taking into account Dmax that is less than 50 mm and the percentage of elements less than 80 µm, which exceed 35%, the material, classified as fine soil according to the GTR.

Atterberg Limits

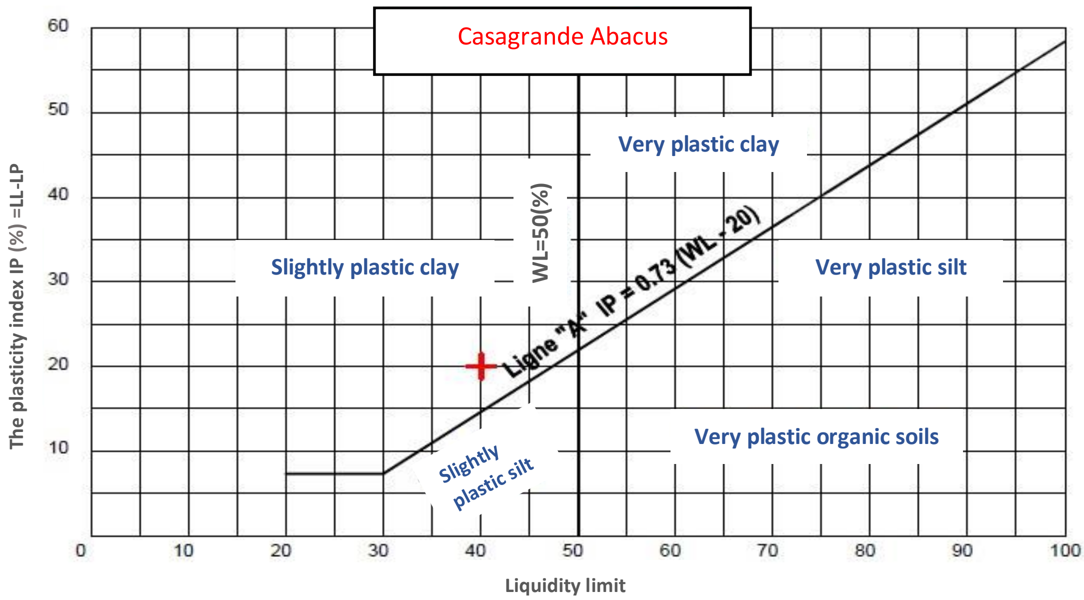
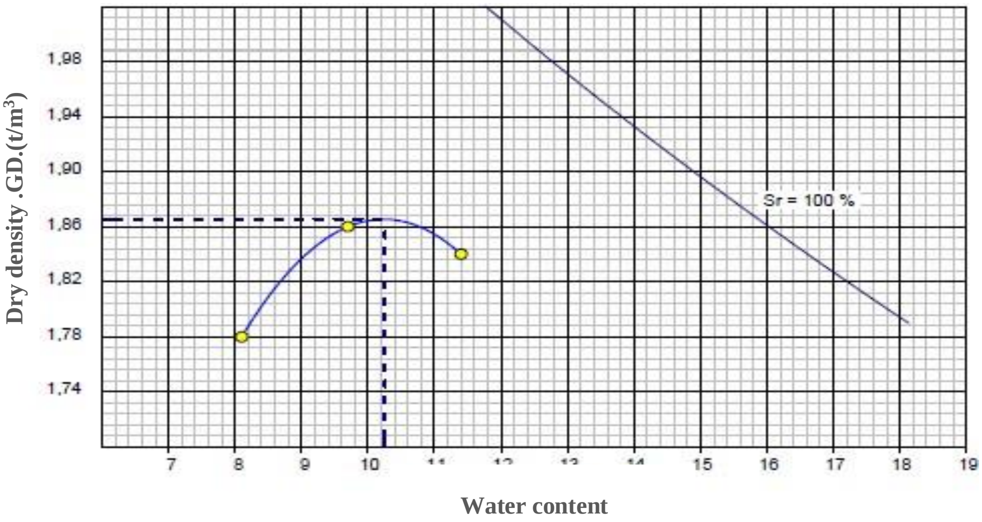


Figure III.4: The abacus of Casagrande.

The result obtained from this test shows that the analyzed soil corresponds to a loamy clay soil with low plasticity.

Modified Optimum Proctor



γ_d = 1.87 (t/m^3)

Wopm = 10.3 (%)

Figure III.5: Proctor curve.

The optimum density of this material is 1.87 t / m, for a water content of around 10.3%, which corresponds to a dense soil.

CBR test

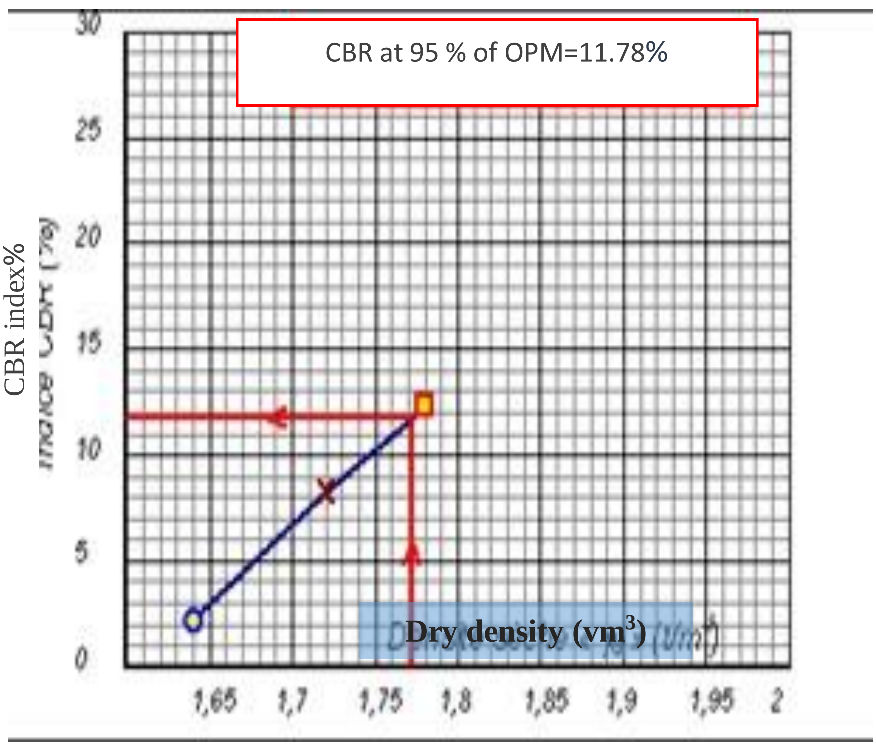


Figure III.6: CBR curve at 95% of the OPM.

The value of the immediate CBR index of the soil is 11.78%, the soil is classified in S2 according to the new pavement dimensioning catalog CTTP.

Shear test

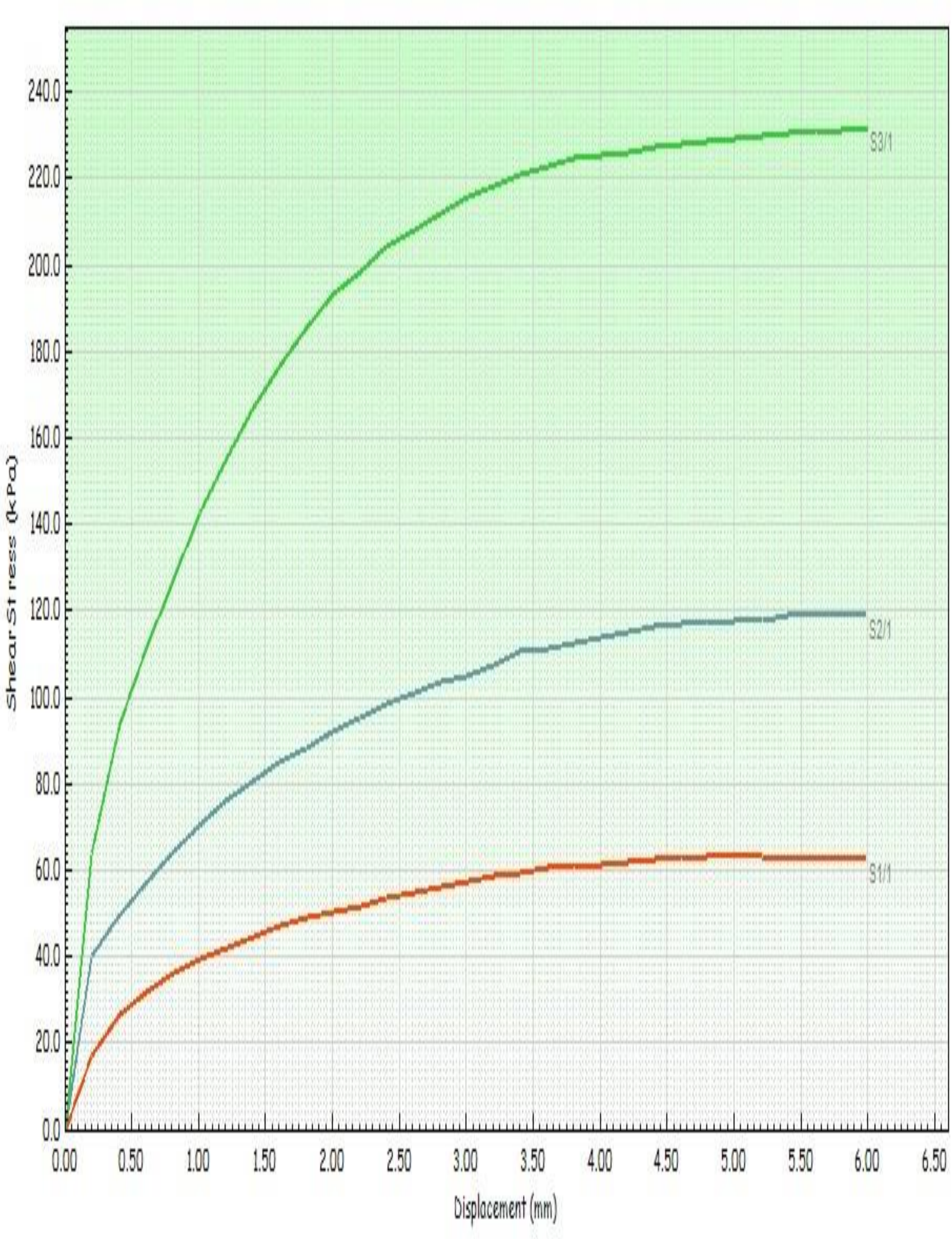


Figure III.7: Stress - deformation curve of the soil shear test

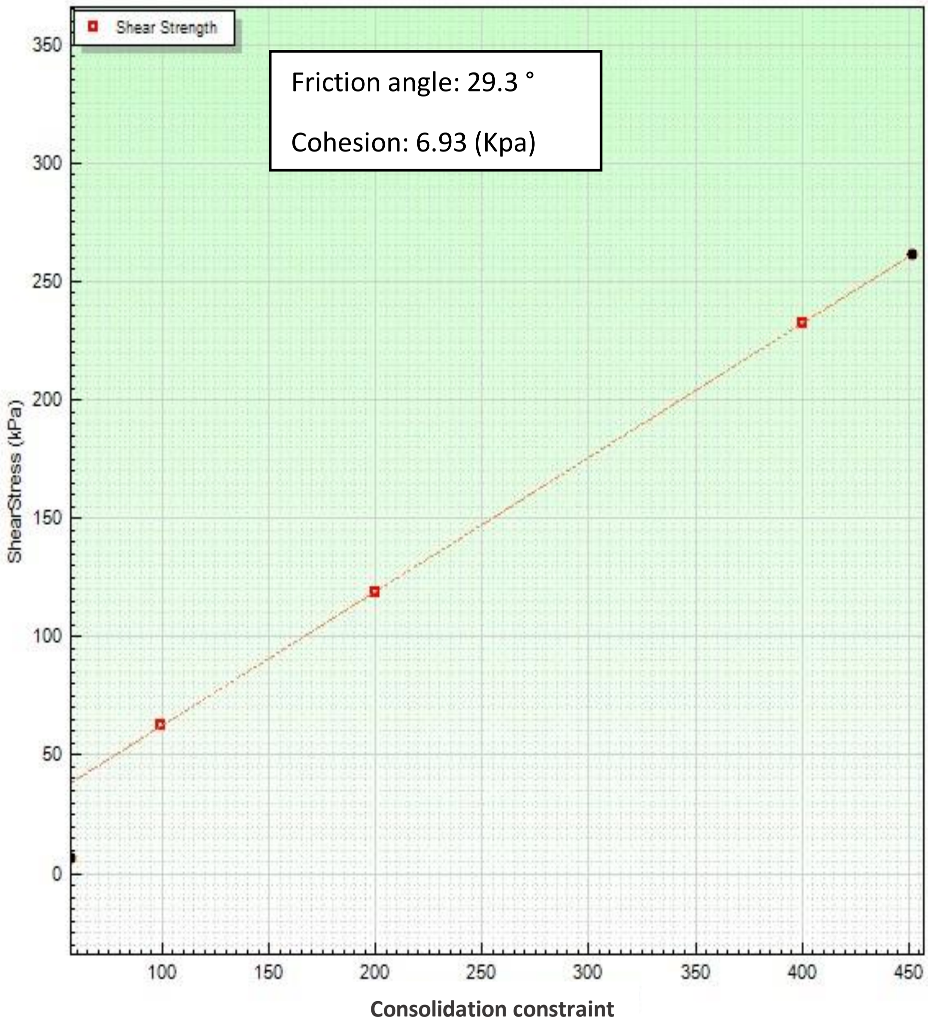


Figure III.8: Intrinsic curve of the control soil

The values obtained from the rectilinear type shear test (consolidated drained with the casagrande box): the drained cohesion is 6.93 kPa and the internal friction angle is 29.3 °.

In conclusion, according to NF P 11 300, the soil sample analyzed corresponds to a fine soil, of class have The plasticity measured and then confirmed after identification by the methylene blue test VB indicates a low plastic A2 soil. It is a clayey loam soil with medium moisture fines.

The conditions of use of class A2 materials for the construction of subgrade layers a in the GTR road technical guide. Note that A2 soils are very sensitive to meteorological conditions, which can very quickly interrupt the work site due to an excess of water content or, on the contrary, lead to a material that is very difficult to compact, which means treating them.

Methylene blue value of a soil (MBV)

- **Interpretation**

From the test (MBV), we have the following relations:

$$VBS = Pb / Pe = 105/3 = 3.5$$

Pb: weight of methylene blue

Pe: sample weight

P%: the sieve pass

P% (0 / 5mm) = 80.22%

$$VBS = 3.5 \times 80.22 / 100 = 2.81 \text{ g in } 100 \text{ g (of soil)}$$

The soil blue value is the parameter that represents the amount of methylene blue that adsorbed to the external and internal surfaces of soil particles.

From VBS methylene blue value test results, we found loamy clay soils because the VBS value was between 2.5 and 6.

Carbonate content

- **Interpretation**

The chemical analysis of the soil and from shows the presence of carbonate at 14%, organic matter at 0.10 and traces of $SO4^-$ sulphate and cl^- chlorides.

III.6 Chemical treatment of the natural fiber of the date palm and Al Halfa

III.6.1 Chemical treatment and extraction of date palm fiber

The plant fibers tested come from the leaves of date palms. These fibers are of negligible cost because they are in abundance in Algeria because it has more than 18.5 million date palms.

This natural and renewable resource thus deserves to be valued after a simple chemical treatment based on Na OH because a complex treatment makes the fiber more expensive and less competitive on the market and the goal of our work is to find an ecological material. With good mechanical characteristics.

Figure III.9: The fiber of the date palm

III.6.2 Chemical protocol for the treatment of date fiber [64]

1. Cut the date fibers into small pieces (0.5 to 1cm)

2. Washing with water eliminates dust

3. Preparation of the Na OH solution with a concentration of 2% (20g / 1L)

4. Put a mass of the Date palm fiber in a bicher and add the Na OH solution that we have prepared, leave the fiber in this solution for 72 hours at room temperature

5. Fiber washing with water.

6. put the fiber in a solution of sulfuric acid at 1% concentration (10g / 1L) for 5 min.

7. Wash again with fresh water.

8. Immerse in distilled water for 15 min to obtain a neutral pH.

9. Finally dry the sample in the oven at a temperature of 70 ° for 05 hours.

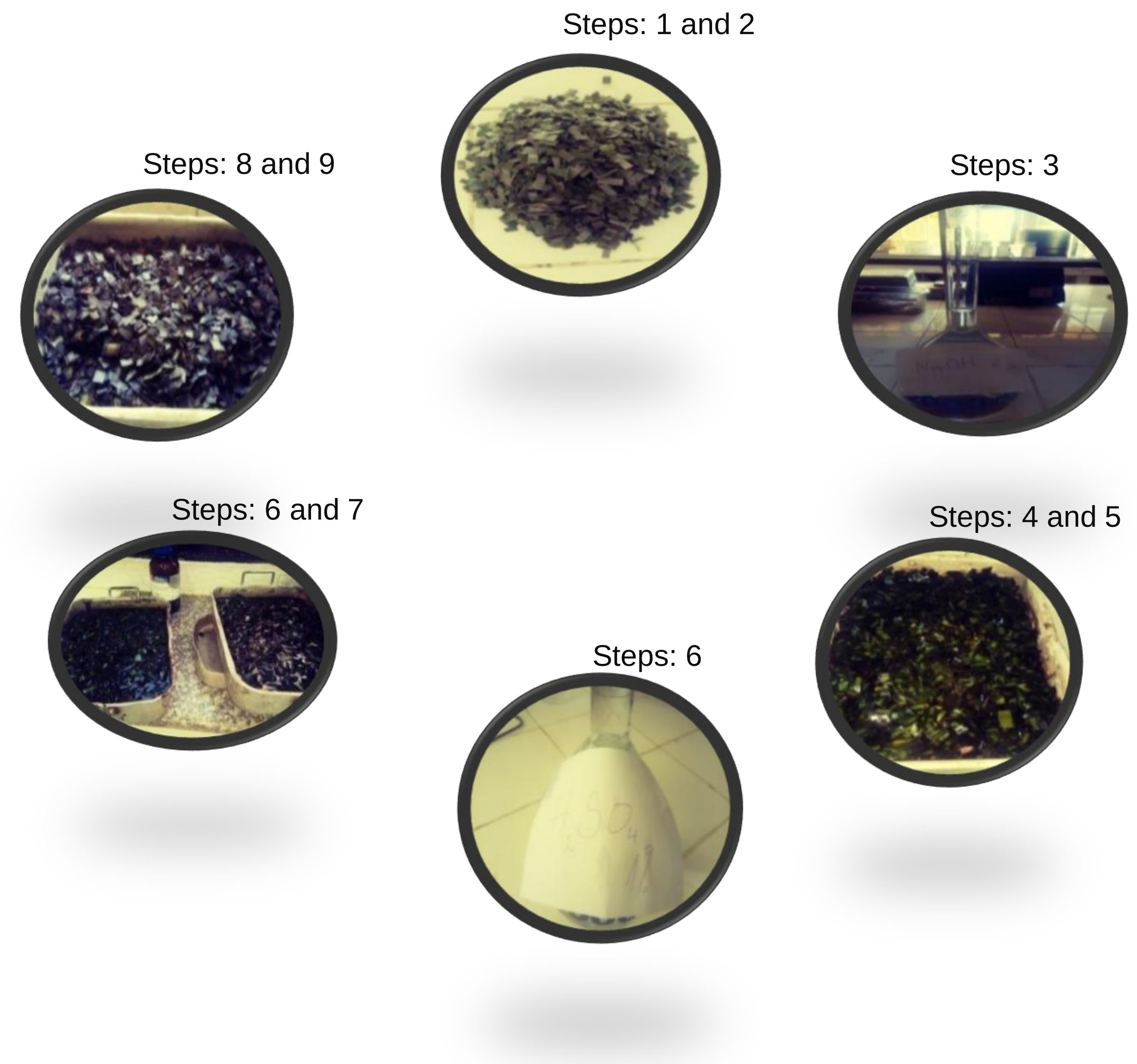


Figure III.10: Complete protocol for the treatment of date fiber.

III.6.3 Treatment and extraction of ALFA fiber [65], [66]

In this study, we opted for a simple treatment on the halfa fiber, because a complex treatment will make the fiber more expensive and less competitive on the market. In addition, the aim of this work is to find an ecological material with good mechanical characteristics; however, the use of complex chemical treatments regenerates toxic waste that is difficult to recycle.

The treatment we have chosen for these fibers is alkaline based on NAOH.

Figure III.11: HALFA fiber

III.6.4 AlHalfa chemical treatment protocol [67]

1. Cut the halfa fibers into small pieces (0.5 to 1 cm) and grind well.

2. Washing with water removes dust and some of the wax.

3. The 50g / l NAOH solution was prepared.

4. Put a mass of ALFA fiber in a 1-liter bicher and add the NAOH solution, which has to be prepared before, and let stand for 24 hours.

5. Wash the ALFA fiber after 24h of NAOH

6. Prepared a solution of acetic acid CH3COOH 20ml / l

7. Put halfa in a beaker and add the acetic acid. We leave for 2 min, which will allow the neutralization of naoh.

8. Wash the fiber with water and put in an oven at 105 ° C for 6 hours.

Figure III.12: Representation of the fiber after chemical treatment.

III.7 Tests on the treated soil (Date fiber) [43]

A series of pre-mechanical (energy) and mechanical tests we did on the soil with deferent percentages (3%, 5%, and 7%) of Date fiber, in order to assess the influence of the latter on the behavior of the ground.

III.7.1 pre-mechanical tests (energetic)

-Proctor test

-CBR test

III.7.1.1 The Proctor test of soil treated with Date palm fiber

- **Case N ° 1: soil +0 3% of Date palm fiber**

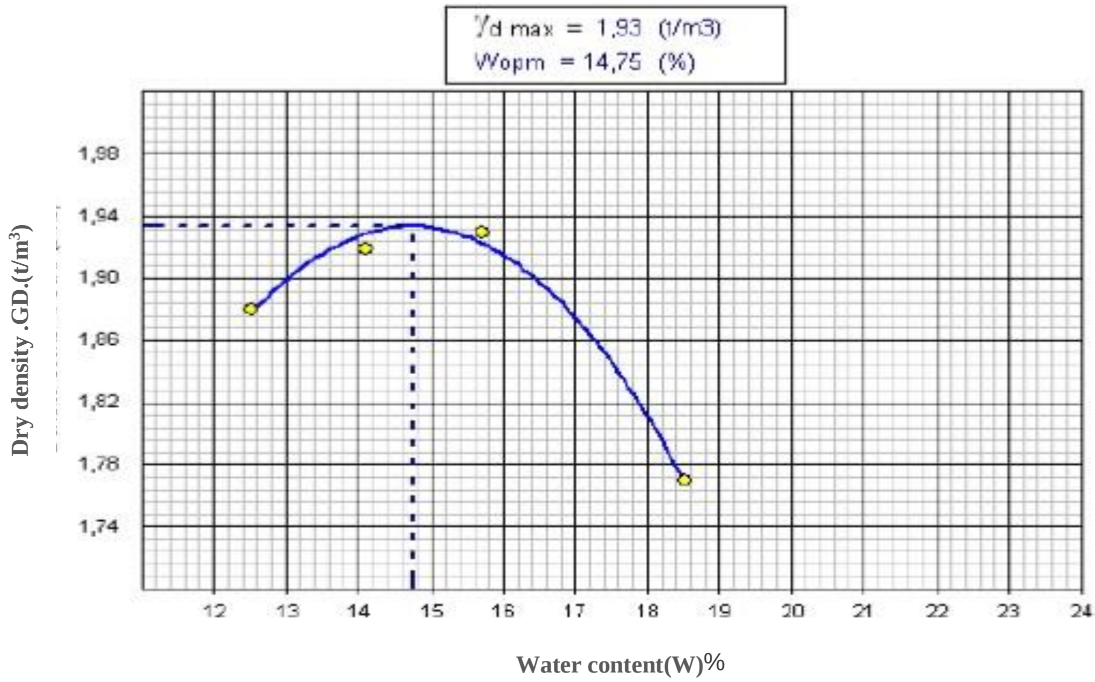


Figure III.13: Proctor curve (soil + 3% Date fiber).

The optimum density of this mixture is 1.93 t / m, for a water content of around 14.75%, corresponds to a dense soil.

- Results interpretation

The results of the modified Proctor test carried out on the soil with the addition of 3% fiber show an improvement in dry density of 1.93 (t / m3) for an optimum water content of 14.75% - compared to the control sample, c.-à-d.that the soil becomes denser.

Case N ° 2: soil + 5% Date palm fiber

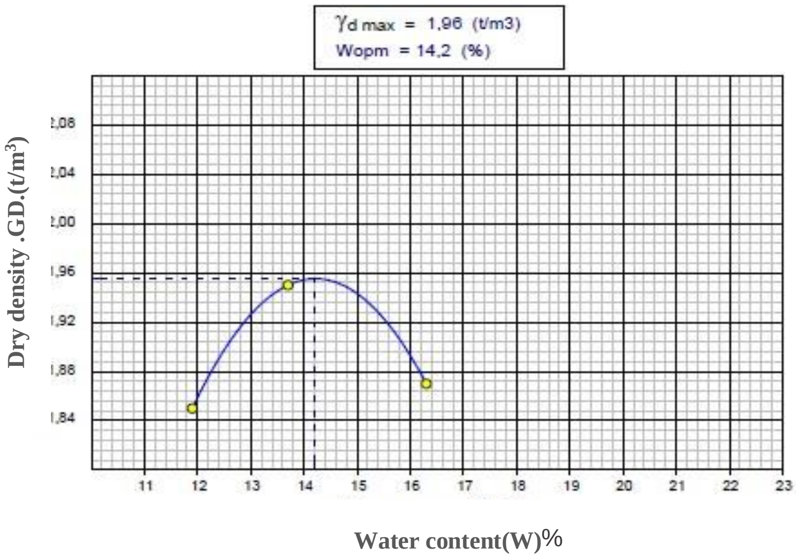


Figure III.14: Proctor curve (soil + 5% Date fiber).

The optimum density of this mixture is 1.96 t / m, for a water content of around 14.2%, corresponds to a dense soil.

❖ **Results interpretation**

The results found of the Proctor test carried out on the soil sample + 5% fiber, are further improved, with a maximum dry density of 1.96 (t / m3) for an optimum water content of 14.2 %.

➢ **Case N ° 3: Soil + 7% date fiber**

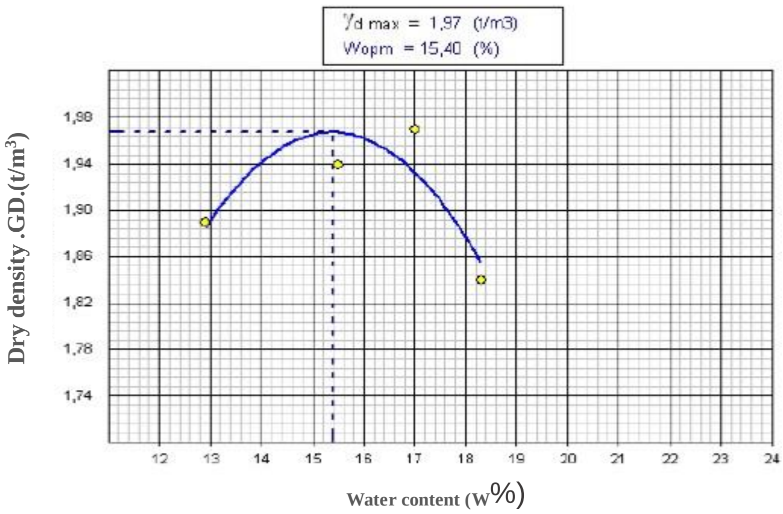


Figure III.15: Proctor curve (soil + 7% Date fiber).

The optimum density of this mixture is 1.97 t / m, for a water content of around 15.40%, corresponds to a dense soil.

❖ **Results interpretation**

The results found of the modified Proctor test on the soil with 7% fiber show a slight increase in the dry density of 1.97 (t / m3) for a water content of about 15.40% per relative to the ground + 5% fiber.

III.7.1.2 The CBR test of soil treated with Date palm fiber

➢ **Case N ° 1: soil + 3% date palm fiber**

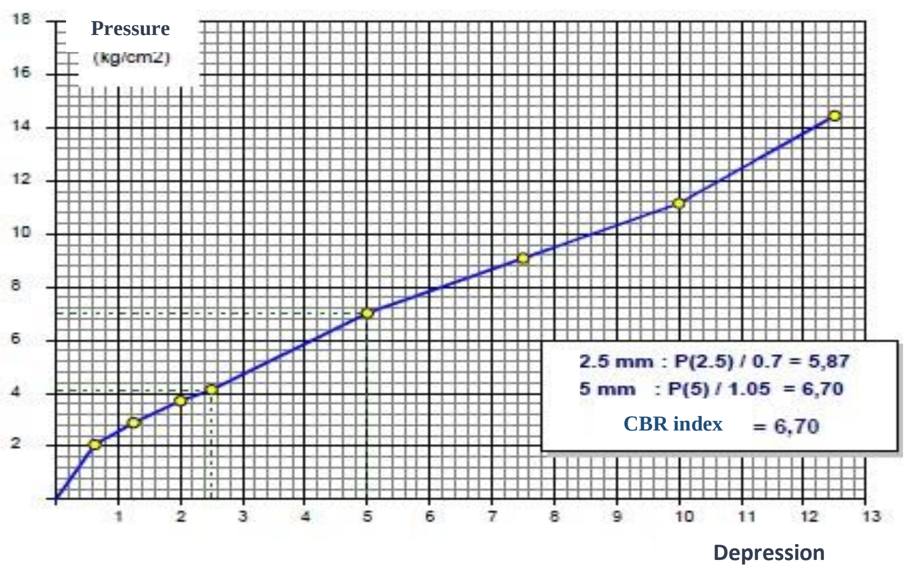


Figure III.16: Curve of the CBR test (for a compaction energy of 10 strokes).

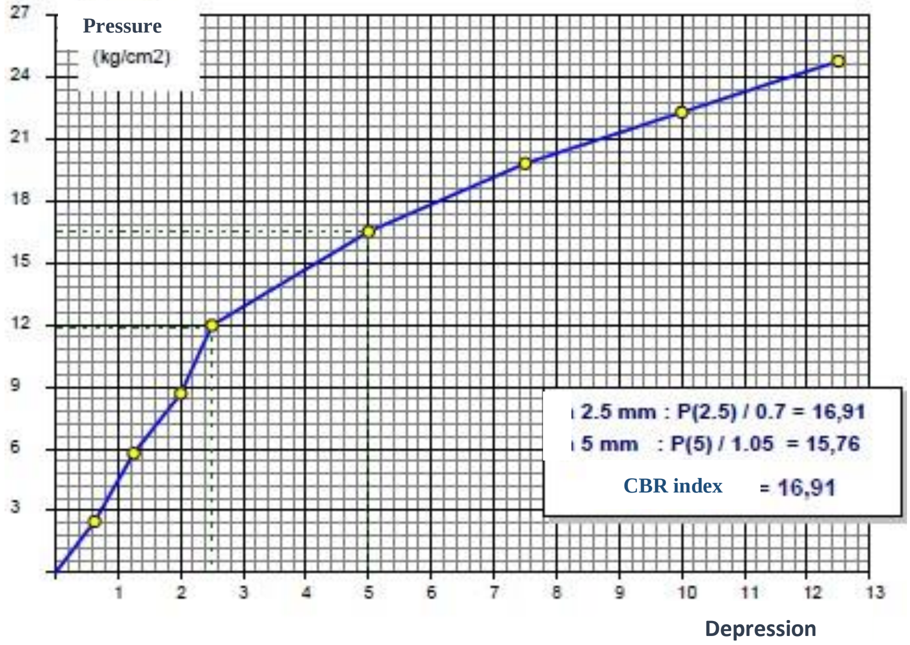


Figure III.17: Curve of the CBR test (for a compaction energy of 25 strokes).

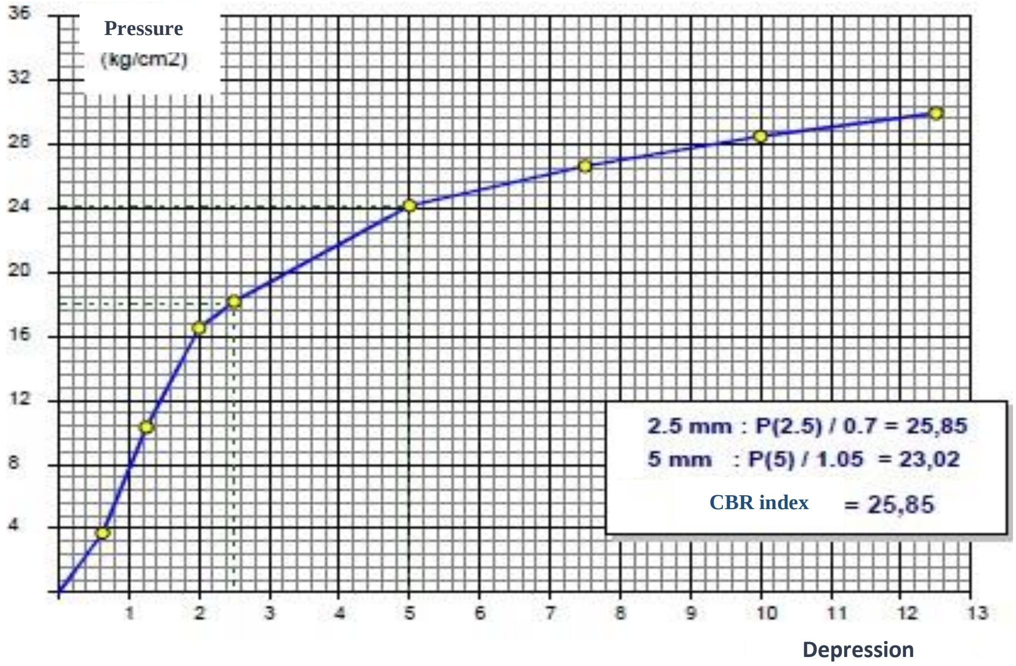


Figure III.18: Curve of the CBR test (for a compaction energy of 56 strokes).

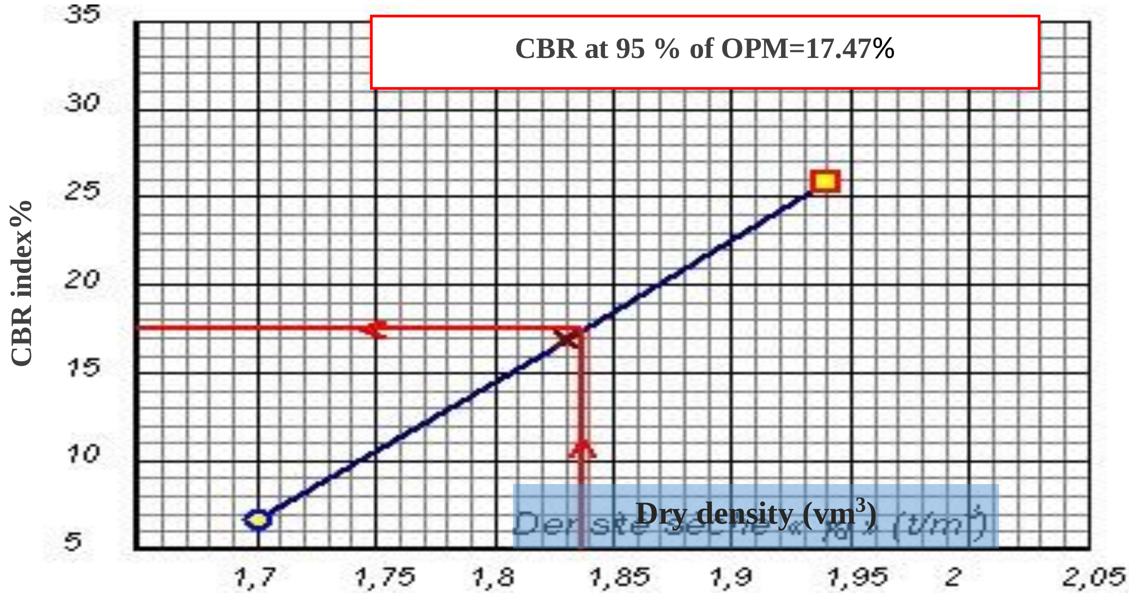


Figure III.19: CBR index curve at 95% of the OPM (soil + 3% fiber).

❖ Results interpretation

The value of the CBR index at 95% of the OPM is 17.47%: we notice that the addition of 3% of fiber improves the soil lift that goes from 11.78% (control soil) to 17, 47% (soil + 3% fiber).

- **Case N ° 2: Soil + 5% Date palm fiber**

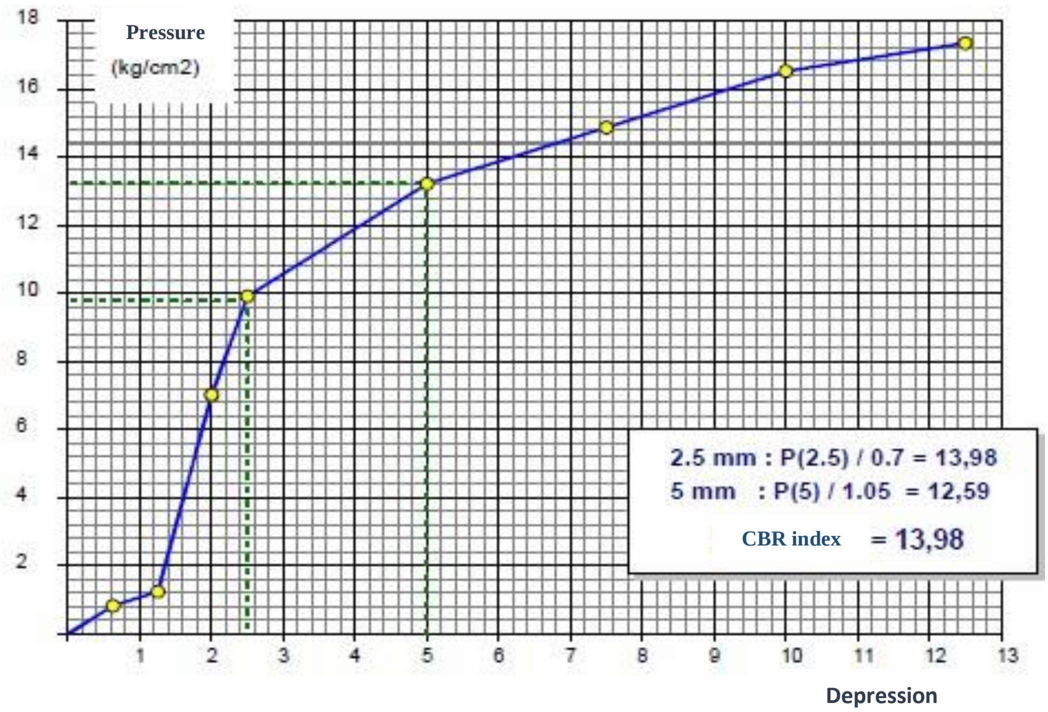


Figure III.20: Curve of the CBR test (for a compaction energy of 10 strokes).

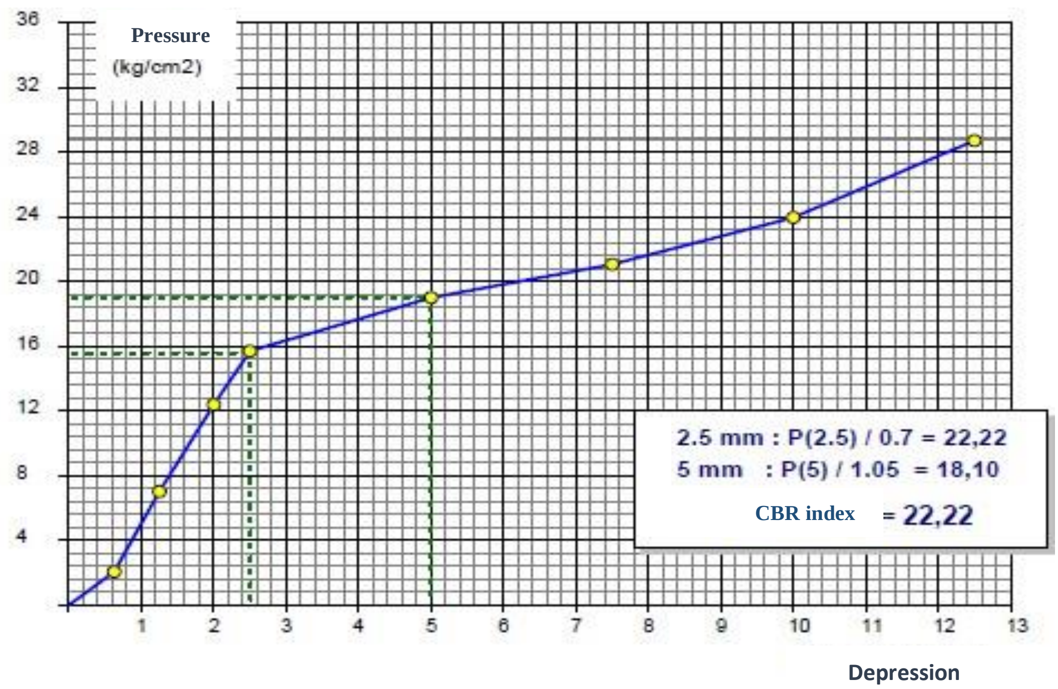


Figure III.21: Curve of the CBR test (for a compaction energy of 25 strokes).

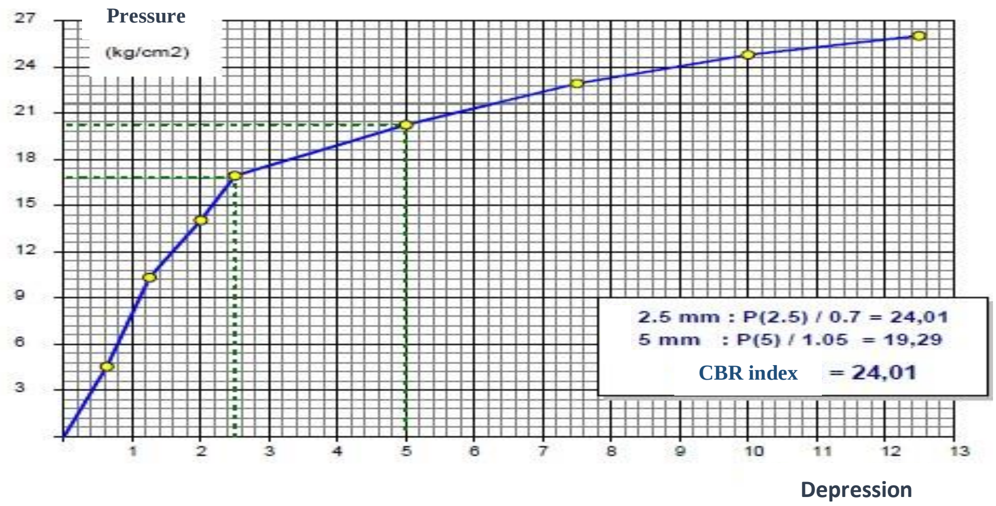


Figure III.22: Curve of the CBR test (for a compaction energy of 56 strokes)

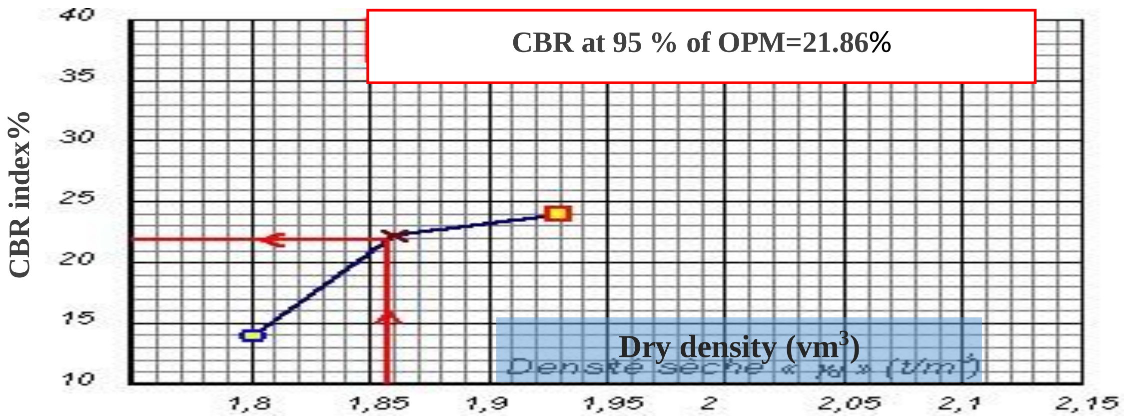


Figure III.23: CBR index curve at 95% of the OPM (soil + 5% fiber).

❖ **Interpretation of results**

The value of the 95% CBR index of the OPM is 21.86%: the addition of 5% of fiber gives a 95% CBR index of the OPM better than the CBR index of the control soil and of soil + 3% of the fiber

Case N ° 3: soil + 7% date palm fiber

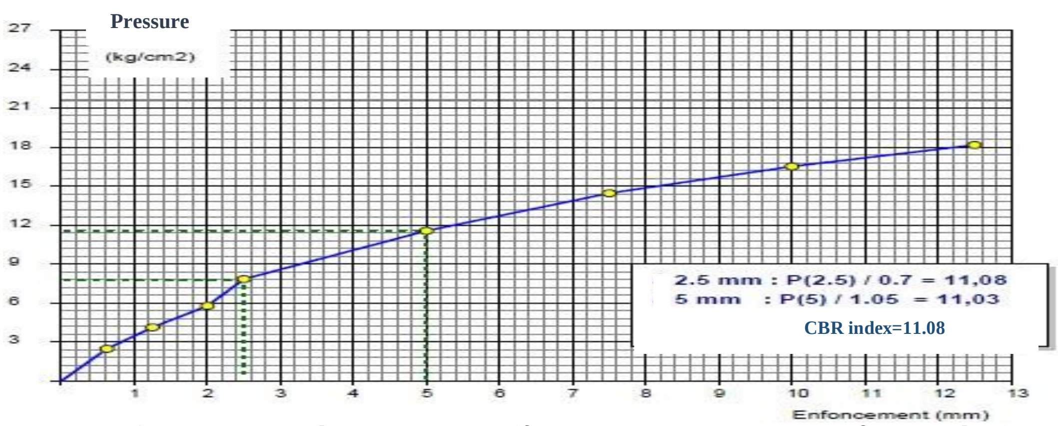


Figure III.24: the CBR curve (for a compaction energy of 10 strokes).

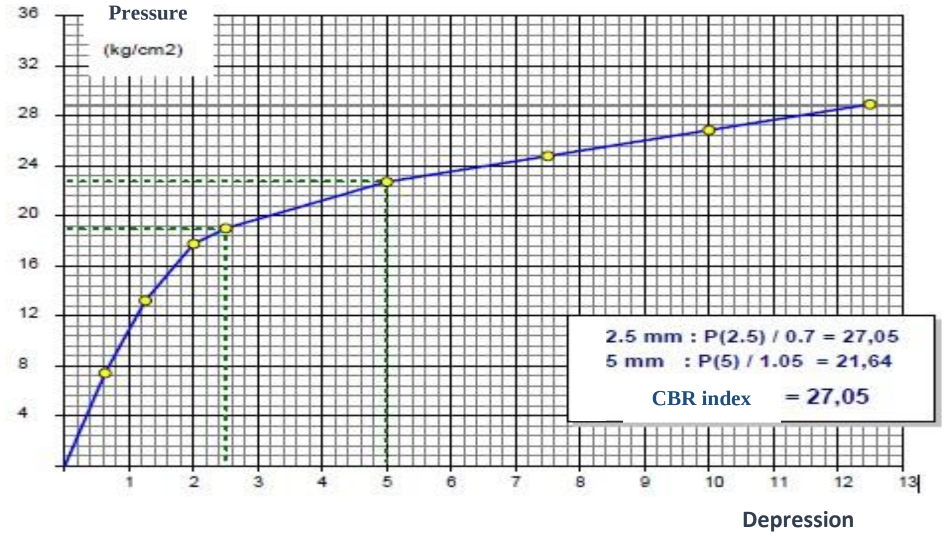


Figure III.25: The CBR curve (for a compaction energy of 25 strokes).

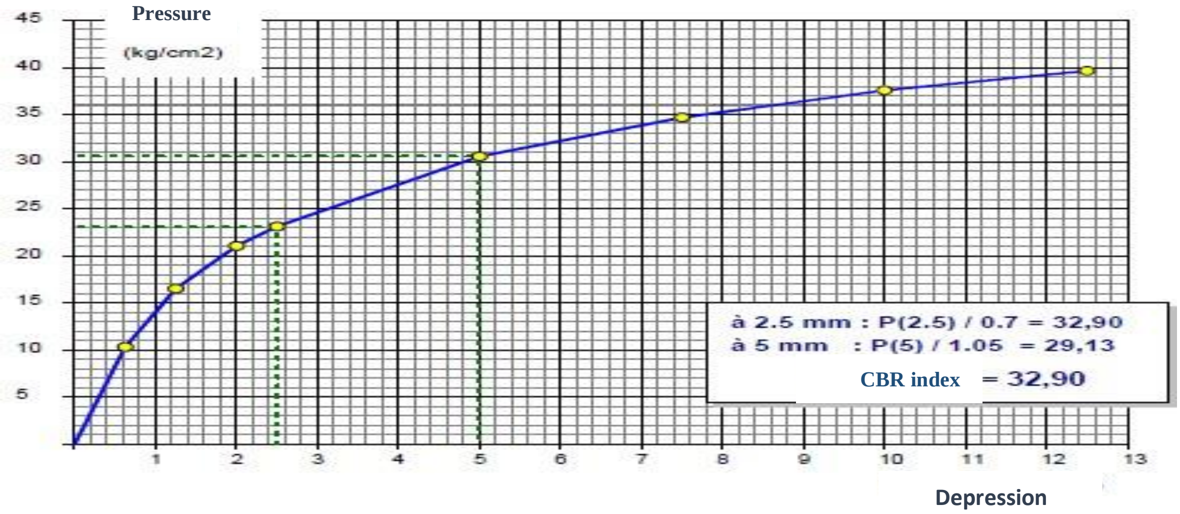


Figure III.26: The CBR curve (for a compaction energy of 56 strokes).

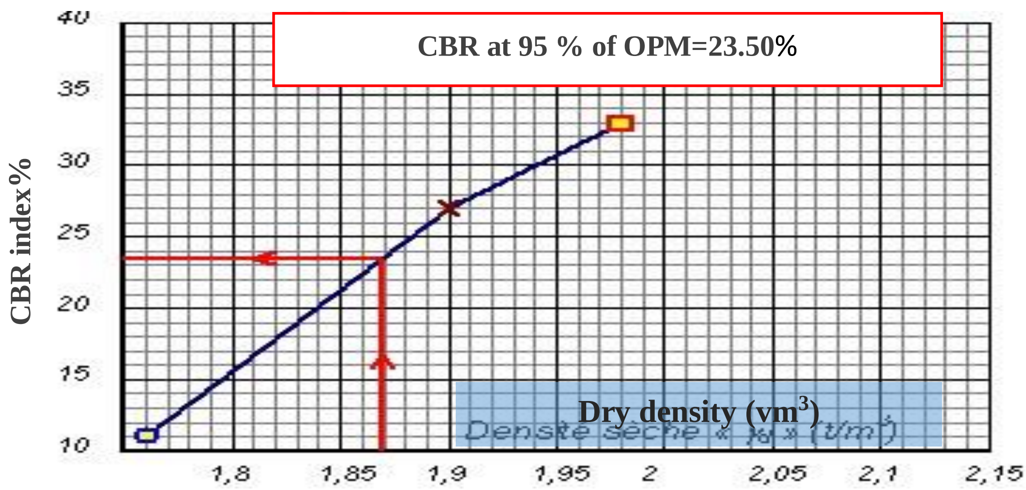


Figure III.27: CBR index curve at 95% of the OPM (soil + 7% fiber).

- **Interpretation of results**

The value of the CBR index at 95% of the OPM of the soil + 7% of fiber is 23.50%: which shows an improvement in the soil lift compared to the control soil and the soil + 3 and 5 % of fiber.

In conclusion, we noticed that the value of the CBR index at 95% of the OPM improves with the addition of the Date fiber, and each time the percentage of the addition (Date fiber) increases, l 'CBR index increases.

III.7.2 Mechanical tests

III.7.2.1The casagrande box shear test consolidated drained (CD)

The consolidated and drained casagrande type (CD) box shear test conducted three (03) soil samples with different percentages (3%, 5% and 7%) of date fiber.

On each canned sample 03 cells of material, on which we apply stresses of 1 bar, 2 bar, 4 bar respectively.

- **Case N ° 1: ground shear (CD) + 3% Date palm fiber**

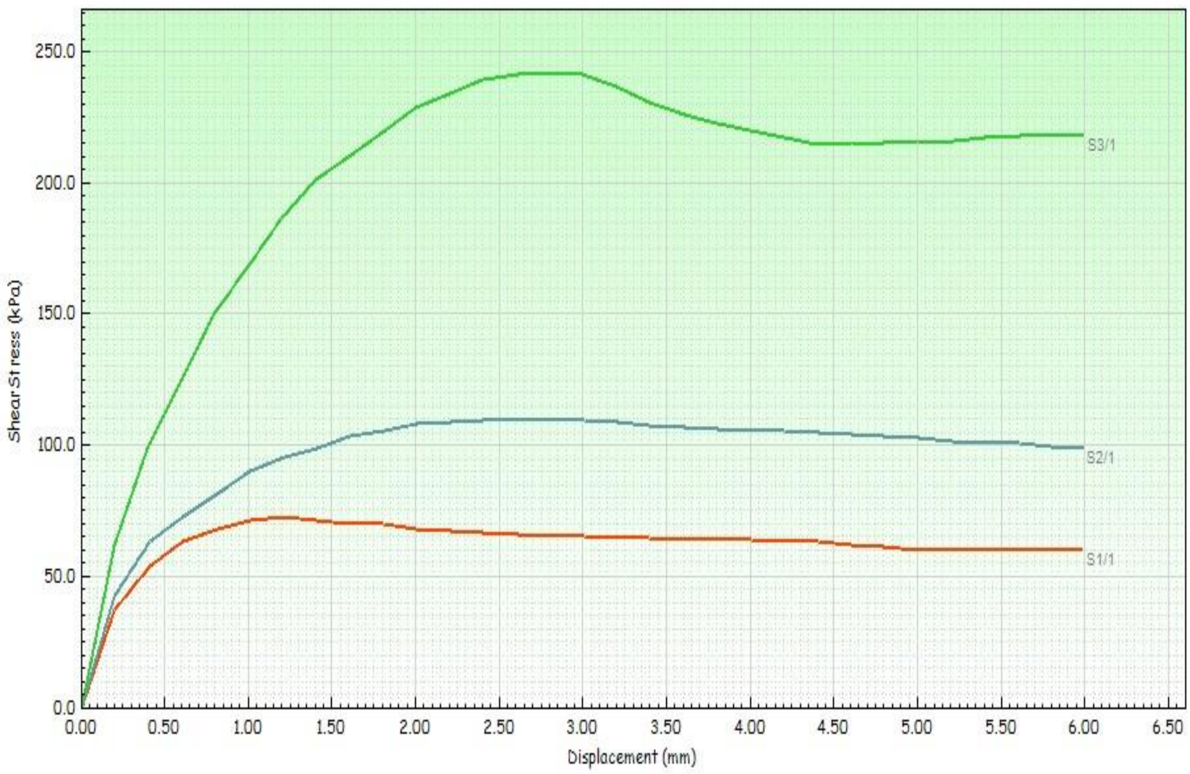


Figure III.28: Stress-strain curve of the shear test (soil + 3% fiber).

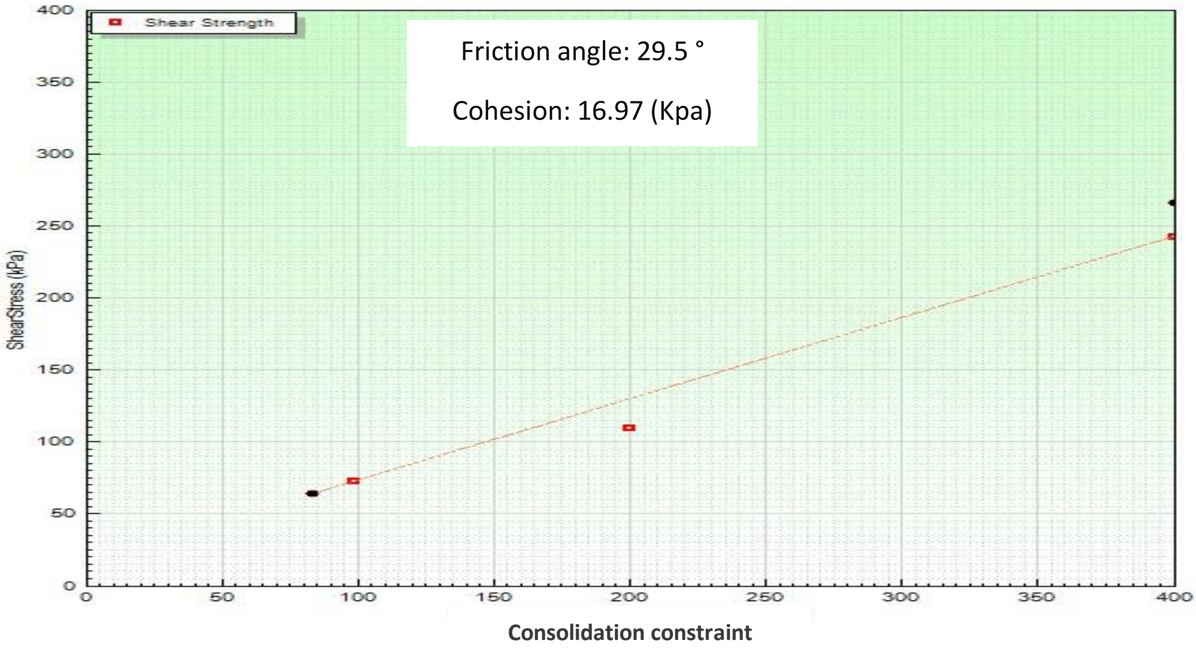


Figure III.29: Intrinsic curve of the shear test (soil + 3% fiber).

- **Interpretation of results**

The values obtained from the CD shear test: the drained cohesion is 16.97 kPa and the internal friction angle is 29.5 °.

We noticed that the addition of 3% of fiber improves the mechanical parameters of the soil, in fact, the value of the drained cohesion passes from 6.93 kPa to 16.97 KPa and the value of the internal friction angle passes from 29, 3 ° to 29.5 °.

Case N ° 2: Ground shear (CD) + 5% Date palm fiber

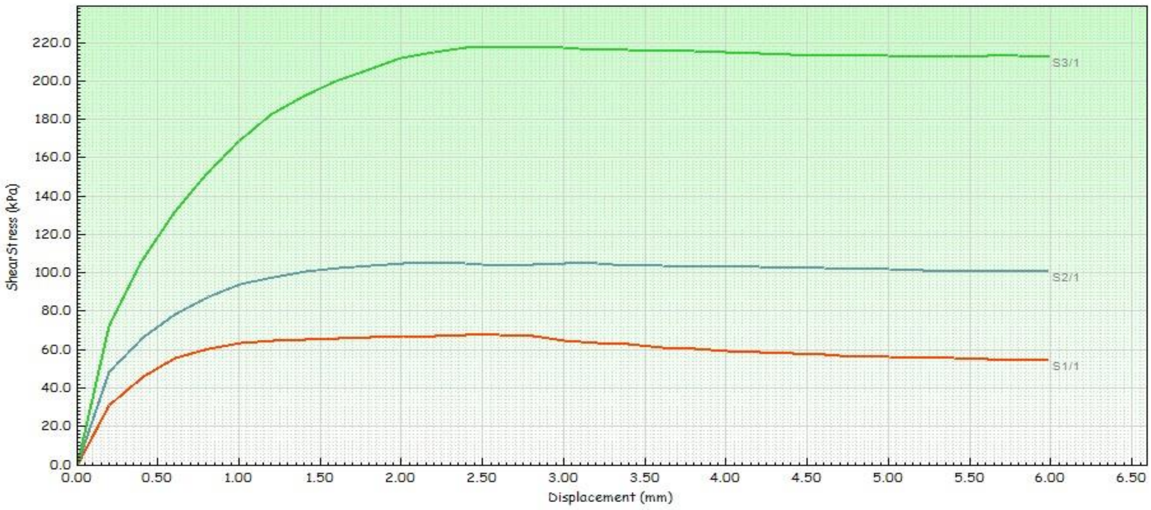


Figure III.30: Stress - strain curve of the shear test (soil + 5% fiber).

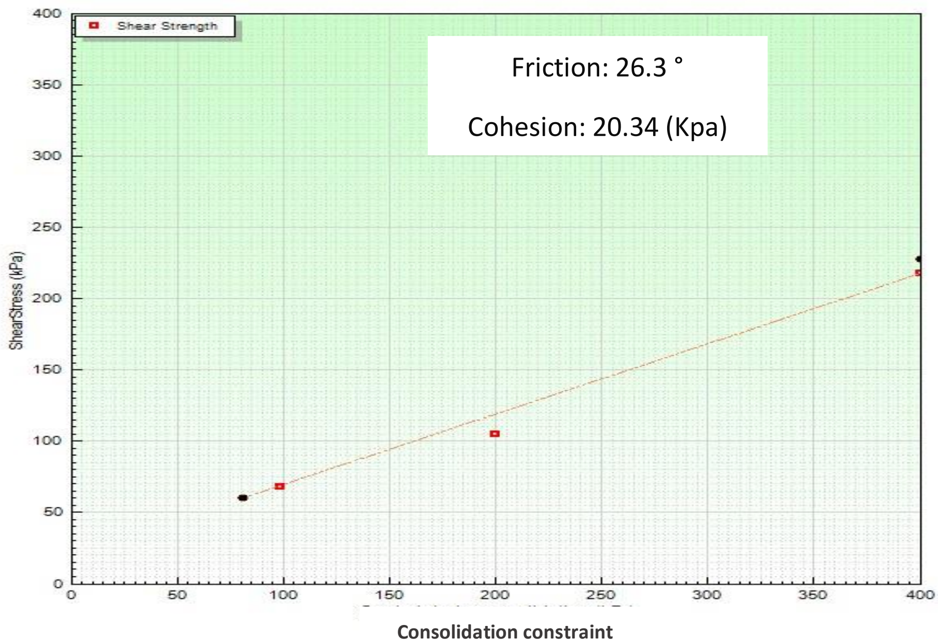


Figure III.31: Intrinsic curve of the shear test (soil + 5% fiber).

❖ **Results interpretation**

The values obtained from the CD shear test: the drained cohesion is 20.34 kPa and the internal friction angle is 26.3 °.

Note that the addition of 5% fiber improves soil cohesion (20.34 KPa) compared to the control soil samples (6.97 kPa) and soil + 3% fiber (16.97 KPa), on the other hand the value of the internal friction angle (26.3 °) decreases compared to the values obtained on the control soil samples (29.3 °) and soil + 3% (29.5 °) of fiber.

➢ **Case N ° 3: soil shear (CD) + 7% Date palm fiber**

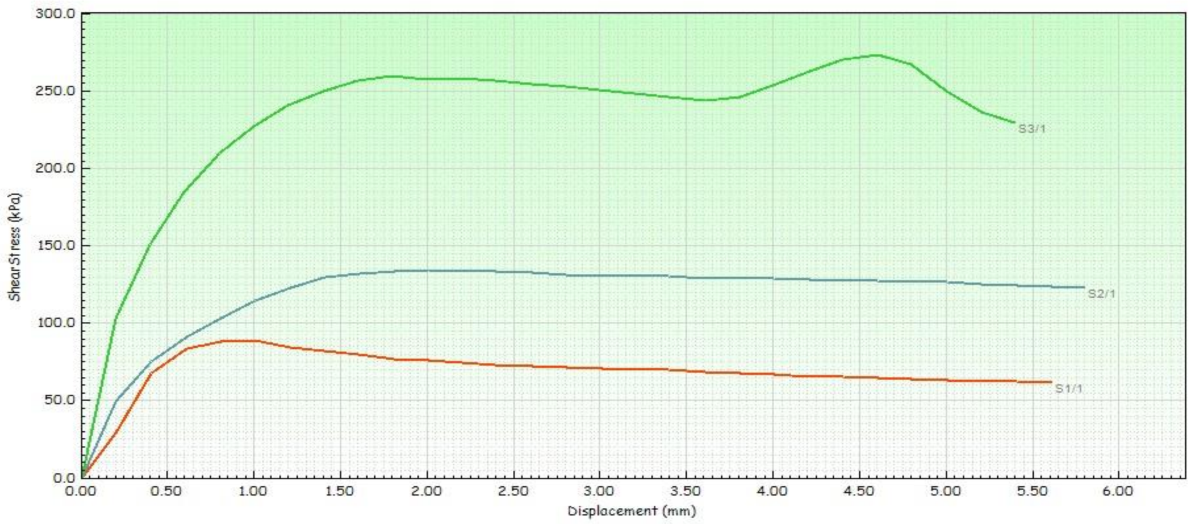


Figure III.32: Stress - strain curve of the shear test (soil + 7% fiber).

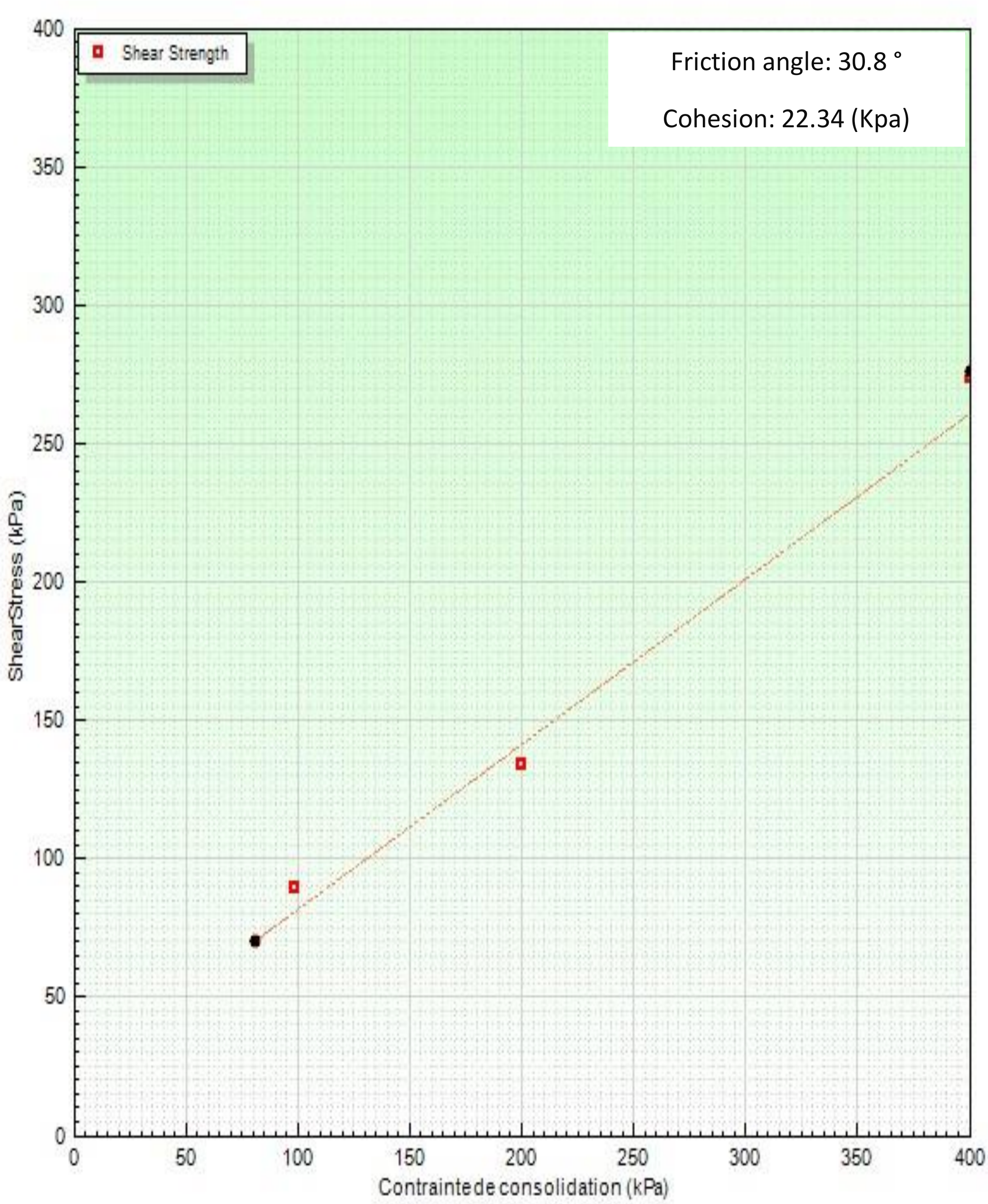


Figure III.33: Intrinsic curve of the shear test (soil + 7% fiber).

❖ **Results interpretation**

The CD drained consolidated type shear test with a mixture composed of soil + 7% Date fiber gave better and higher mechanical characteristics compared to the samples: control soil, soil + 3% fiber, soil + 5 % fiber.

The mechanical characteristics drawn from this test: a drained cohesion of 22.28 KPa and an internal friction angle of 30.8 °.

III.7.3 reinforced soil tests [44]

III.7.3.1 Pre-mechanical (energy) tests

III.7.3.1.1 CBR test of soil reinforced with Alfa fiber (3%).

• **Immediate CBR:**

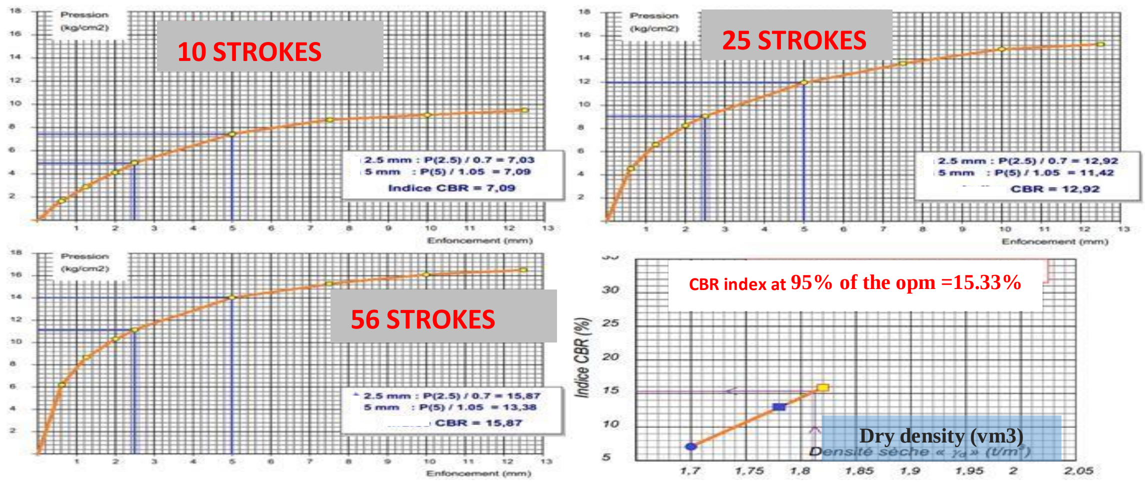


Figure III.34: Immediate CBR curves (56.25 and 10 strokes) and dry density as a function of CBR index of the soil reinforced with (3%) Alfa fiber.

• **CBR soaked:**

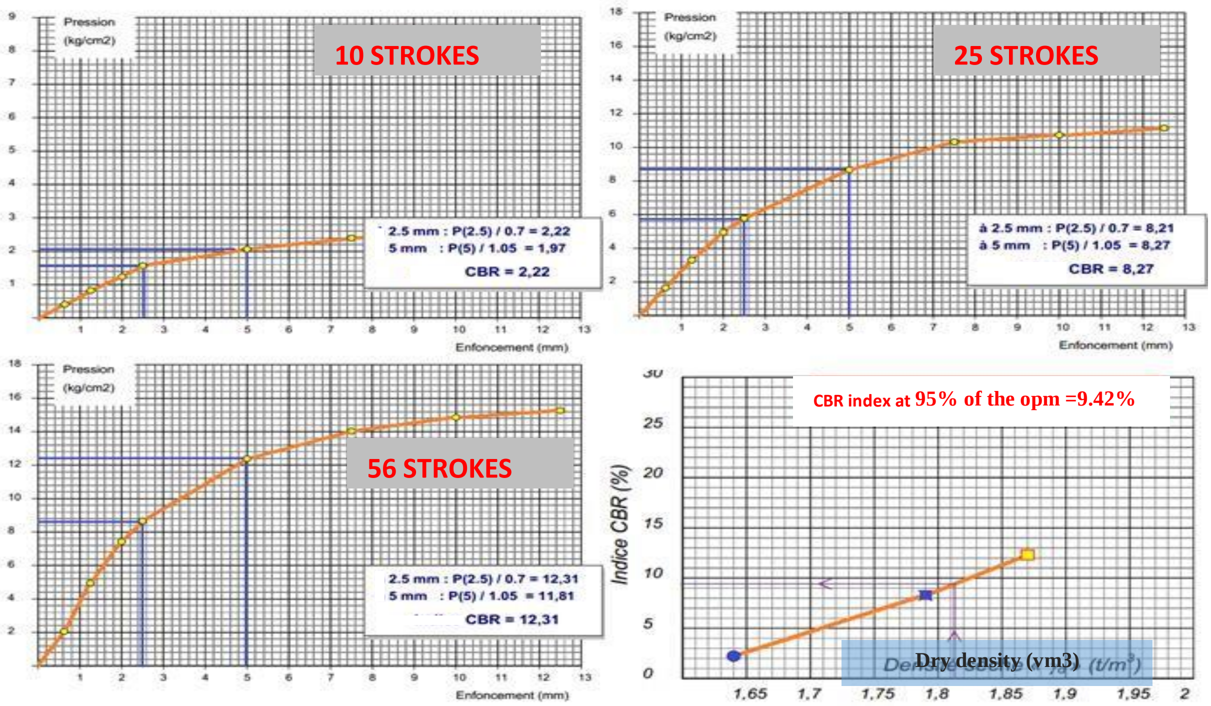


Figure III.35: The soaked CBR curves (56.25 and 10 strokes) and the dry density as a function of CBR index of the soil reinforced with (3%) Alfa fiber

III.7.3.1.2 CBR test of soil reinforced with Alfa fiber (5%).

• Immediate CBR:

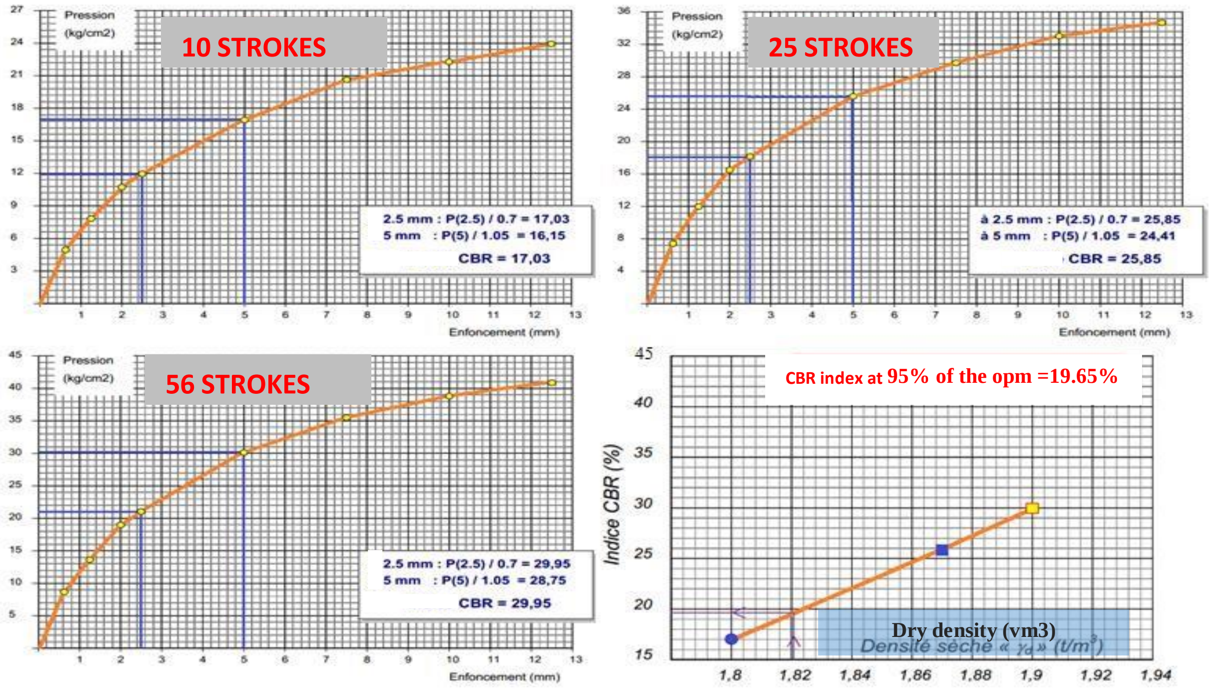


Figure III.36: Immediate CBR curves (56.25 and 10 strokes) and dry density as a function of CBR index of the soil reinforced with (5%) Alfa fiber.

• CBR soaked:

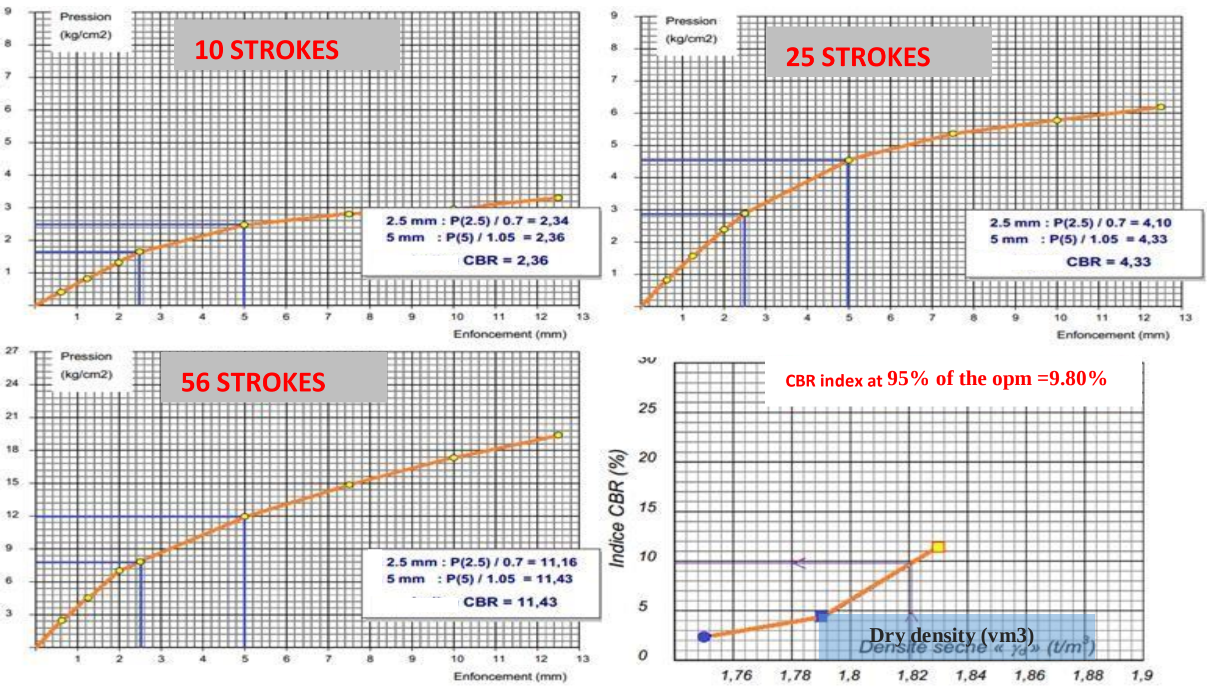


Figure III.37: The soaked CBR curves (56.25 and 10 strokes) and the dry density as a function of CBR index of the soil reinforced with (5%) Alfa fiber.

III.7.3.1.3 CBR test of soil reinforced with Alfa fiber (7%).

• Immediate CBR:

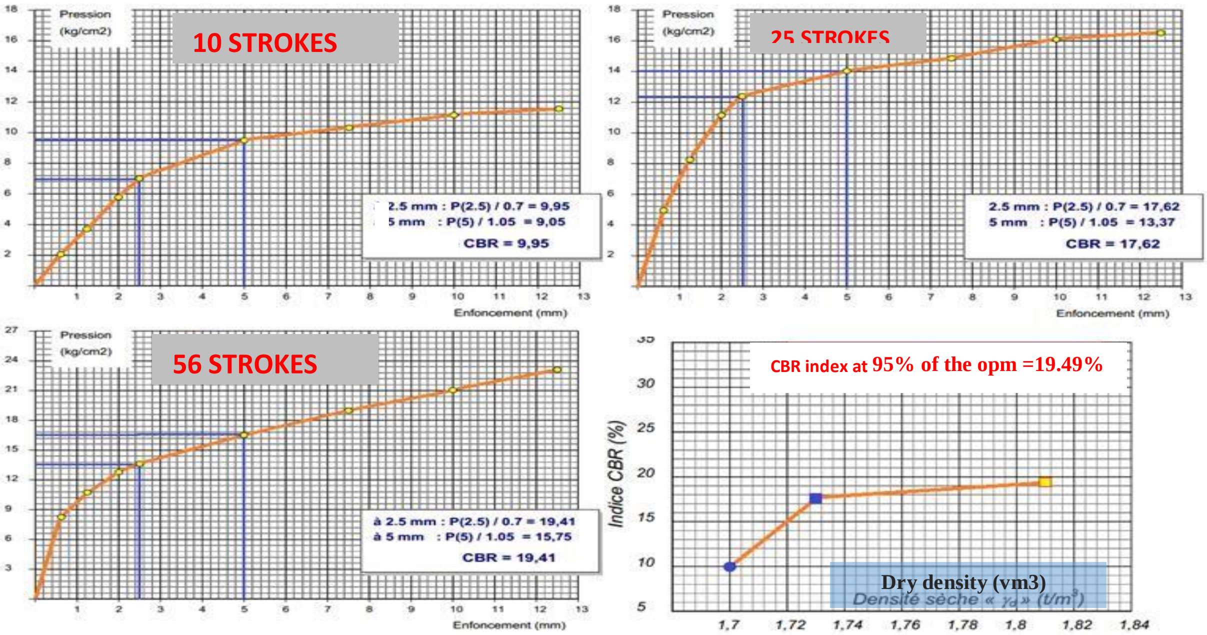


Figure III.38: Immediate CBR curves (56.25 and 10 strokes) and dry density as a function of CBR index of the soil reinforced with (7%) Alfa fiber.

• CBR soaked:

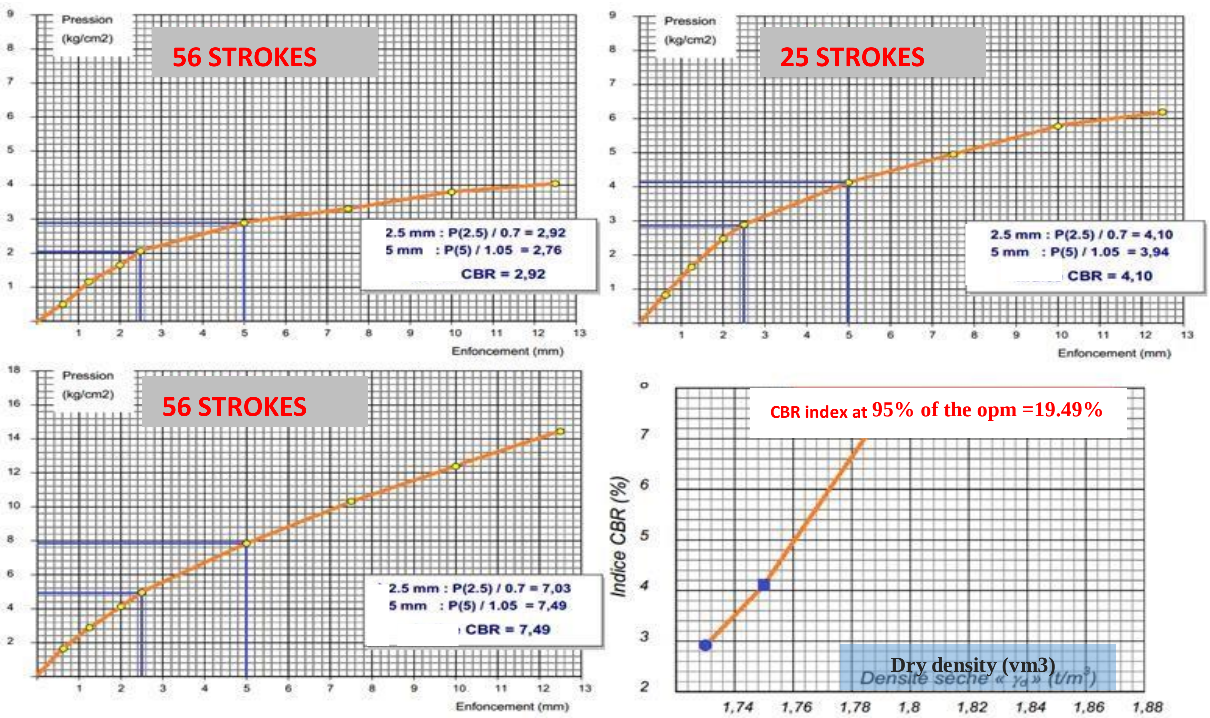


Figure III.39: The soaked CBR curves (56.25 and 10 strokes) and the dry density as a function of CBR index of the soil reinforced with (7%) Alfa fiber.

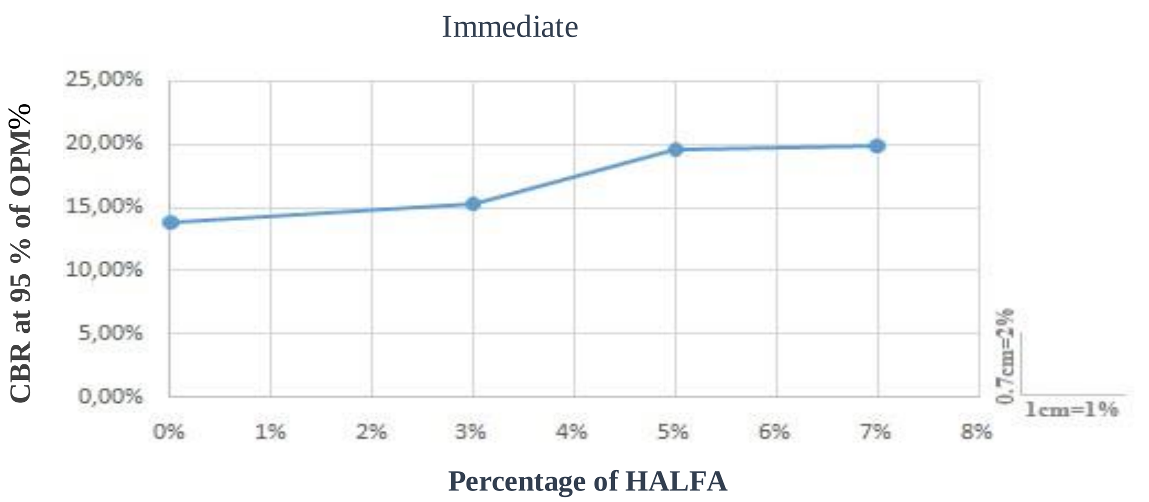


Figure III.40: The curve of the CBR index at 95% of the OPM as a function of different percentages of Halfa for immediate CBR.

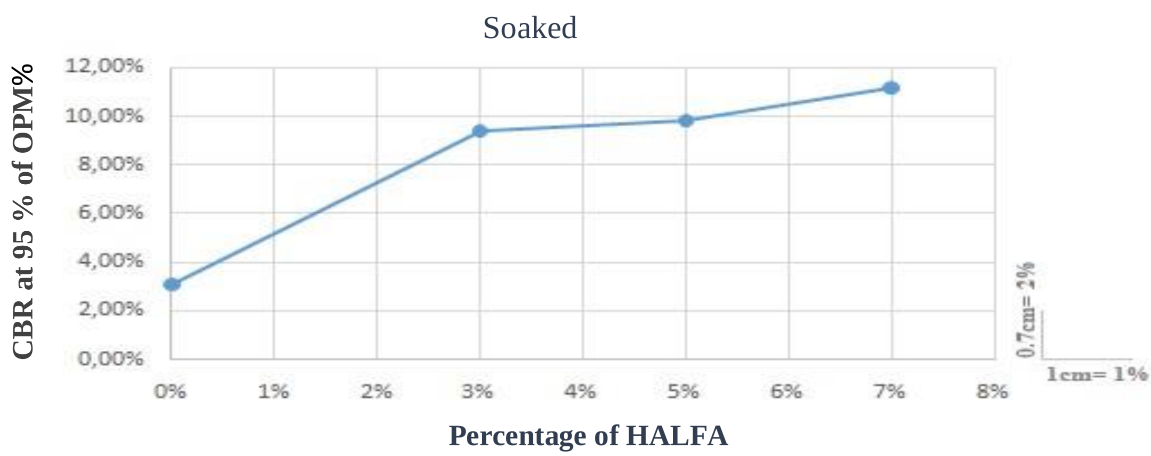


Figure III.41: The curve of the CBR index at 95% of the OPM as a function of different percentages of Halfa for soaked CBR.

- **Interpretation**

According to the results obtained for the different water contents, whether for imbibed CBR or immediate CBR, we wanted to follow the CBR index at 95% of the OPM for each concentration of the Halfa fiber as s 'is shown in figures (23, 24).

We notice an increase in the CBR index to 95% of the OPM in the percentages of 5% and 7%, whether for the immediate CBR or for the soaked CBR. Which means that we have an improvement in our soil.

III.7.4 Mechanical Tests

III.7.4.1 Shear Test (soil with different concentrations of Halfa)

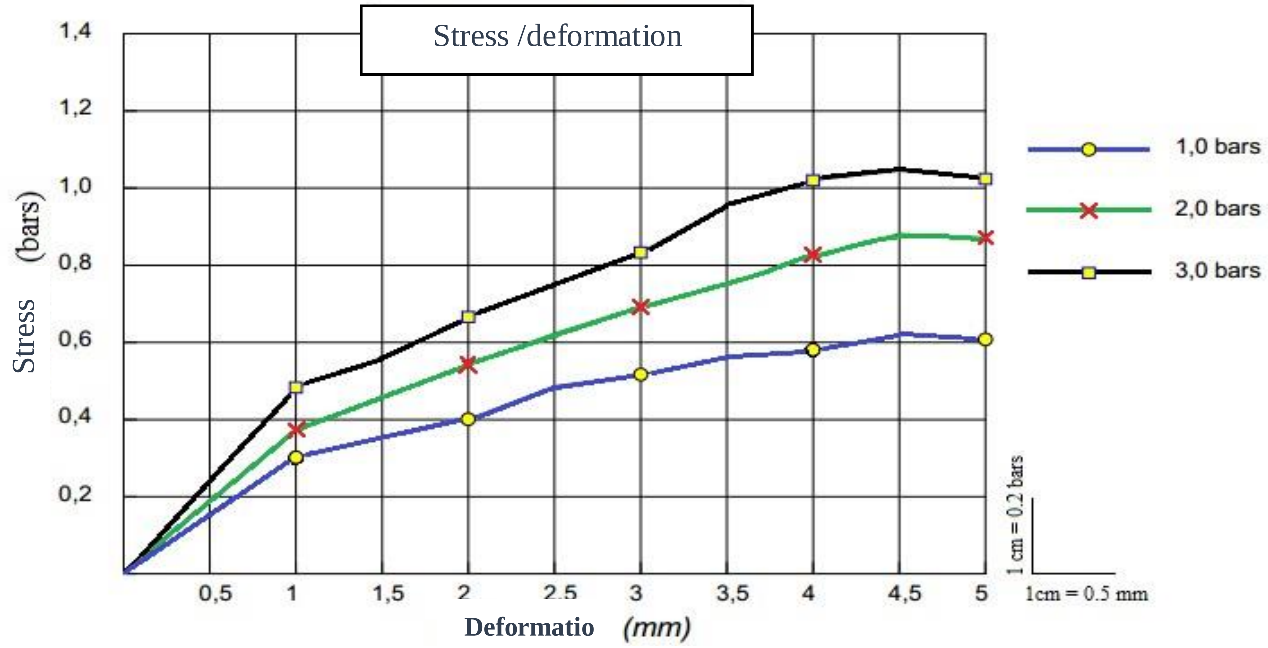


Figure III.42: Representations of the shear strength (at constant speed 1.5 mm / min) of the soil with 3% Halfa.

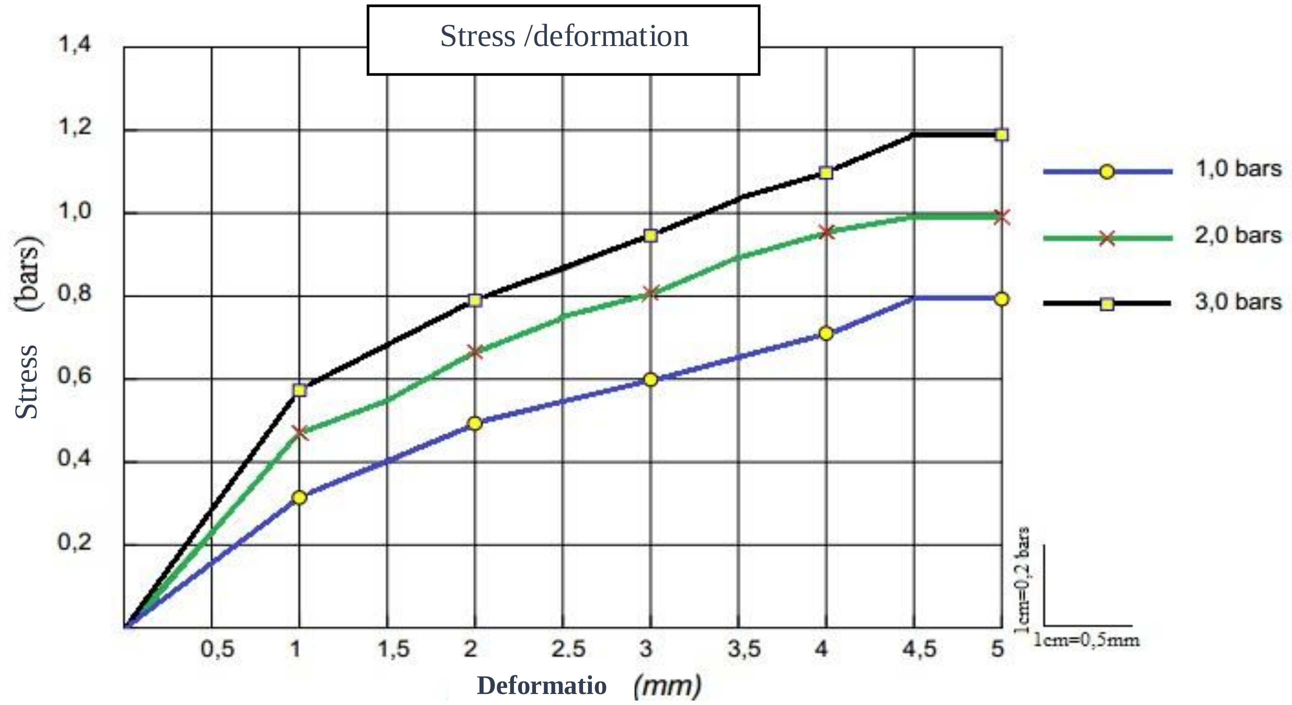


Figure III.43: Representations of the shear strength (at constant speed 1.5 mm / min) of the soil with 5% Halfa.

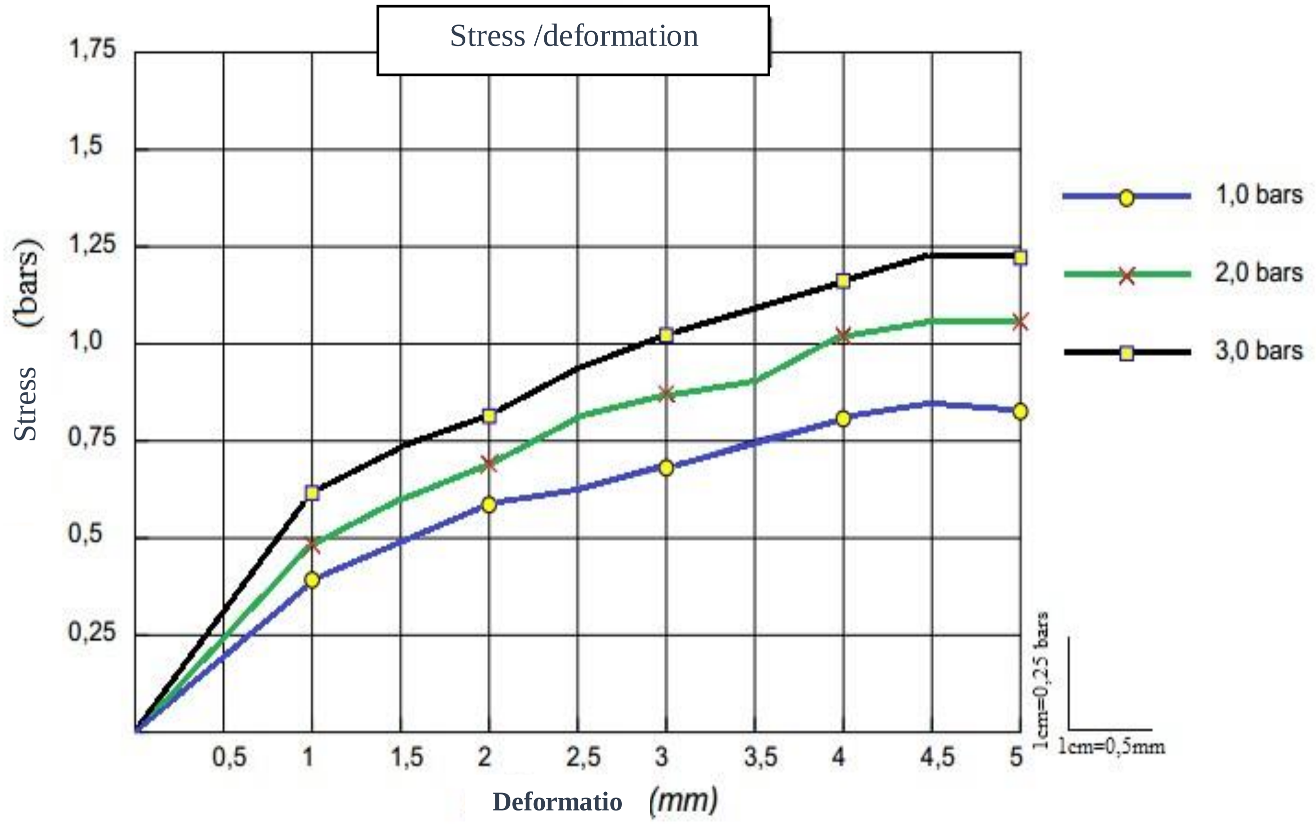


Figure III.44: Representations of the shear resistance (at constant speed 1.5 mm / min) of the soil with 7% of Halfa.

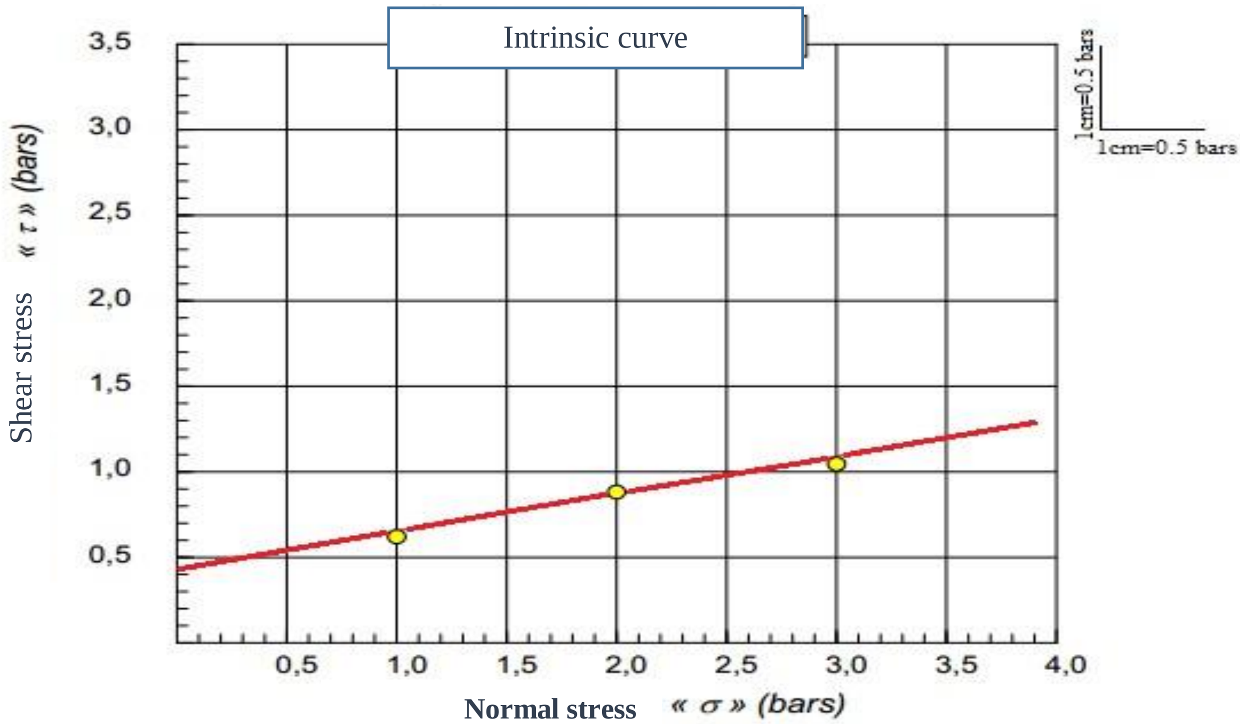


Figure III.45: The intrinsic soil curve with 3% Halfa.

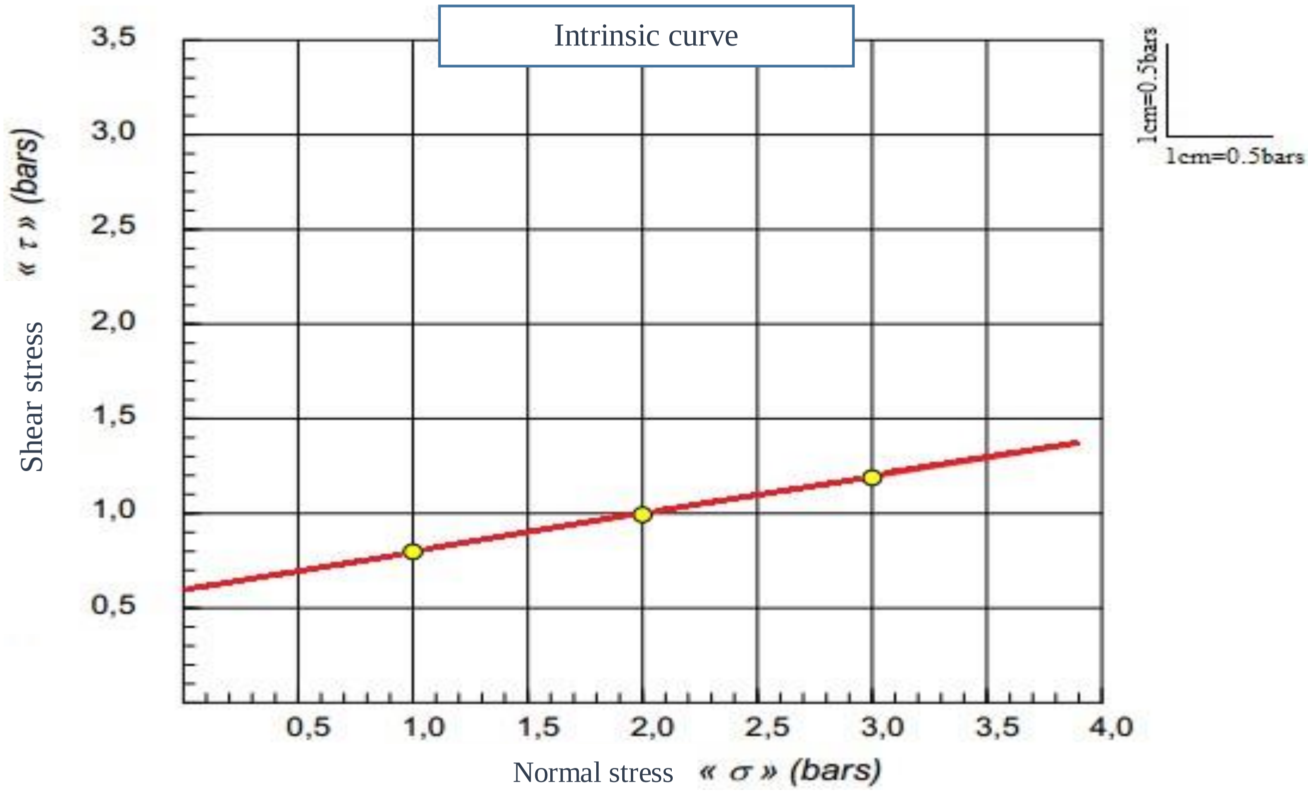


Figure III.46: The intrinsic soil curve with 5% Halfa.

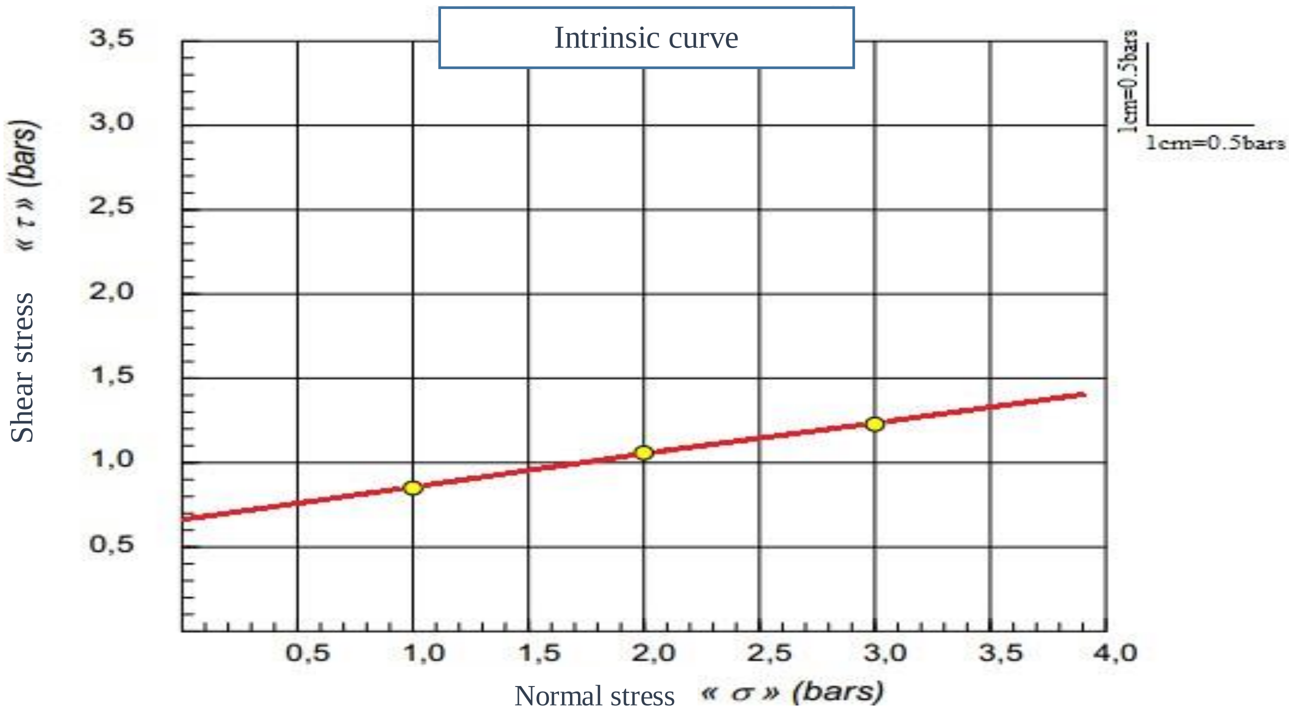


Figure III.47: The intrinsic soil curve with 7% Halfa.

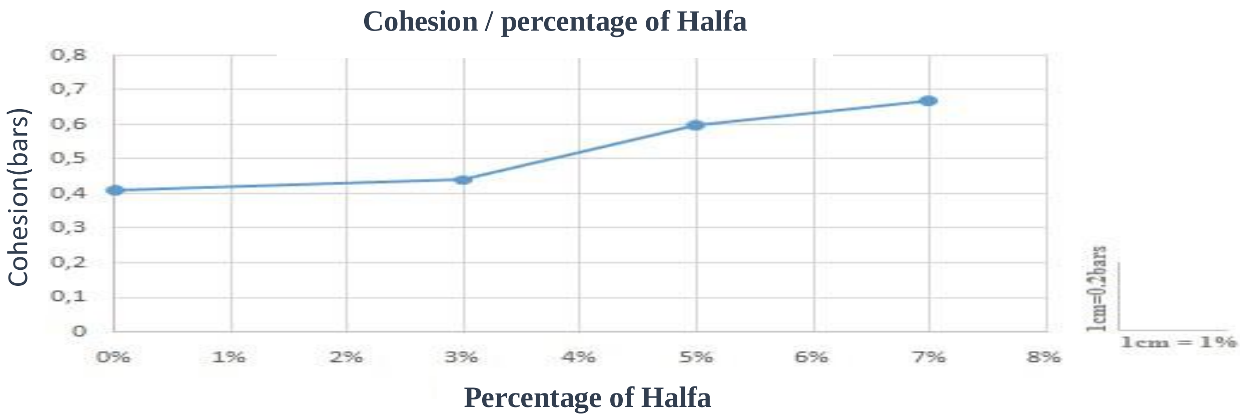


Figure III.48: Curve of the cohesion as a function of different percentages of the Halfa fiber.

❖ **Interpretation**

From the intrinsic curves in figures (45, 46 and 47), we can only deduce the cohesion and the friction angle are as follows:

3% C = 0.44 bars = 44 KPa ϕ = 12, 27 degrees

5% C = 0, 60 bars = 60 KPa ϕ = 11, 06 degrees

7% C = 0, 67 = 67 KPa ϕ = 10, 73 degrees

A remarkable improvement in the curve of figure (48) the value of the cohesion increased in the soil, which had the percentages 5% and 7% of the fiber of Halfa.

III.7.4.2 Odometer Compressibility Test (the soil with the different concentrations

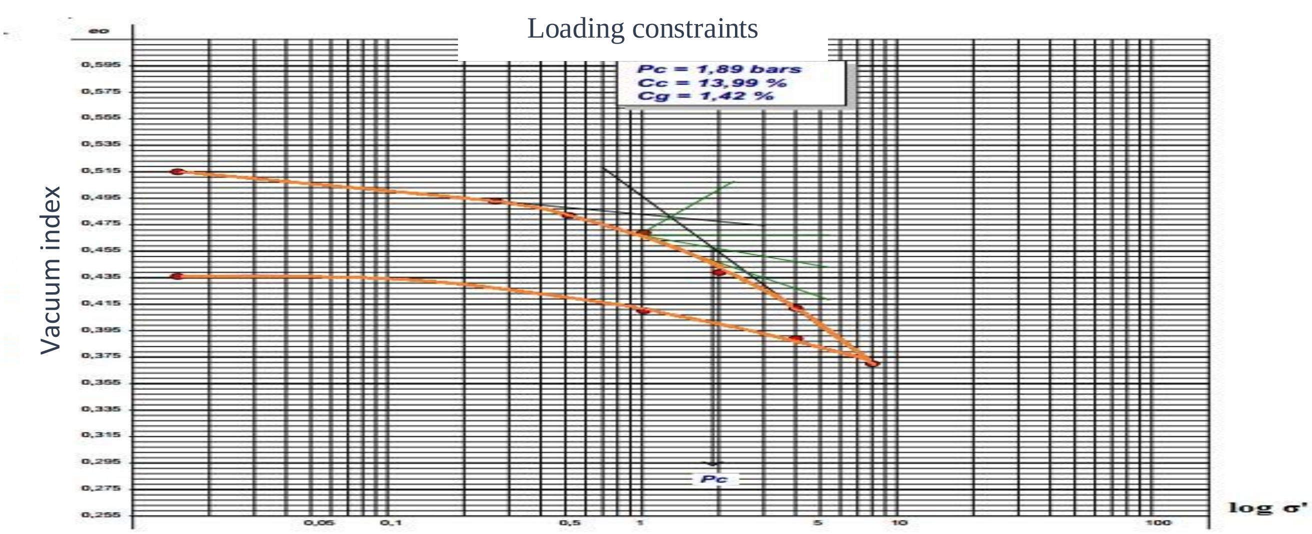


Figure III.49: Representations of the compressibility with the odometer (soil with 3% of halfa).

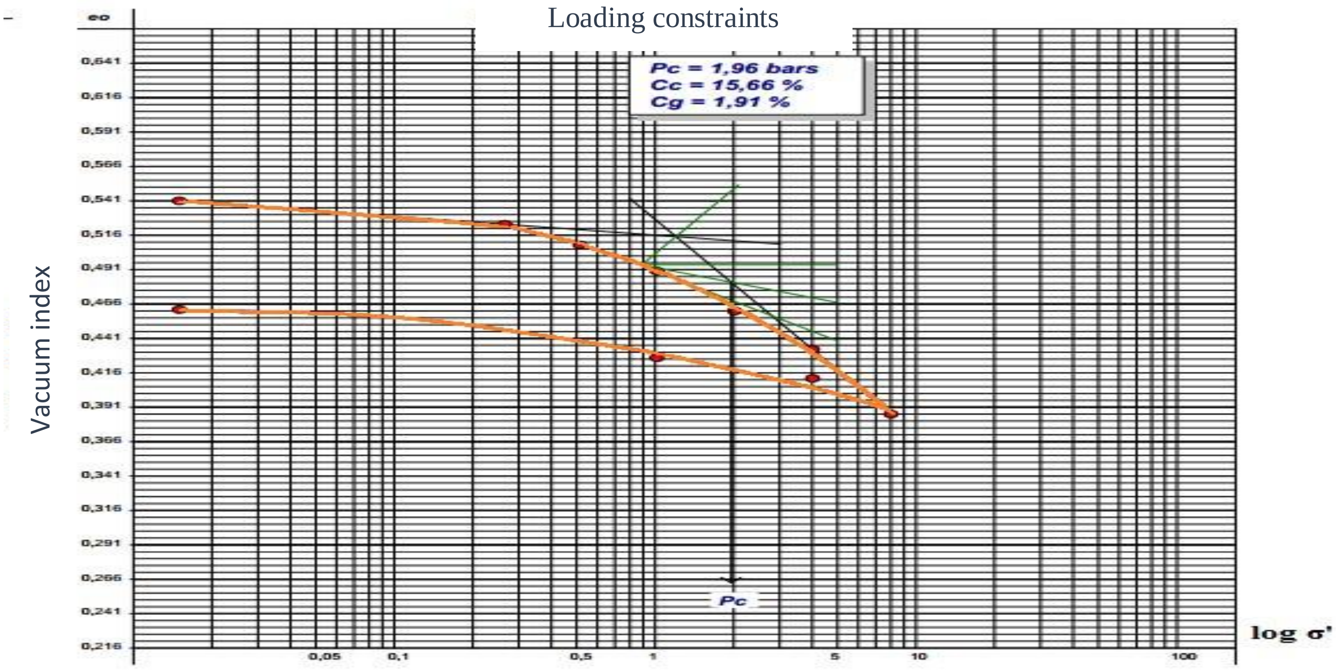


Figure III.50: Representations of the compressibility with the oedometer (soil with 5% of halfa)

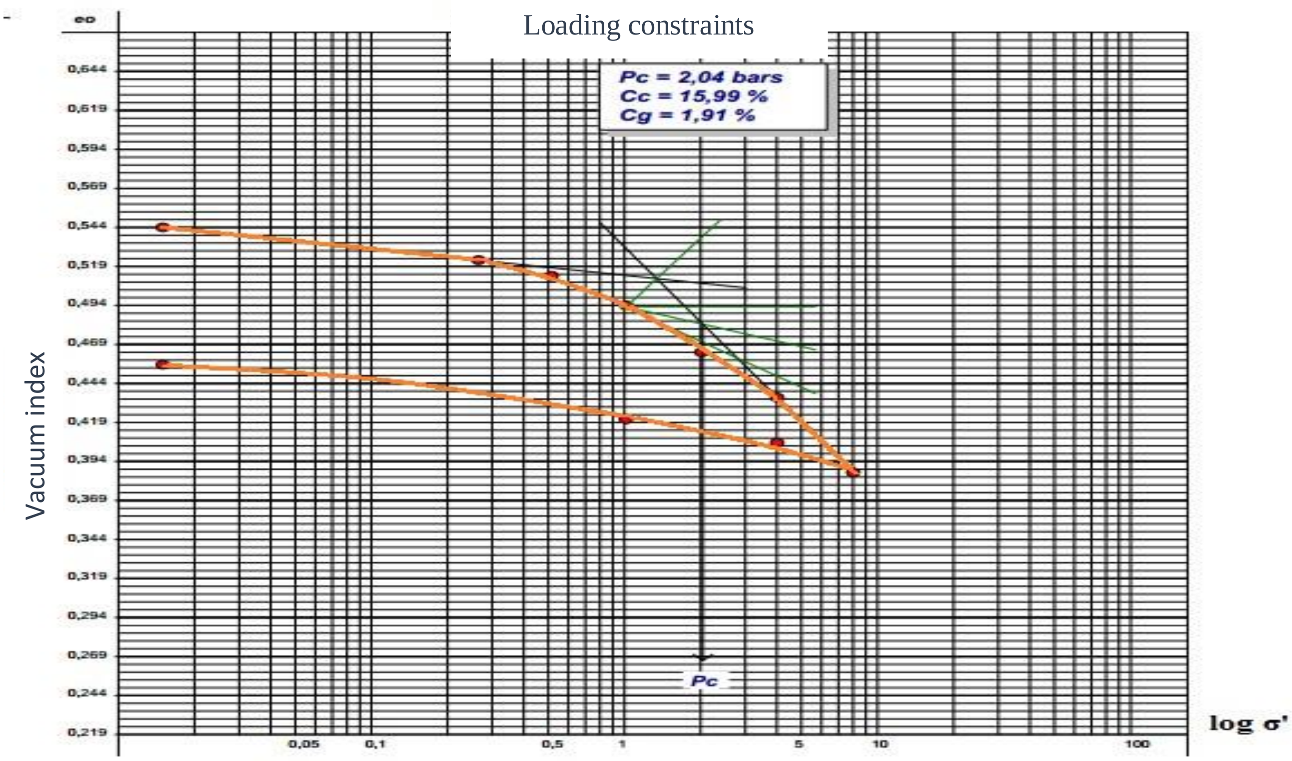


Figure III.51: Representations of the compressibility with the oedometer (soil with 7% of halfa).

- **Interpretation**

For 3%

Pc = 1.89 bars Cc = 13.99% Cg = 1.42% Δh = 0.1036 H = 2.02cm

For 5%

Pc = 1.96bars Cc = 15.6% Cg = 1.91% Δh = 0.101 H = 2.008cm

For7%

Pc = 2.04 bars Cc = 15.99% Cg = 1.91% Δh = 0.1168 H = 2.067cm

From the coefficients (Pc, Cc and Cg), we notice that we have an improvement with the increase in the percentage of halfa.

In addition, the best result is in the percentage of 5% and 7%.

III.8 Conclusion

In this chapter, we have determined the location of the soil sample, and we have administered the various tests necessary to determine soil properties by respecting the established standards to achieve the capping layer based on studies conducted last year.

The study of the characteristics of the constituents of this material show that the sample is class A2 (It is a clayey loam soil with medium moisture fines)that needs a treatment so that it can be used for the construction of the capping layer.

This treatment will be done by natural date palm and halfa fibers with different percentage (3%5% and 7%.).

We give you an idea of how to reconstitute the support soil with the date palm and Halfa fibers (three samples) in different proportions with different cases of fibers, and we studied the effect of the fibers on the soil and the mechanical properties of this study

In addition, we noted that the analyzed characteristics improved in a progressive and positive way with the increase of the percentages of the two types of fibers.

Chapter IV Results interpretation and discussion

IV.1 Introduction

In the previous chapter, we dealt with the effect of fibers (date palm and Halfa) with different concentrations on the mechanical structure of the soil.

In addition, how to achieve satisfactory results proven through previous experiments.

However, in the chapter we will try to compare the real effect of natural fibers in strengthening the soil to see which of the fibers is the best used through curves and results Obtained from tests.

Through the previous two studies, we found that they share two tests (CBR and Shear tests), and since the soil used is identical and from the same site, we can build a simple comparison to understand the role of each of the fibers.

IV.2 Comparison between the two fibers and their effect on the soil

To make the comparison clear and practical, we matched the curves and compared the results obtained.

IV.2 .1 CBR test (date palm/halfa %)

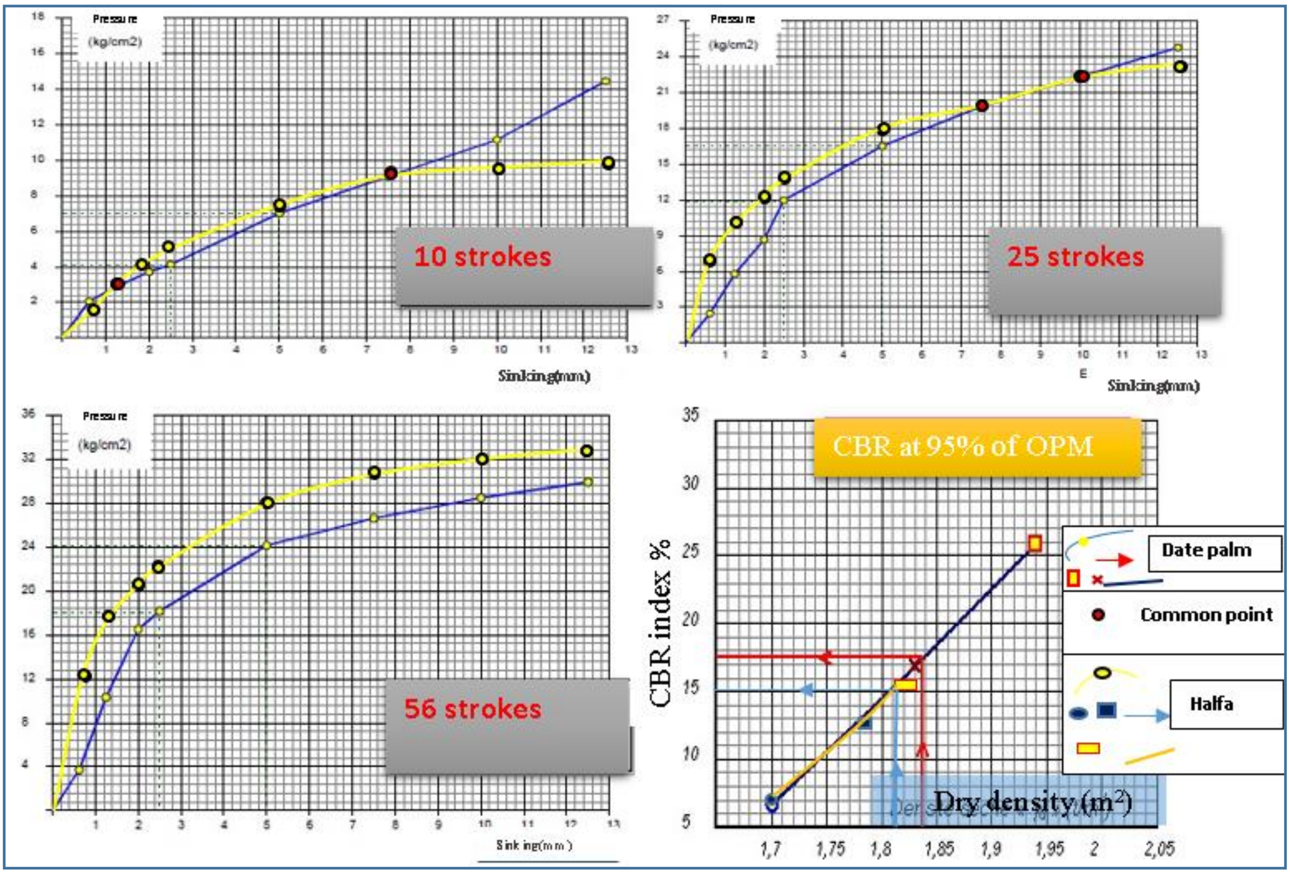


Figure IV.1: Immediate CBR curves (10-25 and 56 strokes) of the soil reinforced with (3%)

➢ **Case of date palm fiber (soil + 3% fiber) :**

- **10 strokes**

At 2.5mm: p (2.5)/0.7=5.87 and at 5mm: p (5)/1.05=6.70 so the CBR index=6.70.

- **25 strokes**

At 2.5mm: p (2.5)/0.7=16.91 and at 5mm: p (5)/1.05=15.76 so the CBR index=16.91.

- **56 strokes**

At 2.5mm: p (2.5)/0.7=25.85 and at 5mm: p (5)/1.05=23.02 so the CBR index=25.85.

CBR index at 95% of the OPM (soil + 3% fiber) =17.47%.

➢ **Case of halfa fiber (soil + 3% fiber) :**

- **10 strokes**

At 2.5mm: p (2.5)/0.7=7.03 and at 5mm: p (5)/1.05=7.09 so the CBR index=7.09.

- **25 strokes**

At 2.5mm: p (2.5)/0.7=12.92 and at 5mm: p (5)/1.05=11.42 so the CBR index=12.92.

- **56 strokes**

At 2.5mm: p (2.5)/0.7=15.87 and at 5mm: p (5)/1.05=13.38 so the CBR index=15.87

CBR index at 95% of the OPM (soil + 3% fiber) =9.42%.

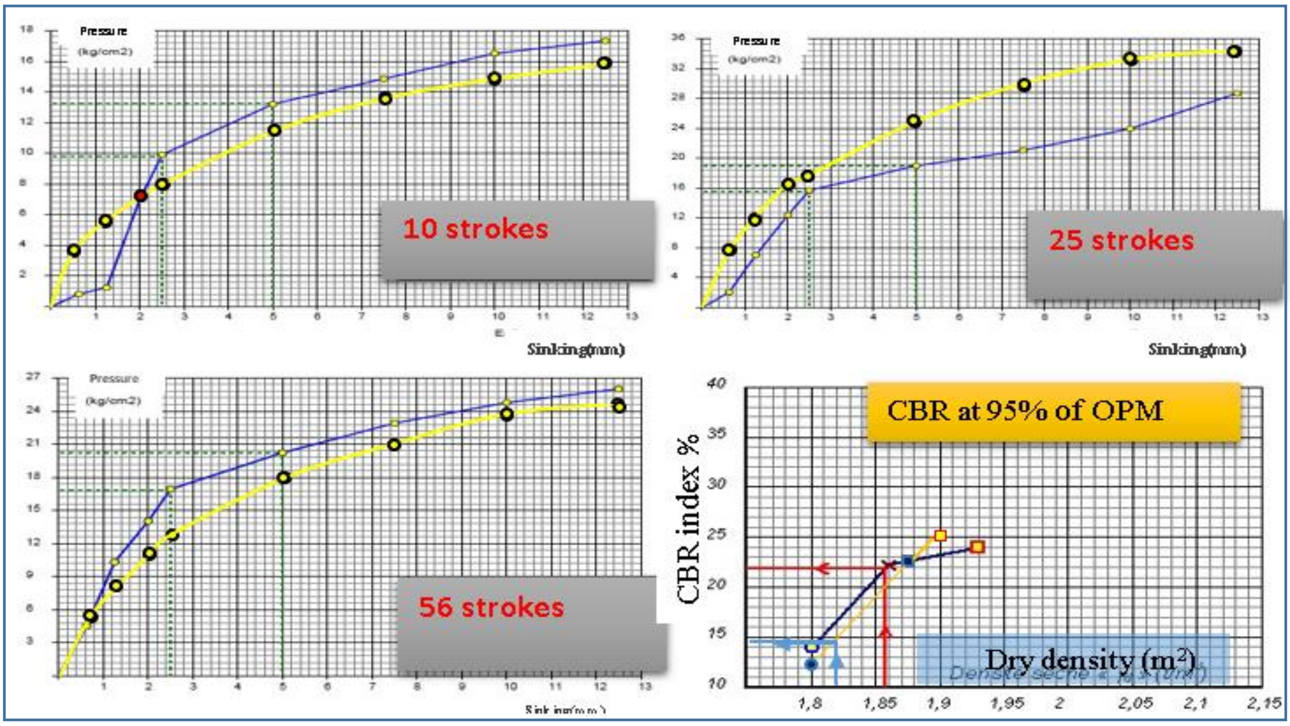


Figure IV.2: Immediate CBR curves (10-25 and 56 strokes) of the soil reinforced with (5%)

- **Case of date palm fiber (soil + 5% fiber) :**

- **10 strokes**

At 2.5mm: p (2.5)/0.7=13.98 and at 5mm: p (5)/1.05=12.59 so the CBR index=13.98.

- **25 strokes**

At 2.5mm: p (2.5)/0.7=22.22 and at 5mm: p (5)/1.05=18.10 so the CBR index=22.22.

- **56 strokes**

At 2.5mm: p (2.5)/0.7=24.01 and at 5mm: p (5)/1.05=19.29 so the CBR index=24.01.

CBR index at 95% of the OPM (soil + 5% fiber) =21.86%.

- **Case of halfa fiber (soil + 5% fiber) :**

- **10 strokes**

At 2.5mm: p (2.5)/0.7=17.03 and at 5mm: p (5)/1.05=16.15 so the CBR index=17.03.

- **25 strokes**

At 2.5mm: p (2.5)/0.7=25.85 and at 5mm: p (5)/1.05=24.41 so the CBR index=25.85.

- **56 strokes**

At 2.5mm: p (2.5)/0.7=29.95 and at 5mm: p (5)/1.05=28.75 so the CBR index=29.95.

CBR index at 95% of the OPM (soil + 5% fiber) =19.65%.

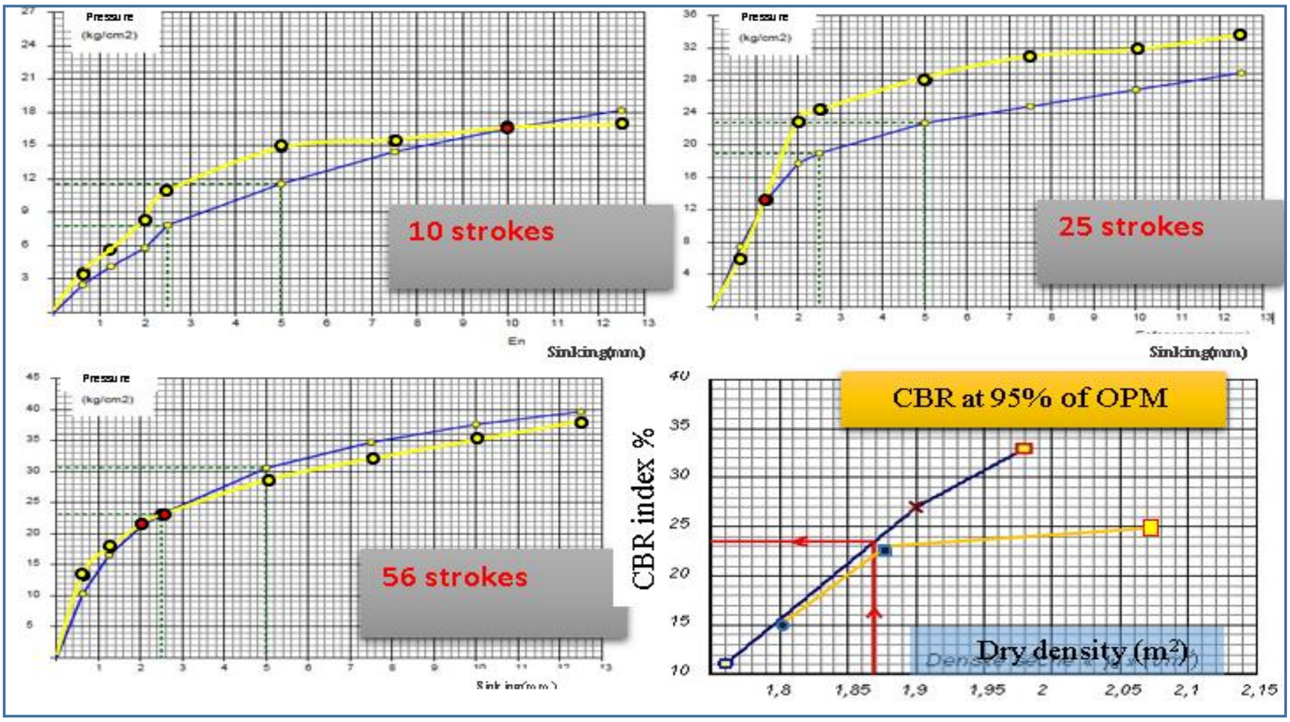


Figure IV.3: Immediate CBR curves (10-25 and 56 strokes) of the soil reinforced with (3%) Alfa/date

- **Case of date palm fiber (soil + 7% fiber) :**

- **10 strokes**

At 2.5mm: p (2.5)/0.7=11.08 and at 5mm: p (5)/1.05=11.03 so the CBR index=11.08.

- **25 strokes**

At 2.5mm: p (2.5)/0.7=27.05 and at 5mm: p (5)/1.05=21.64 so the CBR index=27.05.

- **56 strokes**

At 2.5mm: p (2.5)/0.7=32.90 and at 5mm: p (5)/1.05=29.13 so the CBR index=32.90.

CBR index at 95% of the OPM (soil + 7% fiber) =23.50%.

- **Case of halfa fiber (soil + 7% fiber) :**

- **10 strokes**

At 2.5mm: p (2.5)/0.7=9.95 and at 5mm: p (5)/1.05=9.05 so the CBR index=9.95.

- **25 strokes**

At 2.5mm: p (2.5)/0.7=17.62 and at 5mm: p (5)/1.05=13.37 so the CBR index=17.62.

- **56 strokes**

At 2.5mm: p (2.5)/0.7=19.41 and at 5mm: p (5)/1.05=15.75 so the CBR index=19.41.

CBR index at 95% of the OPM (soil + 7% fiber) =19.94%.

- **NB**:

Through the results obtained from the CBR test, and by comparing the curves related to the two soil samples with different concentrations of halfa and date palm fibers, we found that the date palm fiber gave better results than the halfa fiber.

IV.2. 2 Direct shear test (date palm/halfa %)

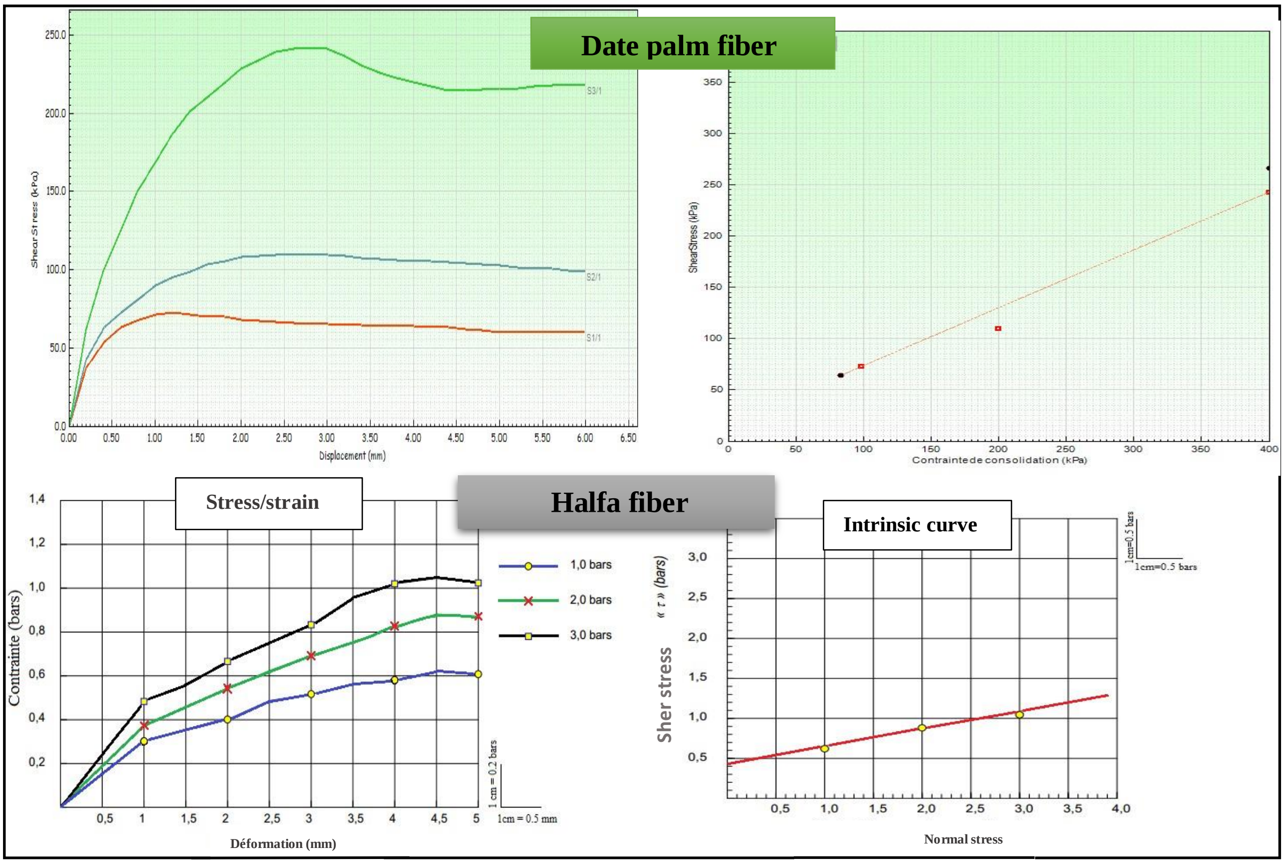


Figure IV.4 Stress – strain and intrinsic curves of the shear test (soil + 3% fiber)

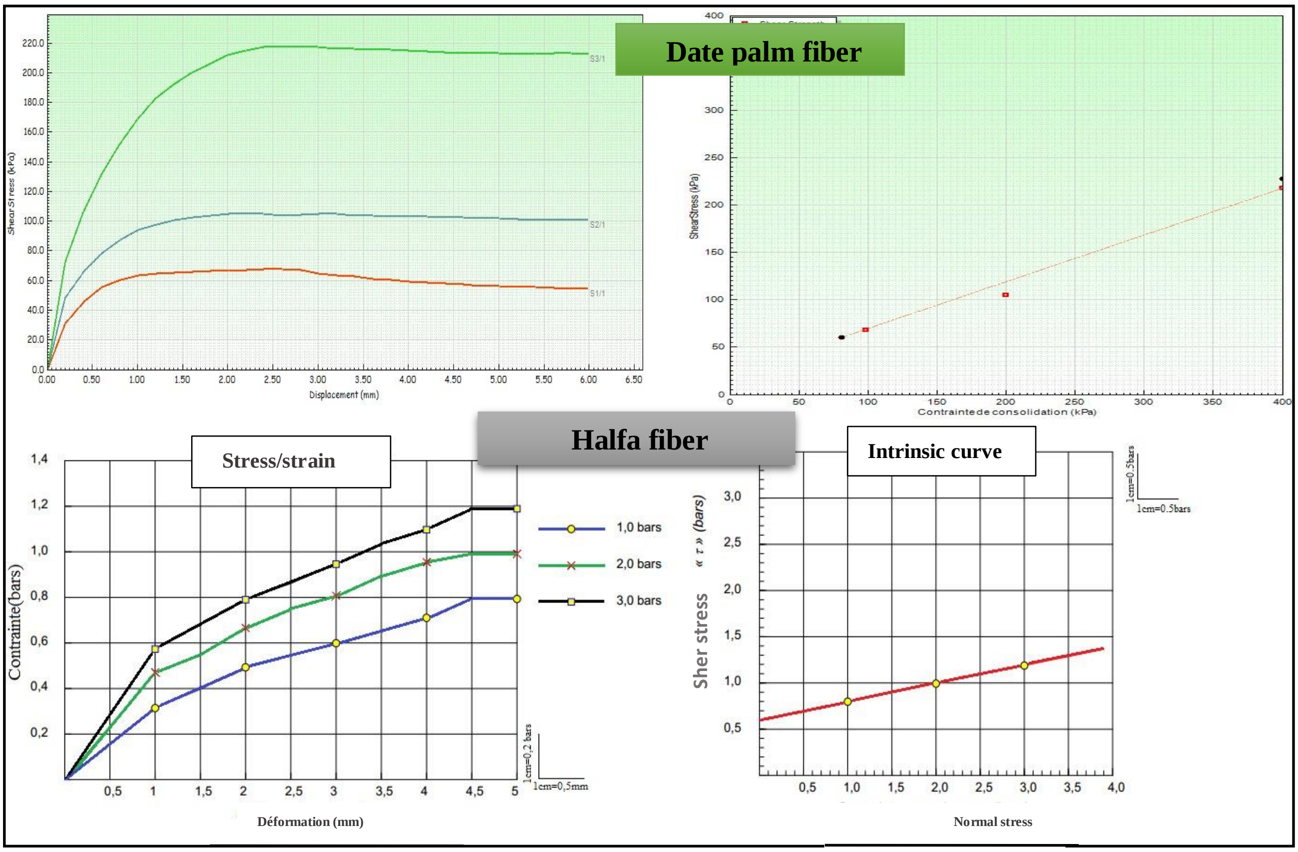


Figure IV.5 Stress – strain and intrinsic curves of the shear test (soil + 5% fiber)

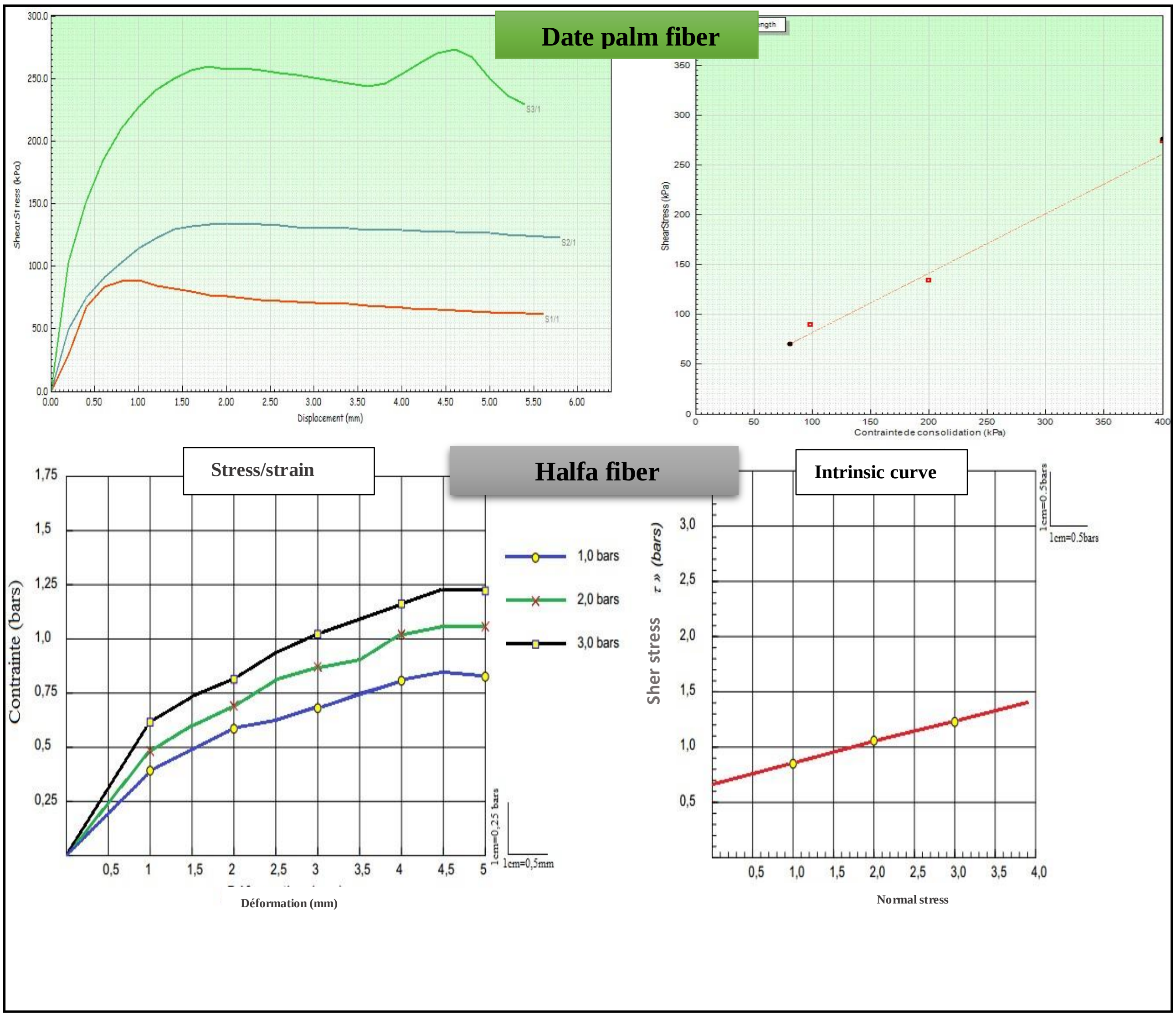


Figure IV.6 Stress – strain and intrinsic curves of the shear test (soil + 7%fiber)

- **NB:**

Through the previous curves, we can obtain the value of cohesion and the angle of friction.

We noticed that the halfa fiber, with different concentrations, especially 5% and 7%, is better than palm fiber in terms of cohesion, on the other hand the date palm fiber showed good results in the values of the friction angle also in concentrations 5% and 7%.

The results are in the following table.

Table IV.1: Comparison of the direct shear test between Halfa and Date palm fibers

Tests %	3% date	3%halfa	5% date	5%halfa	7% date	7%halfa
C (kpa) ϕ (Deg)	6.93 29.3	44 12.27	20.34 26.3	60 11.06	22.34 30.8	67 10.73
Direct shear DS	-halfa better than Date palm in cohesion - date palm better than halfa in the friction angle		-halfa better than Date palm in cohesion -date palm better than halfa in the friction angle		-halfa better than Date palm in cohesion -date palm better than halfa in the friction angle	

IV.3 Final comparison

Based on a comparison of tests results between date fibers and half of different proportions (3%, 5% and 7%). the fibers showed a questionable improvement in the geotechnical properties of the soil in various aspects.

According to the comparison of immediate CBR test results (95% CBR of OPM). Date palm is better than halfa, which means that adding a date palm increases the bearing properties of the soil, so it is suitable for use in the capping layer.

In contrast, the soil with halfa showed better shear parameters than date palm especially the cohesion when comparing the results of the shear test. Which means that the soil treated with halfa is more resistant to shear forces, and that makes it suitable for use in backfill / cuttings.

IV.4 Conclusion

In this chapter, we conducted a comparison on the effect of fibers on the soil and how is it influencing geotechnical properties. Experiments have shown that these fibers have a reinforcing effect that increases with the increase in the concentration of the fiber.

The mixture of soil and fiber proves to be more effective than soil alone, by making soil-requiring treatment reused.

From the above, we found that date palm fiber is better than the halfa, and this is with regard to our study, as it can be used in the caping. In addition, we must not forget that each of the fibrils gave excellent results through which we can visualize the size of the benefit from using cheap plant fibers with high quality as an alternative solution.

General conclusion, Recommendations and Outlooks

1. General conclusion

Soil reinforcement is a technique for improving materials to make them suitable for use.

To treat the soil is to closely mixing it with a product, date palm or halfa fibers, in order to give it superior mechanical properties. It can improve many materials that in principle would not be usable, thus avoiding replacing the existing soil with noble materials that have become rare.

Our work is an experimental study of valuation of natural fibers in the reinforcement of the capping layer support soil.

represented in silty clay soil extracted as part of a project, “avoidance of the city of Boumerdès”; this research is to optimize the process of soil reinforcement by biomaterials (date palm and halfa fibers) to improve the mechanical and energy properties of the material.

Soil needs most of the time to stabilize to ensure the stability of Infrastructure such as roads, and to achieve this, the soil treated in ways to achieve the necessary properties that makes it durable.

Moreover, this is what our project carries, which allows the use of plant fibers that are chemically treated in an effective way and combine them with the soil to notice the difference between soils with weak properties.

A series of experiments in different proportions (3%, 5% and 7%), which clearly demonstrated the role of fibers in supporting the soil with mechanical properties, that improves as the percentage of fibers increases.

The results obtained from the experiments confirmed the possibility of using natural fibers to support the soil, and get rid of other materials, especially non-environmental and expensive chemicals.

to achieve a bio-economic balance, especially in Algeria that contains these renewable resources and open the way to encouraging innovative practical methods not only in the field of geotechnical, but also in other fields benefit from this modest research.

1. Recommendations

-It is recommended to use plant fibers especially halfa for its ability to resist shearing factors.

-It is recommended to use date palm to increases the bearing properties of the soil in the capping layer.

-Soil chemical analyzes are recommended in order to predict the appropriate chemical treatment of plant fiber.

3. Outlooks

- Study the sustainability of treatment under different severe environmental conditions and in the presence of chemical compounds.
- Studying the possibility of using halfa and palm fibers in one mixture to give better results.
- Due to severity of roads networks currently established in Algeria and their immense importance in building a strong Country we must be develope simple environmentally friendly Methods with fibers such as palm and halfa.
- This study may be an actual starting point to get out from traditional methods to a solution for a stable environment and a motive for developing geotechnical solutions with new ideas that will be a local resource base in the future.

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