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COMPACTION AND SHEAR STRENGTH PROPERTIES OF CLAY BLENDED WITH GAZİANTEP INDUSTRIAL REGION WASTEWATER COMPOSTED SLUDGE

M. Sc. THESIS
IN
CIVIL ENGINEERING

BY
MEHMET SERKAN GİRİŞKEN
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GAZİANTEP ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

GAZİANTEP O.S.B. ATIK SUYUNDAN KOMPOSTLAŞTIRILARAK ELDE EDİLEN ATIK MADDE ile KİL KARIŞIMININ KESME ve SIKIŞTIRMA MUKAVEMETİ PARAMETRELERİ

İNŞAAT MÜHENDİSLİĞİ
YÜKSEK LİSANS TEZİ

MEHMET SERKAN GİRİŞKEN
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Compaction and Shear Strength Properties of Clay Blended With Gaziantep Industrial Region Wastewater Composted Sludge

M.Sc. Thesis
in
Civil Engineering
University of Gaziantep

Supervisor
Assist. Prof. Dr. Hamza GÜLLÜ

by

Mehmet Serkan GİRİŞKEN

Ağustos 2010

Gaziantep O.S.B. Atık Suyundan Kompostlaştırılarak Elde Edilen Atık Madde İle Kil Karışımının Kesme ve Sıkıştırma Mukavemeti Parametreleri

Gaziantep Üniversitesi
İnşaat Mühendisliği
M.Sc. Tezi

Danışman
Yrd. Doç. Dr. Hamza GÜLLÜ

Mehmet Serkan GİRİŞKEN
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ABSTRACT

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GİRİŞKEN, Mehmet Serkan
M.Sc. in Civil Eng.
Supervisor: Assist. Prof. Dr. Hamza GÜLLÜ

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In this thesis, compaction and shear strength properties of this region`s clay in case of interaction with some additives was studied. This additive material subjected in this thesis was soil of Gaziantep industrial region wastewater treatment plant`s composted sludge. This additive was mixed with predefined ratios. These ratios are:

- 100% for Atterberg Limit Test
- 100% for Specific Gravity Test
- 0% - 5% - 10% - 20% - 30% - 40% - 50% - 60% - 100% for Direct Shear Test,
- 0% - 5% - 10% - 20% - 30% - 40% - 50% - 60% - 70% - 80% - 100% for Unconfined Compressive Test,
- 0% - 5% - 10% - 20% - 30% - 40% - 50% - 60% - 70% - 80% - 100% for Standard Proctor Test.

ASTM (American Society for Testing and Materials) international standards are occurred during the test procedures. According to the test results, some changes has been observed on bearing capacity of soils, water absorption so water content of new soil mixture, also index parameters.

Key Words: Industrial region wastewater, composted sludge, compaction, direct shear, unconfined compressive strength

ÖZET

GAZİANTEP O.S.B. ATIK SUYUNDAN KOMPOSTLAŞTIRILARAK ELDE EDİLEN ATIK MADDE İLE KİL KARIŞIMININ KESME VE SIKIŞTIRMA MUKAVEMETİ PARAMETRELERİ

GİRİŞKEN, Mehmet Serkan
Yüksek Lisans Tezi, İnş Müh. Bölümü
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Bu tezde, Gaziantep bölgesindeki karakteristik kil zemin ile organize sanayi bölgesi arıtma tesisinde yapılan kompostlaştırma işlemi sonrası çıkan atık malzemenin, killi zemin ile karıştırılması ile elde edilen yeni zeminde sıkıştırma ve kesme kuvvetlerine karşı oluşan yeni parametreler gözlenmiştir. Karışımlar değişik yüzdelerde her deney için farklı olarak ele alınmıştır. Bu yüzdeler şöyledir:

- Atterberg limit deneyleri için %100,
- Özgül ağırlık deneyleri için %100,
- Standart proktor deneyi için %0 - %5 - %10 - %20 - %30 - %40 - %50 - %60 - %70 - %80 - %100
- Serbest basınç deneyi için %0 - %5 - %10 - %20 - %30 - %40 - %50 - %60 - %70 - %80 - %100
- Kesme kutusu deneyleri için %0 - %5 - %10 - %20 - %30 - %40 - %50 - %60 - %100

İlgili deneylerin tamamı ASTM (Amerikan Malzeme ve Test Derneği) standartları referans alınarak yapılmıştır. Yapılan deneyler sonucunda elde edilen verilere göre yeni zeminin taşıma kapasitesi, kesme kuvvetine karşı direnci, su emme oranları, su muhtevaları ve indeks parametrelerinde değişiklikler gözlenmiştir.

Anahtar Kelimeler: Organize sanayi atık su, kompostlaştırılmış çamur, sıkıştırma, kesme kutusu deneyi, serbest basınç deneyi

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CONTENTS

LIST OF FIGURE

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Nowadays, the discussion in environmental impact is widespread in every field of study because the environment problems exist in all parts of the world and become more serious in the future. In today's construction world of the environmental remediation market, meeting the project specifications typically involves modifying the physical properties of the soil. In many instances, this is also true of the geotechnical construction market. Techniques and equipments used for environmental work can, therefore, often be applied to solve geotechnical problems. Extensive urbanization and industrialization in low land and coastal regions of many countries have required improving very soft ground in its shear strength and compressibility as to handle its stability and settlement problems.

One of strategies to reduce environmental problems in geotechnical base is to reuse waste materials from industrials or construction materials as backfill materials, sub grade, sub base, and stabilizer. Utilization of these waste materials has the twofold benefit of conserving natural resources and disposing of the waste materials. In-situ soil modification / stabilization technique improve the bearing capacity of the soil to allow foundation construction.

1.2 Purpose of The Thesis

The use of waste products in modification of the granular soils in order to remove some environmental problems and create new useful findings in the field of engineering. In geotechnical engineering, soft ground problems concerning to low shear strength and high compressibility are solved by means of ground improvement. In geo-environmental aspect, the application in ground improvement is generally adopted for stabilization of waste materials.

CHAPTER 2

LITERATURE SURVEY

2.1 General

The effect of wastewater composted sludge on clay or soil was investigated in few articles. Recycling of wastewater, types of recycling wastewater, effects of sludge on environment or land are mentioned briefly. Unfortunately, because this is not a well known subject, or not a well studied subject earlier there is not much article or thesis published in common. There was so limited written or published source that could be used as reference studies.

2.2 Wastewater Composted Sludge

Application of sludge from urban wastewater treatment plants in road's embankments was studied [1]. In that study, different kinds of compost have been tested for highway revegetation; sewage sludge has only been used for agricultural purposes. The aim of the study is to prevent slope degradation taking to erosion on road embankments. The most important factor that influences erosion is cover crop [2, 3]. Vegetation has several favorable effects to protect slopes from erosion. Cover crop blocks and retains water coming from rainfall and splash erosion decreases. The infiltration rate is greater in soils with plants than in soils without them [4]. These effects, together with evapo-transpiration, permit the reduction of free water on the surface and, therefore, protecting the slope from surface runoff.

Other effects include: modification of natural properties and soil fastening thanks to the roots, which create an intimately linked fiber frame, protection from traffic, and isolation, because a microclimate that reduces temperature and humidity variations is created on the soil surface. Thus, there is a decrease in the natural weathering process. So plants have a very important role in erosion control and slope stabilization. However, the characteristics of the embankments are not usually suitable for plants since materials are basically selected according to their resistance characteristics. Some of wastes are used in this study. These are already been accepted in engineering [5, 6]. These wastes are industrial waste which are thermal power station ashes, iron and steel industry ashes and mine dead, mainly from coal. Urban wastes which are urban incinerator ashes, used tires, demolition wastes, used engine oils, waste plastic and glass and organic waste which is olive vegetable waters.

In the study [1], that was a different view that effects wastewater on soil or land. In this study, wastewater compost is used for planting some plants and investigating whether it prevents erosion or not. The experiment they made was carried out in a semi-arid environment, which is characterized by high climate erosive – little but intense rainfall – and limited vegetation, where erosion processes make a big impact. A highway embankment in the Waste Recycling and Composting Plant of G´ador (Almeria, South of Spain) was selected [1].

Due to the innovation of this application, there is no specific set of regulations to date. Heavy metals content just as microbiological parameters for the used sludge in the research are in accordance with the agriculture legislation that is currently in force or as a draft, and that should be more restrictive for that area than for the proposed use in this research. Therefore, it can be concluded that this application does not represent any threat to public health [1].

Municipal and industrial solid waste and sewage sludge produced wastewater treatment systems caused significant environmental problems. This waste is usually removed and /

or can be evaluated with four methods. These are landfills, incineration, composting and sea-discharge.Sea-discharge and partly landfills is not used because of pollution, none formation and transformation [1]. In recent years, more and more sewage sludge produced from wastewater treatment plants were beneficially used instead of land filling, ocean dumping or incineration (Stukenberg et at., 1993). In 1998, about 41%of the sewage sludge produced was applied to the land (USEPA, 1999). It is expected that this proportion will increase to 48% in 2010. By definition, land application involves the spreading of bio-solids or the sewage sludge further treated by aerobic/anaerobic digestion, composting or alkaline stabilization on the soil surface or injecting bio-solids into the soil (Epstein, 2003).

Composting is a method of sludge stabilization in which sludge organics are decomposed by microorganisms in the presence of oxygen. The result of sludge composting is the production of a stabilized, humus-like product can be used, for example, as a soil amendment, for erosion control, as mulch or other soil-like products. Composting is dependent on several operational parameters, which include oxygen availability within the compost, moisture content, temperature, and biodegradable volatile solids content of the compost.

As a result, until now, sludge was never considered as material for road construction. Nevertheless, this research shows that the application of these bio-solids in roads embankments increases cover crop with low seed dosages a high cover crop can be achieved. This increase in cover crop has a direct effect in erosion reduction in the embankments and therefore in the environmental impacts caused by the roads construction. Given the positive results obtained, the use of sewage sludge in road embankments must be encouraged. The treatment cost without vegetal species is very low, and application of bio-solids should be imposed by including them in construction projects. This would also imply more durable roads with higher landscape value and less soil loss.

2.2.1 Land Application of Sewage Sludge – Benefits and Concerns

Sewage sludge is a solid, semi-solid, or liquid residue generated during treatment of domestic sewage in a treatment works. It consists of 90 to 99 per cent water and an accumulation of settle able solids, mainly organic that are removed during primary, secondary or advanced wastewater treatment processes but does not include grit and screenings. Sewage sludge contains significant amounts of nitrogen and phosphorus, two of the essential plant nutrients, as well as lesser quantities of heavy metals such as copper and zinc. Sewage sludge is a potential source of nitrogen and phosphorus for use in crop production. The application of sewage sludge at a controlled rate can improve the physical and chemical properties of soils because sludge typically possesses excellent soil amendment properties.

Sewage sludge also contains constituents that may pose a risk to soil, water, plants, animals or public health. The same constituents in sludge that benefit the soil and crops may also produce detrimental effects if they are applied at excessive rates or under improper conditions. Pathogenic organisms, heavy metals, soluble salts and other trace constituents present in sewage sludge pose serious concerns. Sewage sludge containing pathogenic organisms should be handled and applied in a proper manner to reduce the risks to human and animal health. Pathogens are destroyed over a period of time at a rate that is dependent on the environmental conditions to which they are exposed. By waiting the appropriate length of time after the sludge has been applied before working the land or planting and harvesting a crop, the risks can be reduced.

For land application permissions are required. A permit to construct, extend or alter municipal sewage sludge application works must be obtained from Saskatchewan Environment (SE) before starting construction of such works. A Permit to Operate Sewage Works EPB 294 that includes approval to land apply sewage sludge, must be obtained from SE prior to commissioning and operation. Applications for a Permit to Construct and/or Operate Sewage.

Works EPB 268 is required to be made on prescribed forms obtained from SE. The following additional information will be required to supplement the application:

• Legal description of the land to be used for municipal sewage sludge application, together with plans showing topography, watercourses, general soils classification, water wells within one kilometer radius of the land, residences and other buildings;

• Representative analyses of municipal sewage sludge that is produced at the sewage treatment facility and a summary of the analytical results in comparison to the criteria specified in this guideline;

• Details about sewage sludge stabilization methods and results of sludge analysis;

• The quantity of sewage sludge that will be applied onto the land and application rate;

• Representative chemical and physical descriptions of the soil that will receive sewage sludge;

• Data on water table locations, together with any available information (such as flow and usage) on underlying aquifers;

• The proposed use of municipal sewage sludge including intended crops, application system description and any special management/operation considerations;

•A copy of land control agreements, if applicable;

•contingency plans including details about storage facilities or alternate methods when sewage sludge application is not possible at certain instances and remedial measures to be taken in the event of any emergency situations; and

•The results of hydro geological investigation where one is considered necessary.

The water table in the sewage sludge application area should be sufficiently deep to prevent water table rise to the root of the plants. Use of land for sewage sludge application overlying shallow aquifers utilized for water supplies should be avoided. [2]

2.2.1.1 Example Application: Road Embankments with Wastewater Treatment Plants

The World Commission on Environment and Development published the Brundtland Report in 1987. This document expressed the necessity to promote a sustainable development adapted to an ecological point of view. Since then, the European Union (EU) includes this topic in all of its policies, regulations and documents [3].
The White Paper on the European Transport Policy for 2010, time to decide highlighted the need to develop a sustainable transport. From this point of view, one of the main environmental impacts caused by road construction is slope degradation taking to erosion on road embankments [4]. The most important factor that influences erosion is cover crop [5].

Highway planning and project design of roads embankments and other linear engineering projects are no longer limited by the traditional problems of stability. Nowadays landscape integration, vegetation recovery and reduction of soil loss caused by erosion are parameters which are as important as geotechnical ones. Vegetation has several favorable effects to protect slopes from erosion. Cover crop blocks and retains water coming from rainfall and splash erosion decreases. The infiltration rate is greater in soils with plants than in soils without them [6]. These effects, together with evapo-transpiration permit the reduction of free water on the surface and, therefore, protecting the slope from surface runoff. Other effects include: modification of natural properties and oil fastening thanks to the roots, which create an intimately linked fibre frame, protection from traffic, and isolation, because a microclimate that reduces temperature and humidity variations is created on the soil surface. Thus, there is a decrease in the natural weathering process. So plants have a very important role in erosion control and slope stabilization. However, the characteristics of the embankment are not usually suitable for plants since materials are basically selected according to their resistance characteristics.

On the other hand, humans generate so much waste and so many by-products. Traditional solutions in waste management such as dumping sites or incineration are questioned for several reasons [7]: dumping sites are dangerous because they can affect subsoil water and incineration is an emission source and it is very pollutant in some cases. Therefore, these waste management measures are being restricted by EU directives. These measures have prompted the research for new environmental solutions in the EU even although the society may incur some recycling costs. EU has been working towards recycling materials on highways construction for a number of years. Clients should accept recycled materials in civil engineering as long as their characteristics are the same as those of conventional ones [8]. They should be non-volatile, volumetrically stable and non-noxious leached.

Many products have been researched and some of them have already been accepted in engineering,

- Road building waste: materials from road surface layers, quarry oversize and from mineral dust of bituminous mixture factories.
- Industrial waste: thermal power station ashes, iron and steel industry ashes and mine dead, mainly from coal.
- Urban waste: urban incinerator ashes, used tires, demolition wastes, used engine oils, waste plastic and glass.
- Organic waste: olive vegetable waters.

The waste management problems are becoming worse in town environments because of building up of urban areas. Obligatory by-products are generated in treatment lines, but they are not reused, such as sludge and compost. These by-products are the result of operational wastewater treatment plants and recycling and composting plants all over the world. Both of these problems (erosion in road embankments and urban waste management) seem to be unrelated but, if fertilizing capacity of by-products [9] and the need to improve the agronomic properties of highway embankments materials are considered together, it show up that they are related and their combination could solve partially both problems. Waste fertilization capacity helps cover crop growth and it reduces erosion. Thanks to this new point of view urban waste management could have roads as one of their major customers. This new domain has been barely analyzed before. Recently some literature has appeared in relation to the environmental effects of applying urban wastes to highway embankments [10], but further work need to be done.

This application was designed to study the viability of sludge use for revegetating highway embankments. So, the main raised objectives were the following:

A) To assess the plant growth and analyze the technical and economic viability.
B) Study of the influence of design parameters on embankments following revegetation criteria, not only mechanics criteria.
C) To establish the benefits obtained due to soil fixation, assessing erosion.
In this application, different kinds of compost have been tested for highway revegetation, sewage sludge has only been used for agricultural purposes and its application for helping vegetation establishment on roads embankments is studied. Testing areas measuring 4×5m were constructed on a new highway embankment in an arid location. Several variables are analyzed: side slope, sludge dosage, vegetative species.

Until this application, sludge was never considered as material for road construction. Nevertheless, this research shows that the application of these bio solids in roads embankments increases cover crop. With low seed dosages a high cover crop can be achieved.

This increase in cover crop has a direct effect in erosion reduction in the embankments and therefore in the environmental impacts caused by the roads construction.
In this application, positive results obtained and according to these positive results obtained, the use of sewage sludge in road embankments must be encouraged. The treatment cost without vegetal species is very low, and application of bio solids should

be imposed by including them in construction projects. This would also imply more durable roads with higher landscape value and less soil loss.

Due to the innovation of this application, there is no specific set of regulations to date. Heavy metals content just as microbiological parameters for the used sludge in the research are in accordance with the agriculture legislation that is currently in force or as a draft, and that should be more restrictive for that area than for the proposed use in this research. Therefore, it can be concluded that this application does not represent any threat to public health.

In this research dehydrated sludge has been used, which has seriously incremented manipulation costs. It has been estimated than the use of liquid sludge could be more efficient, even although transportation costs are higher, since manipulation and irrigation costs would be lower and there is no dehydration cost.

CHAPTER 3

MATERIALS AND METHOD

3.1 Materials

3.1.1 Clay

Clay is a naturally occurring material composed primarily of fine-grained minerals. Clay deposits are mostly composed of clay minerals, a subtype of phyllosilicate minerals, which impart plasticity and harden when fired or dried; they also may contain variable amounts of water trapped in the mineral structure by polar attraction. Organic materials which do not impart plasticity may also be a part of clay deposits.

3.1.1.1 Physical Properties

According to the test results, which will be explained with details later on the thesis report, the Gaziantep clay which we took as reference has physical features below;

Table 3.1 Specific gravity of Gaziantep clay

mass of soil	56.53 g
mass of pycnometer	109.50 g
mass of pycnometer + water	241.30 g
mass of pycnometer + water + clay	275.13 g
mass of pycnometer + clay	167.68 g
Gs =	**2.49**

Table 3.2 Atterberg Limits of Gaziantep clay

	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage limit
Clay	29 %	26 %	3	2 %

3.1.2 Gaziantep Industrial Region Wastewater Composted Sludge

3.1.2.1 Physical Properties

The color of Gaziantep Industrial Region wastewater compost is dark brown and black. Because of used wood chips in composting process, the color can change. If solid waste is composted well, the compost is odorless. Also specific gravity of Soil of Gaziantep Industrial Region wastewater compost is important as physical properties.

Table 3.3 Specific gravity of soil of industrial region waste water composted sludge

mass of soil	42.31 g
mass of pycnometer	109.50 g
mass of pycnometer + water	241.30 g
mass of pycnometer + water + compost	255.67 g
mass of pycnometer + compost	152.27 g
Gs =	**1,51**

Table 3.4 Atterberg limits of wastewater composted sludge

	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage limit
Composted sludge	29 %	-	-	0.3 %

3.1.2.2 Chemical Properties

The results of analysis of wastewater compost that have been brought from of Gaziantep Industrial Region for the experiments are given in table 3.5,

Table 3.5 Chemical analysis report of wastewater composted sludge

Parameters		**Gaziantep Industrial Region Wastewater Composted Sludge**
Chloride	(mg/l)	131,5
Fluoride	(mg/l)	0,48
Sulphate	(mg/l)	3,57
Dissolved organic carbon	(mg/l)	40,07
Total dissolved solid	(mg/l)	699
Phenols	(mg/l)	< 0,07
Total organic carbon	(mg/kg)	267388
BTEX(benzene,toluene,ethyl benzene,xylenes)	(mg/kg)	< 0,05
PCBs	(mg/kg)	< 0,01
Mineral Oil	(mg/kg)	41,28
Loss on ignition	(%)	39,56
Arsenic (As)	(mg/l)	< 0,005
Barium (Ba)	(mg/l)	0,092
Crom (Cr)	(mg/l)	< 0,0005
Copper (Cu)	(mg/l)	0,004
Mercury (Hg)	(mg/l)	< 0,0005
Molybdenum (Mo)	(mg/l)	0,032
Nickel (Ni)	(mg/l)	< 0,005
Plumbum (Pb)	(mg/l)	< 0,01
Antimony (Sb)	(mg/l)	< 0,001
Selenium (Se)	(mg/l)	< 0,002
Zinc (Zn)	(mg/l)	0,118

3.2 METHODS

3.2.1 Atterberg Limit Test

The objective of the Atterberg limits test is to obtain basic index information about the soil used to estimate strength and settlement characteristics. It is the primary form of classification for cohesive soils.

Fine-grained soil is tested to determine the liquid and plastic limits, which are moisture contents that define boundaries between material consistency states. These standardized tests produce comparable numbers used for soil identification, classification and correlations to strength.

The liquid (LL) and plastic (PL) limits define the water content boundaries between non-plastic, plastic and viscous fluid states. The plasticity index (PI) defines the complete range of plastic state. Figure 4.1 illustrates it nicely.

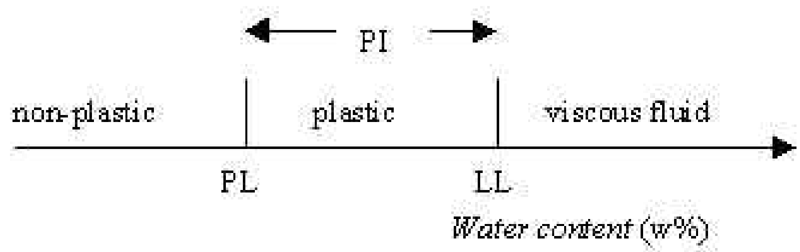


Figure 3.1 Atterberg limits illustration

In these tests ASTM D4318, AASHTO T89 and AASHTO T90 international standards are used.

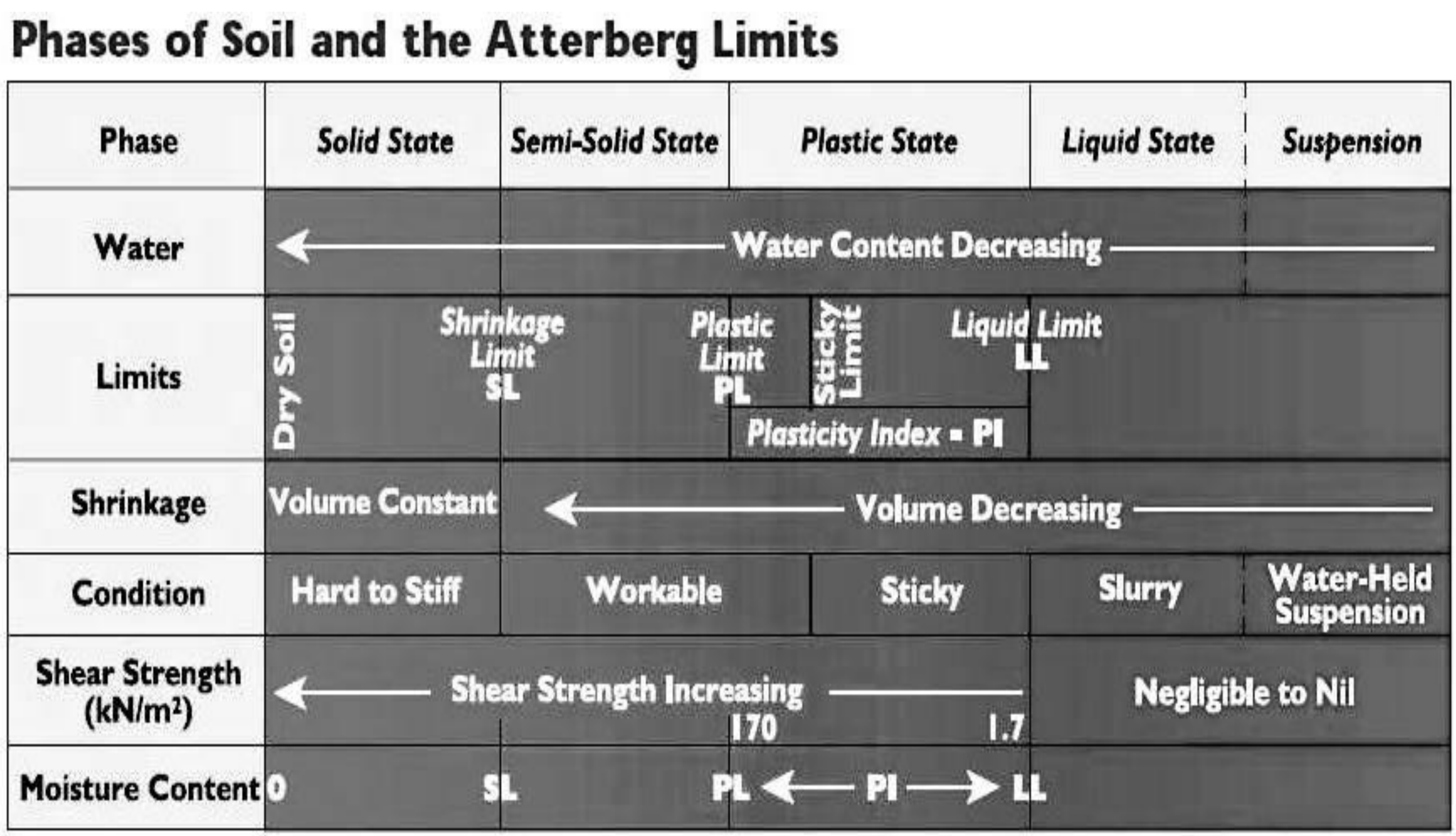


Figure 3.2 Phases between Atterberg limits

3.2.1.1 Liquid limit (LL)

The liquid limit defines the boundary between plastic and viscous fluid states. It is determined using a standard "Liquid Limit Device," which drops a shallow cupfull of soil 1 cm consistently. When a groove cut through the sample closes 1/2", the number of drops is recorded and a moisture content sample processed.

Repeating the procedure for a total of four drop-count ranges provides enough data to plot on a semi-log scale. From the plot, the moisture content at 25 drops defines the Liquid Limit.

Procedure of liquid limit test is that firstly, it must be verified that the limit device cup falls 1 cm and the block at the end of the grooving tool handle is a 1 cm gage. Then, 1 cm block edge is placed at the worn spot on the base and the handle is rotated because there should be no discernible click or bump of the cup. These stages are for preparing the equipment.

The stages of liquid test are that firstly, approximately 100 grams of soil in the mixing bowl (not on the LL device) is placed and thoroughly mix and this soil should pass a #40 sieve. Secondly, the soil is smoothed to a uniform thickness in the cup (like how water would level). Then a groove in the soil is cut carefully cut from back to front using the grooving tool. It is important that the tool is held perpendicular to the inside surface of the cup, beveled edge toward the front and the groove is no wider than the tool, especially if several passes are made. After that, the crank is turned at 120 rpm until the bottom of the groove closes 1/2 inch. If the drop count is between 30 and 35, return the sample to the mixing bowl, remix and repeat test. If drop count < 30, return the sample to the mixing bowl and dry with paper towels, lamp or fan. If drop count > 35, return the sample to the mixing bowl and add a little water. After the acceptable results the number of drops is recorded and a water content determination (microwave) is made with approx. 5 g of soil from the point where the groove closed. Then, the rest of the sample to the mixing bowl is returned and a little water is added. Finally, test is repeated for the rest of the drop count ranges indicated.

To determine the liquid limit, values of water content (W) and log (number #of drops) are plotted and from the plot, water content at 25 drops is the liquid limit.

3.2.1.2 Plastic Limit (PL)

The plastic limit (PL) defines the boundary between non-plastic and plastic states. It is determined simply by rolling a thread of soil and adjusting the moisture content until it breaks at 1/8 inch diameter.

Procedure of plastic limit test is that firstly, a small specimen of the soil is rolled on the glass plate to form a thread using the palm of your hand. Second, the soil is attempted to roll to 1/8 inch diameter. If the thread breaks larger than 1/8in., a small amount of water is added, mixed thoroughly and tried again. Then, the soil is rolled to 1/8 in. diameter. If it does not break, it is kneaded in your hands and tried again. If it breaks or falls apart, it is delaminated as a tube, or formed small barrels. After that, the entire thread is placed in the moisture content can and the cover is closed. Then, the steps that he soil is attempted to roll to 1/8 inch diameter and the soil is rolled to 1/8 in. diameter are repeated for two more trials. All the threads are added to the same moisture content can. Finally, the moisture content is determined (microwave).

To calculate the plasticity index (PI), liquid limit is reduced by plastic limit (PL).

3.2.1.3 Plasticity Index (PI)

It is simply the numerical difference between the liquid limit and the plastic limit for a particular material and indicates the magnitude of the range of moisture content over which the soil remains plastic. It is a measure of the cohesive qualities of the binder resulting from the clay content. Also, it gives some indication of the amount of swelling and shrinkage that will result in the wetting and drying of that fraction tested. If some soils do not have sufficient mechanical interlock they require amounts of cohesive materials to give a satisfactory performance. A deficiency of clay binder may cause raveling of gravel wearing courses during dry weather and excessive permeability.

While an excess of clay has previously been regarded as a dilution of strength, the use of Endurazyme allows the use of these high plastic materials without any dilution of pavement performance.

3.2.1.4 Linear Shrinkage Limit (SL)

The linear shrinkage of a soil for the moisture content equivalent to the liquid limit, is the decrease in one dimension, expressed as a percentage of the original dimension of the soil mass, when the moisture content is reduced from the liquid limit to an oven-dry state. This test method covers the determination of the amount of linear shrinkage and other changes that occur when a preformed thermal insulating material is exposed to soaking heat. This test method is limited to preformed high-temperature insulation that is applicable to hot-side temperatures in excess of 200°F (93°C).

By riffling or quartering, a sample of about 300 g of the material obtained that passed the No 36 B.S. sieve (0.425 mm) prepared according with the procedure for the preparation of disturbed soil samples for testing. This sample is placed in the mixing bowl and thoroughly mixed with de-ionized water using the spatula, until the mass becomes a thick homogeneous paste. Enough water is added to bring it to a consistency equal to or slightly wetter than the liquid limit. When the sample is tested in the liquid limit machine, the groove should close with between 15 and 25 blows.

The inside is greased until it become a clean shrinkage mould. The wet soil is placed in the mould, taking care to thoroughly remove all air bubbles from each layer by lightly tapping the base of the mould. The mould is slightly overfilled and then level off the excess material with the spatula. All soil is removed which adheres to the rim of the mould. The specimen is then allowed to dry at room temperature for about 24 hours until a distinct change in color can be noticed. Transfer into an oven and dry at between 105 °C and 110 °C. After that, the specimen is left to cool and then measure its longitudinal shrinkage L_s to the nearest millimeter. If the specimen get cracks into pieces, it should be hold the separate parts together and then measuring the shrinkage Ls. If the specimen would curl in the mould, it would then be removed carefully and measure the length of the top and bottom surfaces. The mean of these two lengths is subtracted from the internal length of the mould to obtain the shrinkage.

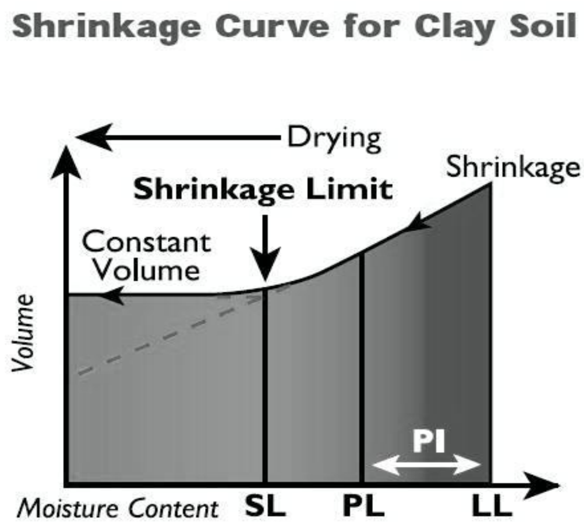


Figure 3.3 Linear shrinkage limit curve

3.2.2 Specific Gravity

It is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material. Specific gravity usually means relative density with respect to water. The term "relative density" is often preferred in modern scientific usage.

If a substance's relative density is less than one then it is less dense than the reference; if greater than 1 then it is denser than the reference. If the relative density is exactly 1 then the densities are equal; that is, equal volumes of the two substances have the same mass. If the reference material is water then a substance with a relative density (or specific gravity) less than 1 will float in water. For example, an ice cube, with a relative density of about 0.91, will float. A substance with a relative density greater than 1 will sink.

Temperature and pressure must be specified for both the sample and the reference. Pressure is nearly always 1 atm equal to 101.325 kPa. Where it is not, it is more usual to specify the density directly. Temperatures for both sample and reference vary from industry to industry.

3.2.3 Standard Proctor Compaction Test

Standard compaction proctor test determines of maximum dry unit weight which can be used for specification of field compaction and determines relationship between the moisture content and density of soils. The test consists of compacting the soil or aggregate to be tested into a standard mould using a standardized compactive energy at several different levels of moisture content. The maximum dry density and optimum moisture content is determined from the results of the test.

Soil in place is tested for in-place dry bulk density, and the result is divided by the maximum dry density to obtain a relative compaction for the soil in place.

In this test ASTM D698 / AASHTO T99 international standards are used.

Procedure of standard compaction proctor test is that firstly, approximately 10 lb (4,5 kg) of soil breaking all the lumps and passing No. 4 sieve is obtained and approximate amount of water is added to increase the moisture content by about 5%. Second, the weight of empty proctor mould without the base plate and collar are determined. Then, the collar and base plate are fixed and the soil is distributed into three equal parts. The first part is placed in the Proctor mould and compact the layer giving 25 blows. The layer is scratched with a spatula forming a grid to ensure uniformity in distribution of compaction energy to the subsequent layer the other parts are placed and the two steps that are mentioned before are repeated. The final layer should ensure that the compacted soil is just above the rim of the compaction mould when the collar is still attached. After that, the collar is detached without disturbing the compacted soil inside the mould and using a straight edge trim the excess soil leveling to the mould. The weight of the mould with the moist soil is determined.

The sample is extruded and broken to collect the sample for water content determination preferably from the middle of the specimen. Then, an empty moisture can is weighed and the moist soil obtained from the extruded sample is weighed again. This can is kept in the oven for water content determination. The rest of the compacted soil is broken with hand and more water is added to increase the moisture content by 2%. After this, all steps are repeated and during these processes the weight of the mould with the moist soil increases for some time with the increase in moisture and drops suddenly.

Finally, two moisture increments are taken after the weights starts reducing. At least five or six points are obtained to plot the dry unit, moisture content variation (for example Figure4.4).

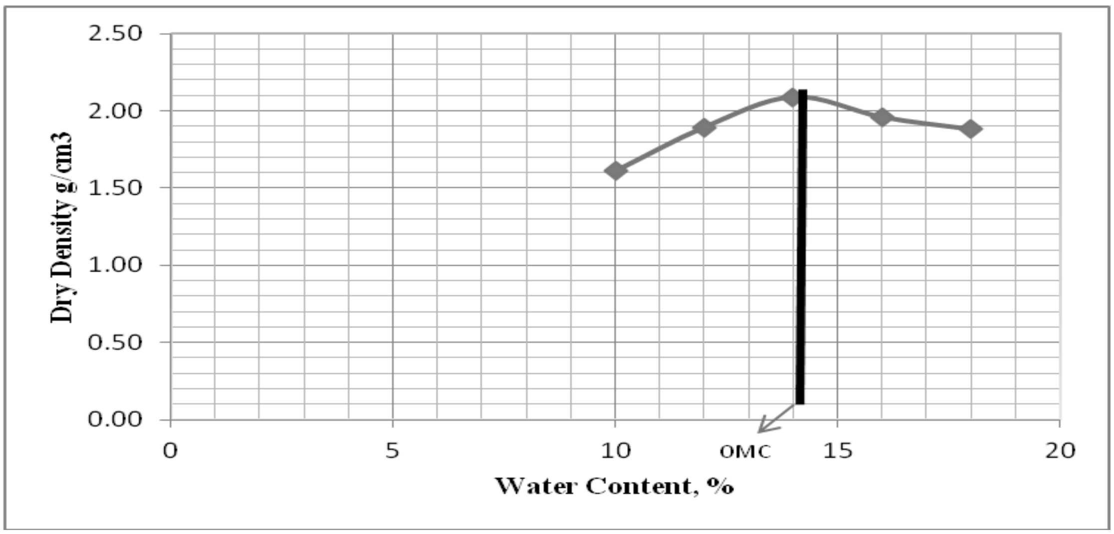


Figure 3.4 Optimum Moisture Content

3.2.4 Unconfined Compression (UC) Test

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the unconfined compressive strength is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

In this test ASTM D 2166 international standards are used.

Procedure of this test is that firstly, the soil sample from Shelby tube sampler is extruded. A soil specimen is cut so that the ratio (H/d) is approximately between 2 and 2.5. (H, the length of soil specimen - d, diameter of soil specimen).

Second, the exact diameter of the top of the specimen is measured at three locations 120^o apart, and then the same measurements on the bottom of the specimen are made. The measurements are averaged and recorded the average as the diameter.

Then, the sample weighed and the mass is recorded on the data sheet.

After that, the deformation (△H) corresponding to 15% axial strain (ε_a) is calculated. Formula is;

$$\text{Axial strain, } \varepsilon_a = \left(\frac{\Delta H}{H_0}\right) \times 100 \quad (3.2.1)$$

$$\text{Stress, } \sigma = \frac{F}{A_c} \text{ where, } A_c = \frac{A_i}{1-\varepsilon} \quad (3.2.2)$$

A_i is the initial area of the specimen (πr_i^2)

The specimen is placed carefully in the compression device and it is centered on the bottom plate. The device is adjusted so that the upper plate just makes contact with the specimen and set the load and deformation dials to zero. The load is applied so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then the load and deformation dial readings are recorded at every 20 to 50 divisions on deformation the dial.

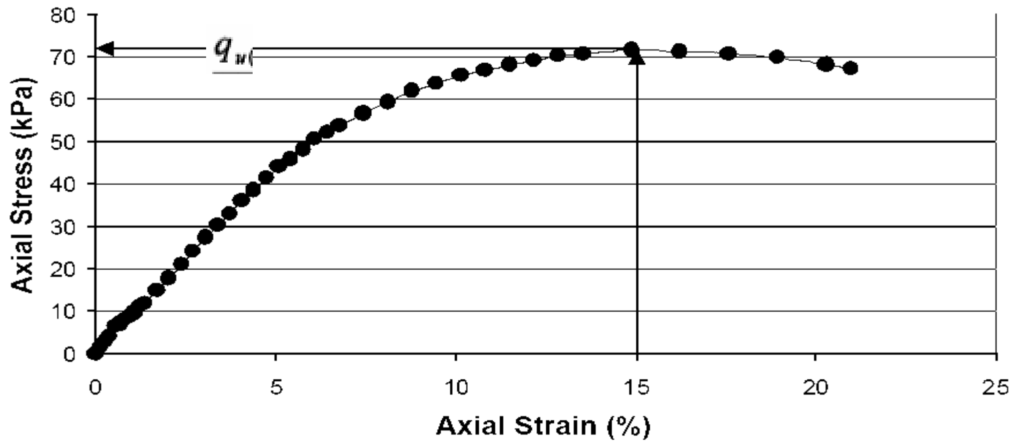


Figure 3.5 Stress vs. Strain

After, the load kept applying until the load (load dial) decreases on the specimen significantly, the load holds constant for at least four deformation dial readings, or the deformation is significantly past the 15% strain that was determined in first measurement. Then, a sketch is drawn to depict the sample failure.

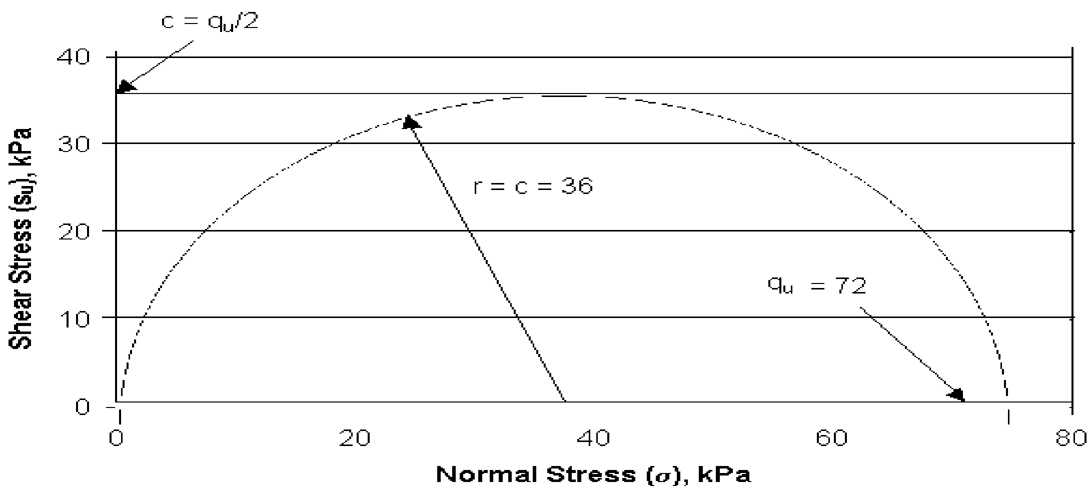


Figure 3.6 Mohr Circle

The sample from the compression device is removed and a sample is obtained for water content determination and the water content is determined. Finally, the sample cross-sectional area, the strain, the corrected area, the specimen stress and the water content are computed and the stress versus strain diagram is plotted. The peak stress of the test is unconfined compressive strength.

3.2.5 Direct Shear Test

This test is performed to determine the consolidated-drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil's shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts, finding the bearing capacity for foundations, and calculating the pressure exerted by a soil on a retaining wall.

In this test ASTM D 3080 international standards are used.

Procedure of this test is that firstly, the initial mass of soil in the pan is weighed. the diameter and height of the shear box is measured and 15% of the diameter in millimeters is computed. Second, the shear box is assembled carefully and it is placed in the direct shear device. Additionally a porous stone and a filter paper are placed in the shear box. Then, the sand is placed into the shear box and level off the top. a filter paper, a porous stone, and a top plate (with ball) are placed on the top of the sand. After that, the large alignment screws are removed from the shear box. The gap is opened between the shear box halves to approximately 0.025 in. using the gap screws, and then back out. The pan of soil is weighed again and the mass of soil used is computed. Then, the assembly of the direct shear device is complete and the three gauges (Horizontal displacement gage, vertical displacement gage and Shear load gage) are initialized to zero.

The vertical load (or pressure) is set to a predetermined value, and then bleeder valve is closed and the load applied to the soil specimen by raising the toggle switch. After, the motor is started with selected speed so that the rate of shearing is at a selected constant rate, and the horizontal displacement gauge, vertical displacement gage and shear load gage readings are taken and the readings are recorded. Finally, taking readings are continued until the horizontal shear load peaks and then falls, or the horizontal displacement reaches 15% of the diameter.

To analyze these steps, the density of the soil sample from the mass of soil and volume of the shear box, the sample area, the vertical (Normal) stress and shear stress are calculated. The horizontal shear stress versus horizontal (lateral) displacement diagram is plotted and the maximum shear stress for each test is calculated. (ex. Figure 4.7)

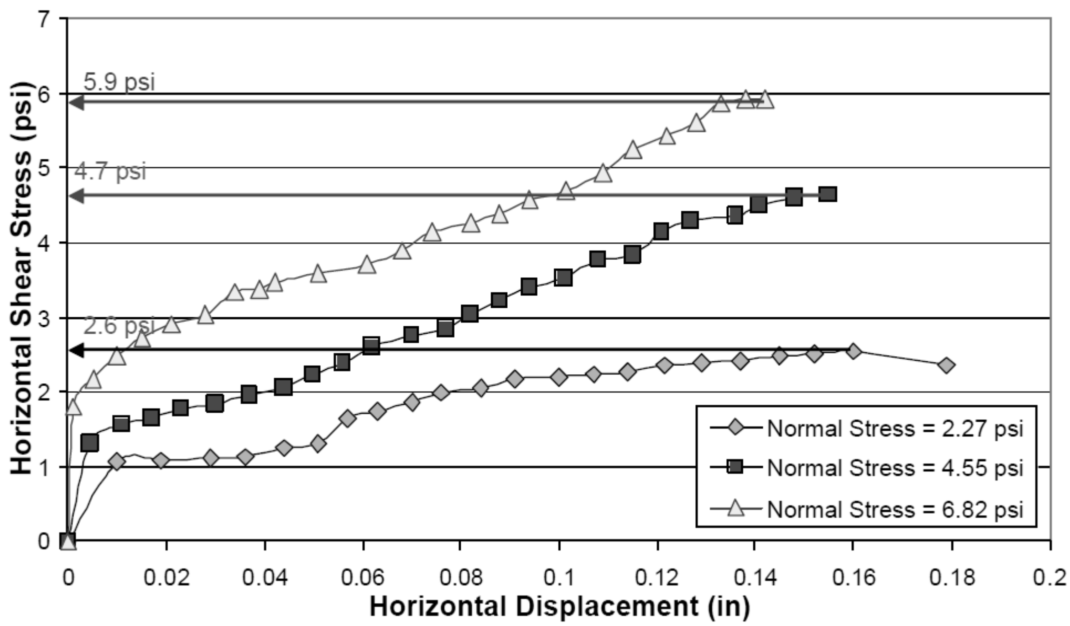


Figure 3.7 Horizontal Displacement vs. Shear Stress

Then, the value of the maximum shear stress versus the corresponding vertical stress for each test diagram is plotted and the angle of internal friction is determined from the slope of the approximated Mohr-Coulomb failure envelope (for example Figure 4.8).

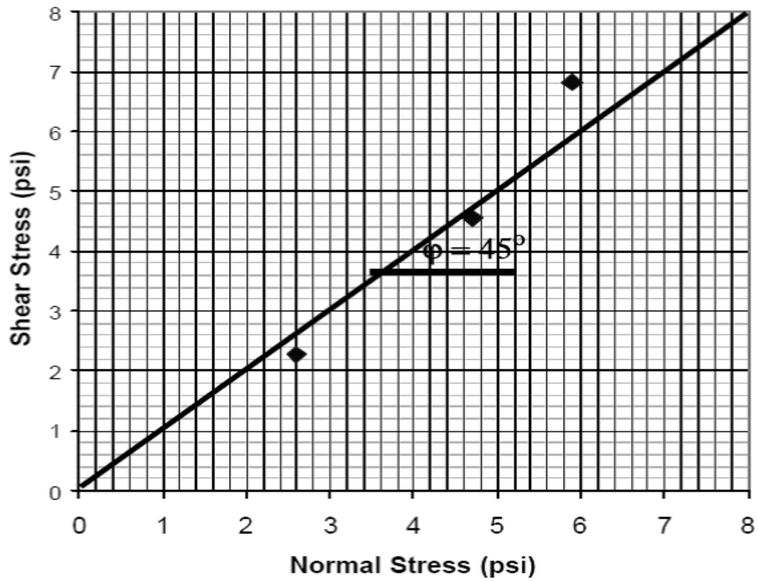


Figure 3.8 Normal vs. Shear stress

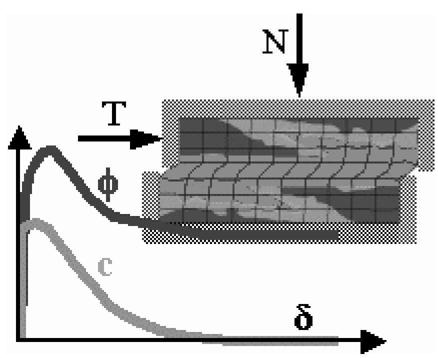


Figure 3.9 Cross-sectional resistance

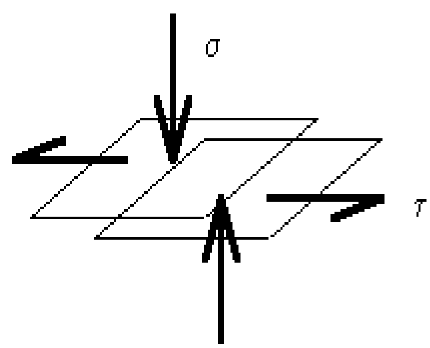


Figure 3.10 Forces

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Atterberg Limit Index Results

For each mixture, liquid limit tests are repeated at least 3 times so 3 graphs obtained, and each graph contains 3 or 4 points in order to have more accurate slope. So the exact point for N=25 would be defined. Also for each graph the closest point to 25 blows, is used in order to define plastic limit for that trial.

4.1.1 Clay

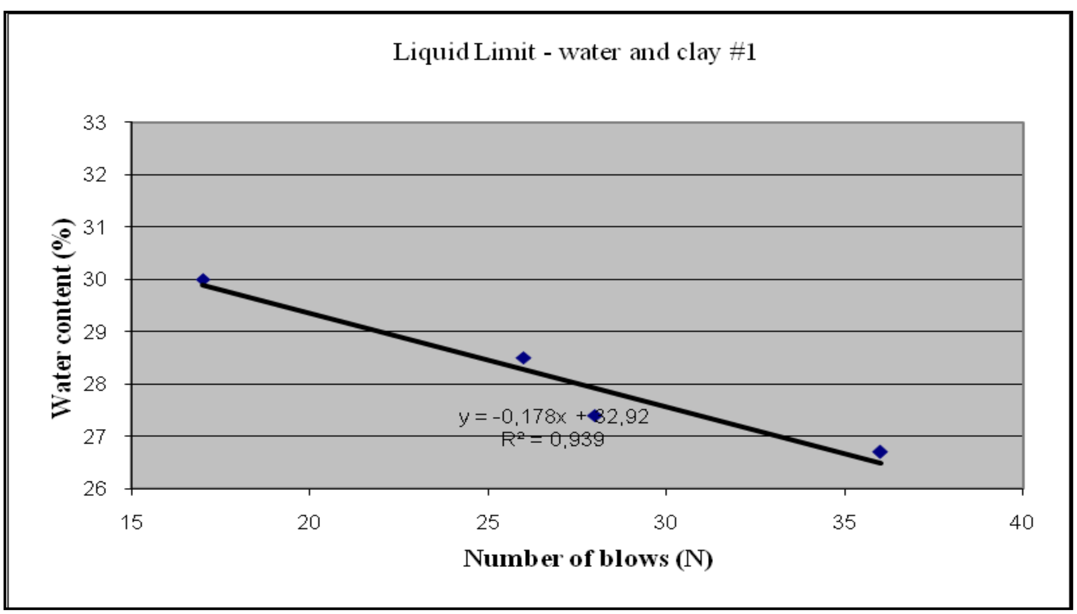


Figure 4.1 LL – Water & Clay #1

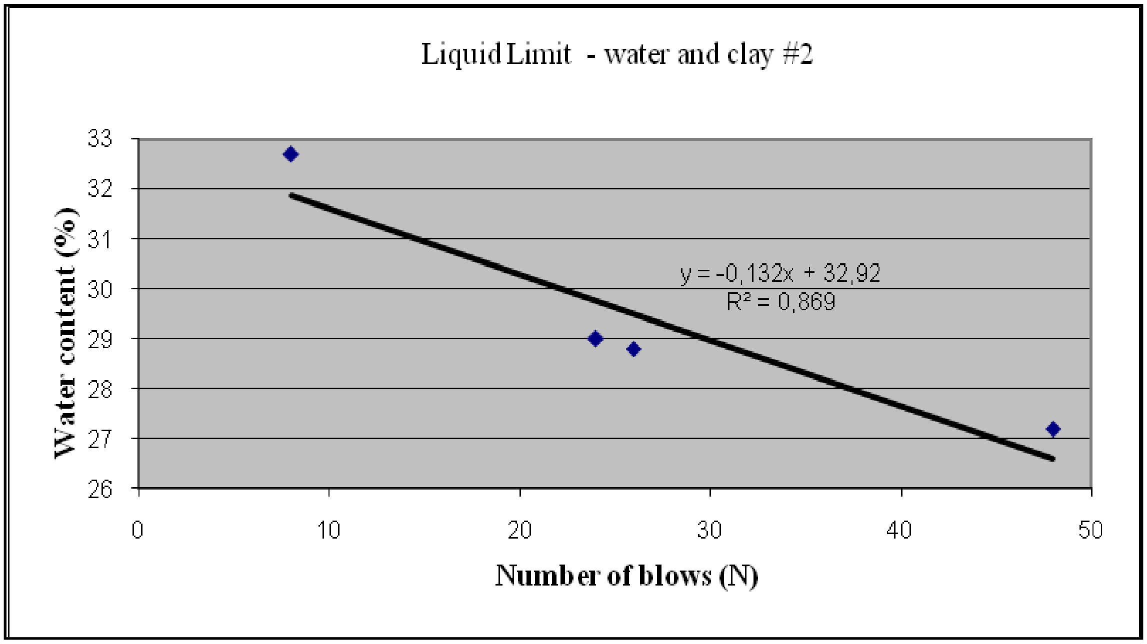


Figure 4.2 LL – Water & Clay #2

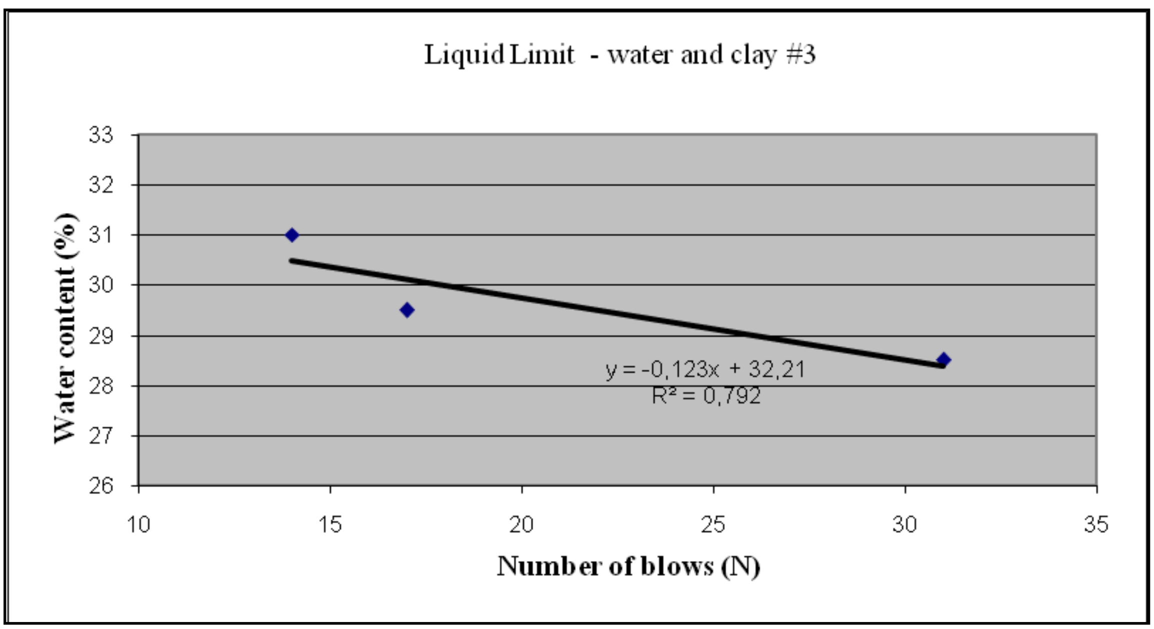


Figure 4.3 LL – Water & Clay #3

When N=25 blows;

$\mathbf{LL_{avr} = 29\%}$ $\mathbf{PL_{avr} = 25\%}$ $\mathbf{PI_{avr} = 4}$ **SL=2%**

4.1.2 Wastewater composted sludge

Because the material is observed as non-liquid non-plastic, falling cone test is applied.

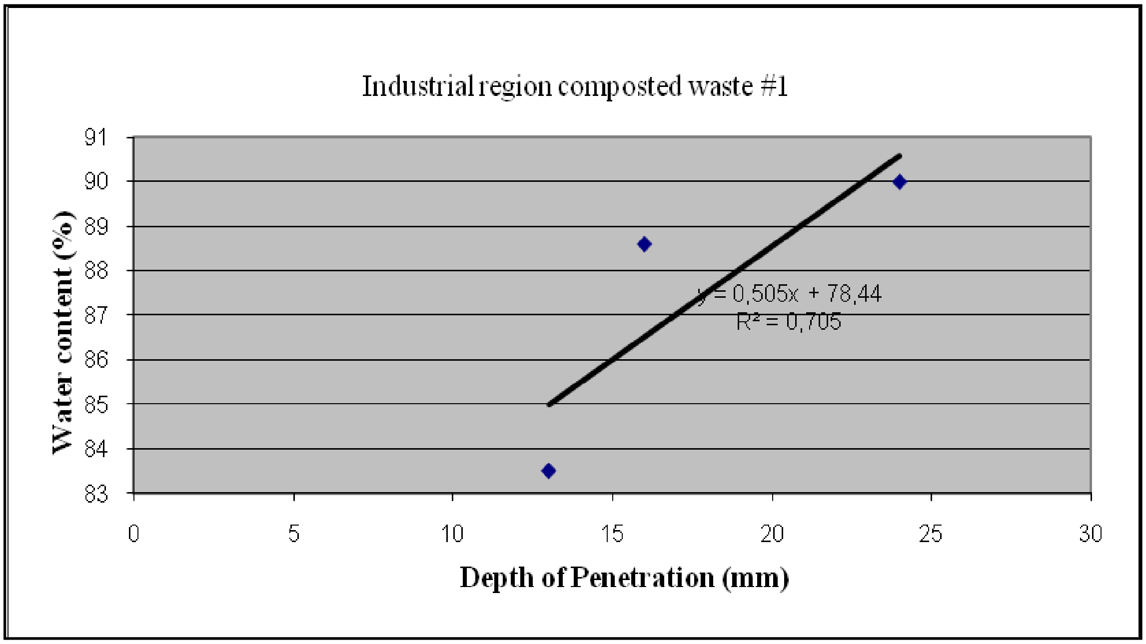


Figure 4.4 LL – Industrial region composted sludge #1

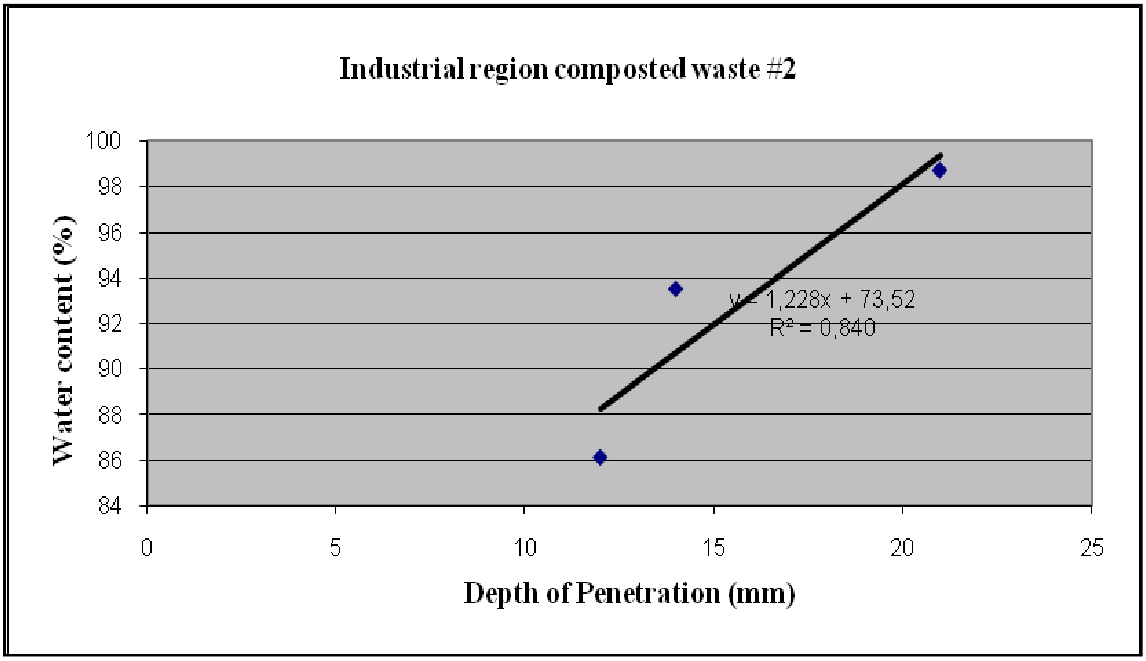


Figure 4.5 LL – Industrial region composted waste #2

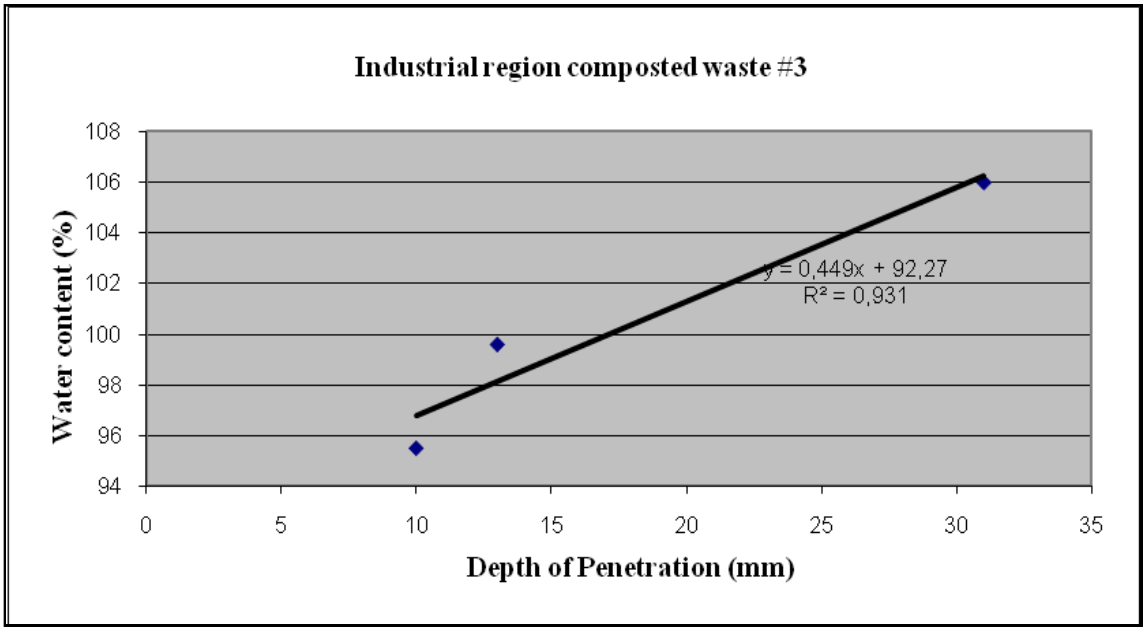


Figure 4.6 LL – Industrial region composted waste #3

When penetration is 20mm;

$\mathcal{W}_{avr}$ (LL)= 29% **SL= 0.3%**

Table 4.1 Atterberg Limit Index Results

	Liquid Limit	**Plastic Limit**	**Plasticity Index**	**Shrinkage limit**
Clay	29 %	25 %	4	2.20 %
Composted sludge	29 %	-	-	0.30 %

4.2 Specific Gravity

Table 4.2 Specific gravity of materials

Material	Gs
Wastewater composted sludge	1,51
Gaziantep Clay	2,49

4.3 Standard Proctor Compaction Test

4.3.1 Gaziantep clay

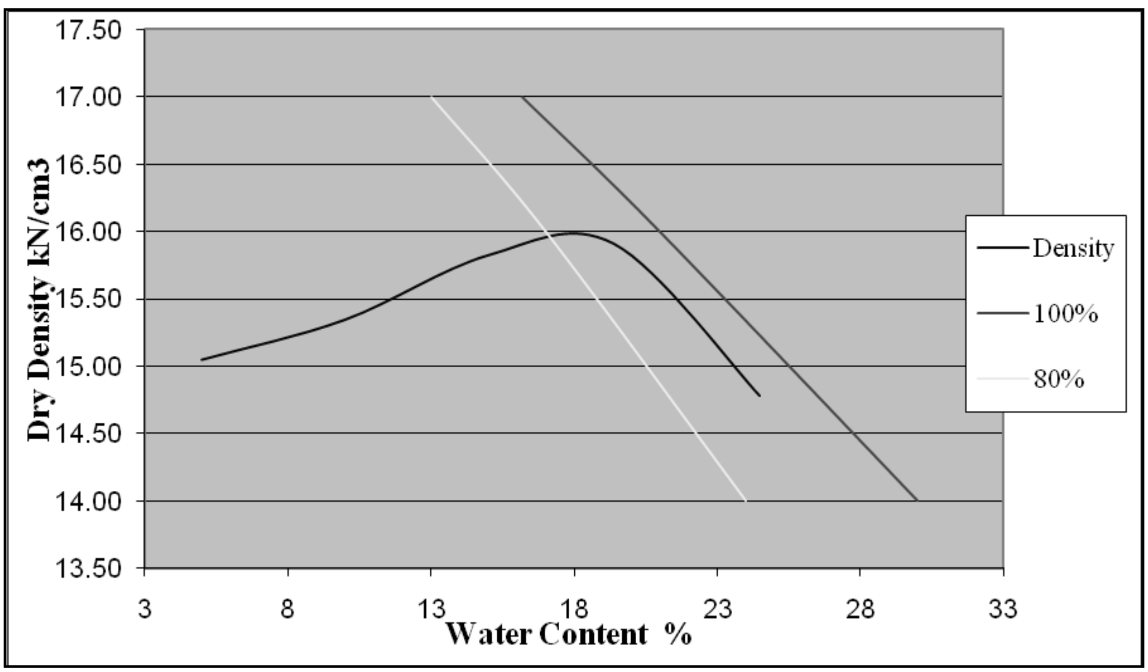


Figure 4.7 Gaziantep clay standard proctor test

Optimum Moisture Content= 18% and Maximum Dry Density= 15.83kN/cm3

4.3.2 Wastewater composted sludge

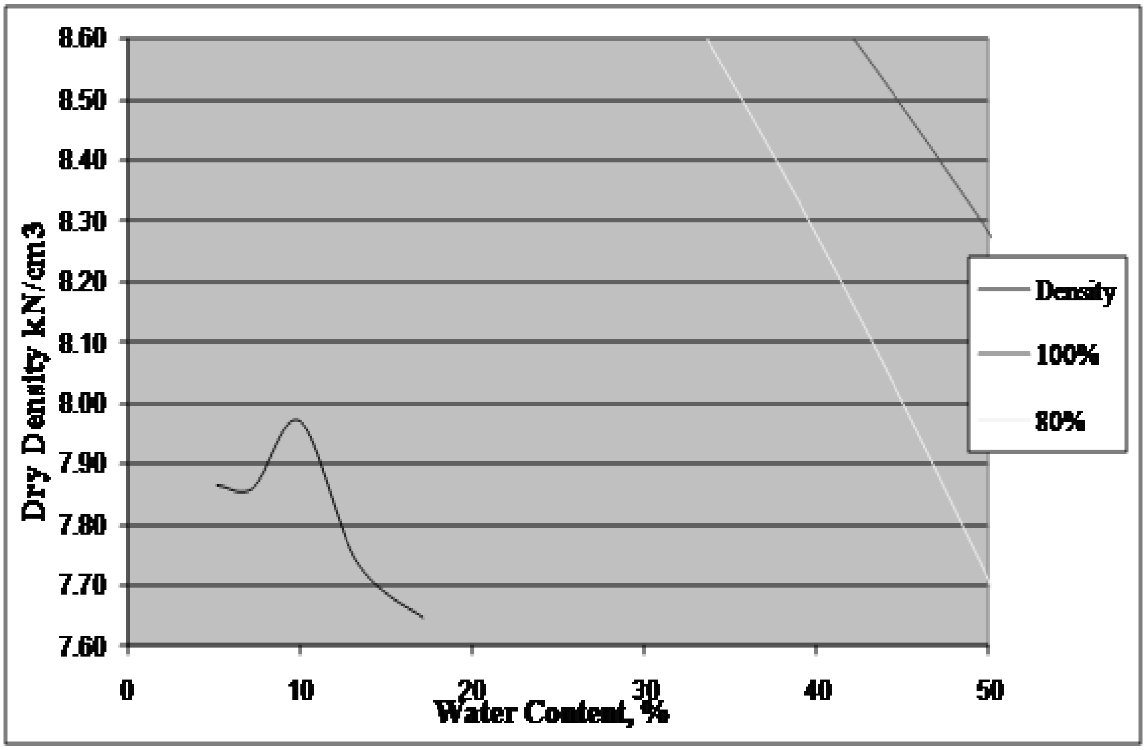


Figure 4.8 Composted sludge standard proctor test

Optimum Moisture Content= 10 % and Maximum Dry Density= 7.98kN/cm3

4.3.3 Gaziantep clay blended with wastewater composted sludge

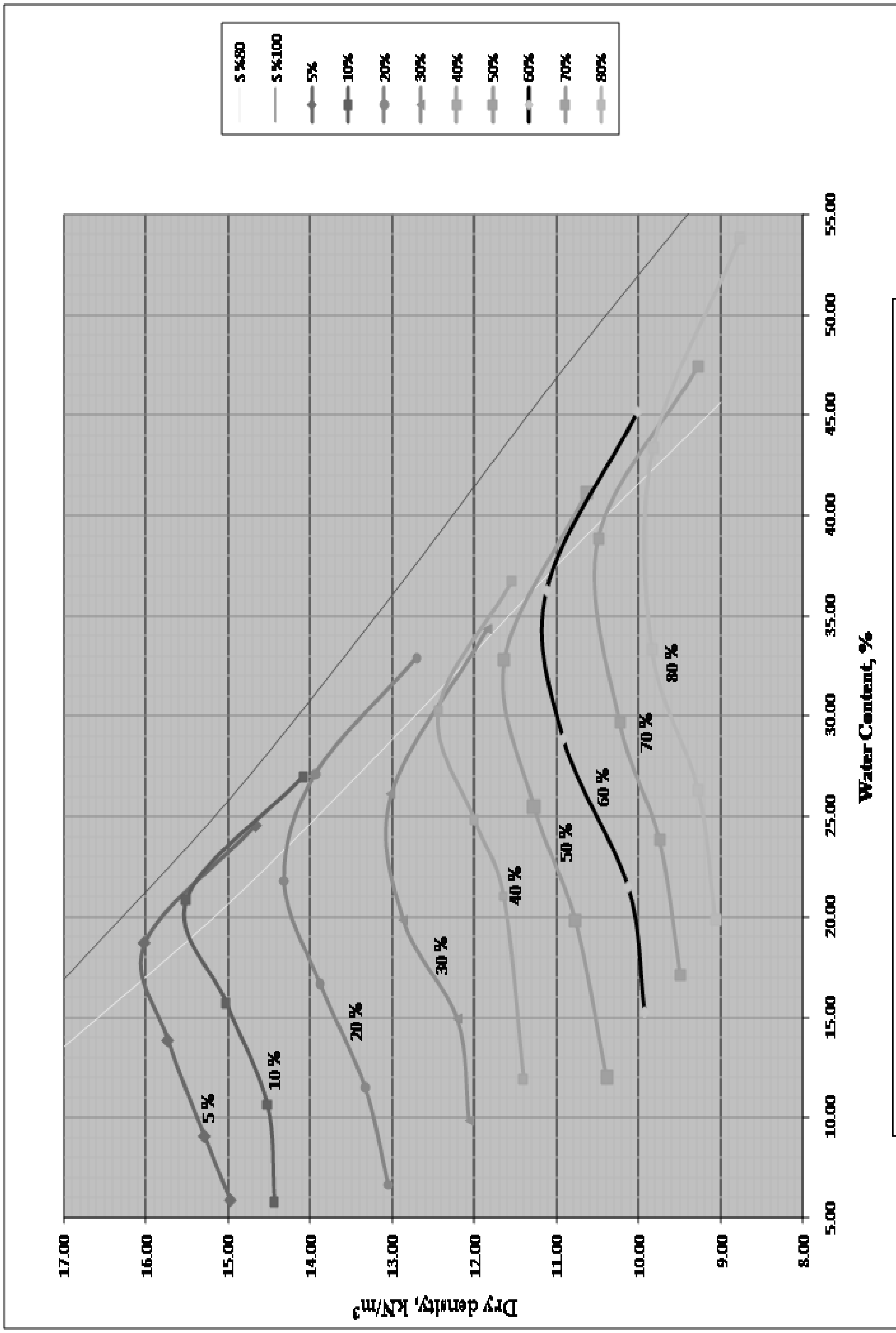


Figure 4.9 Different mixture ratios of composted sludge with clay

Table 4.3 Optimum water content (%) and Max dry density (kN/cm^3) vs. ratios of composted sludge blended with clay

	5 %	**10 %**	**20 %**	**30 %**	**40 %**	**50 %**	**60 %**	**70 %**	**80 %**
γ_{dry} **(kN/m^3)**	13.8	15.7	16.6	19.8	24.8	25.5	28.8	29.7	38.8
w **(%)**	15.7	15.0	13.9	12.9	12.0	11.3	10.9	10.2	9.6

4.4 Unconfined Compression Test

This experiment is especially focused different ratios of composted sludge as an additive to the mixture, the re-generated new soil. In order to be realistic this is more probable to meet such constructional problem of soil than other material mixtures in nature as pollutant.

According to the test results, it the ratios could be grouped into 3. These are:

* 1st group: 5%-10%-20%-30%   * 2nd group: 40%-50%-60%   * 3rd group: 70%-80%

4.4.1 First Group Mixtures : 5% - 10% - 20% - 30%

Figure 4.10 5% sludge included mixture

Figure 4.11 10% sludge included mixture

Figure 4.12 20%sludge included mixture

Figure 4.13 30%sludge included mixture

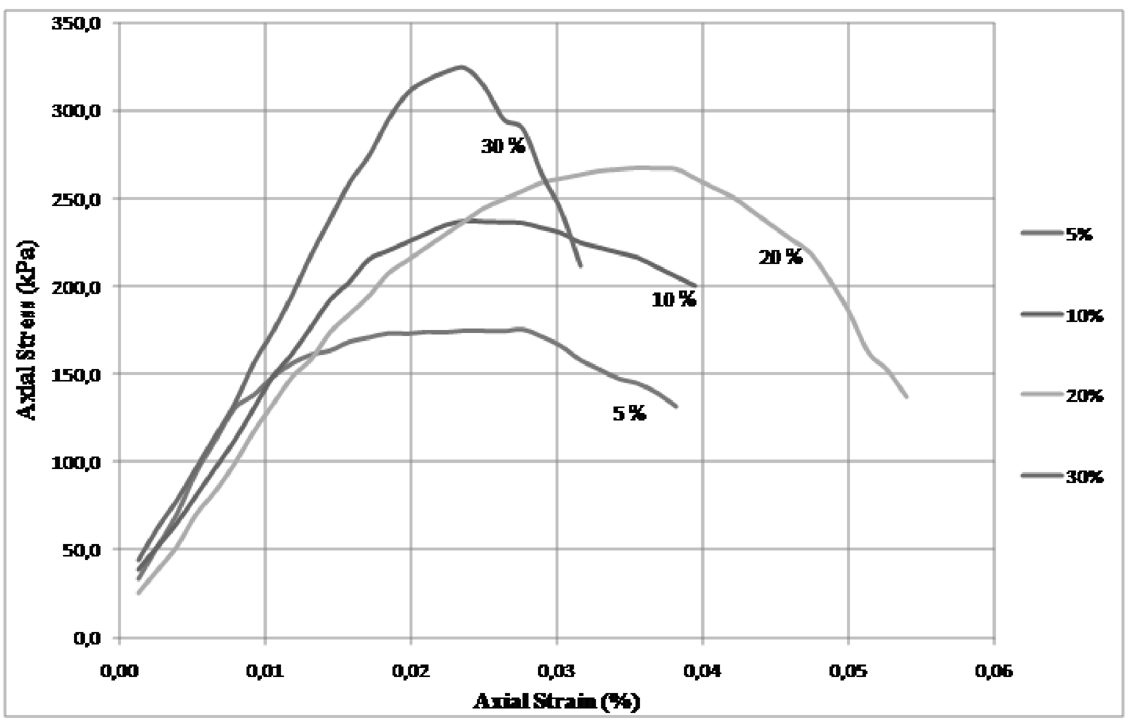


Figure 4.14 Design ratios of composted sludge in Gaziantep clay (%5-10-20-30)

4.4.2 Second Group Mixtures : 40% - 50% - 60%

Figure 4.15 40%sludge included mixture

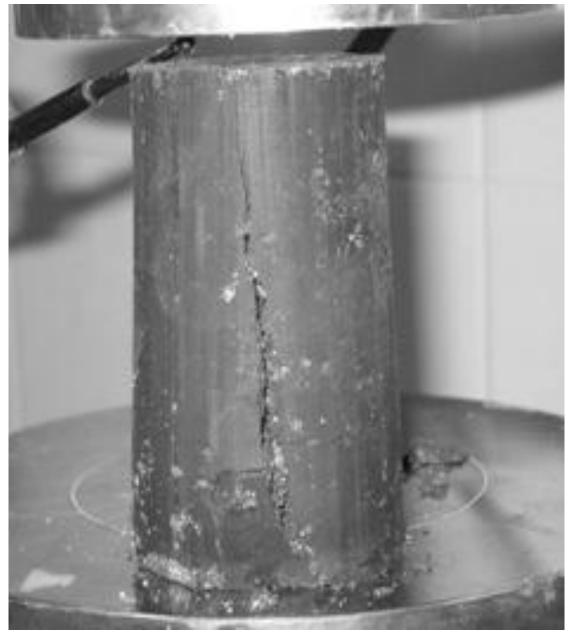


Figure 4.16 40%sludge included mixture

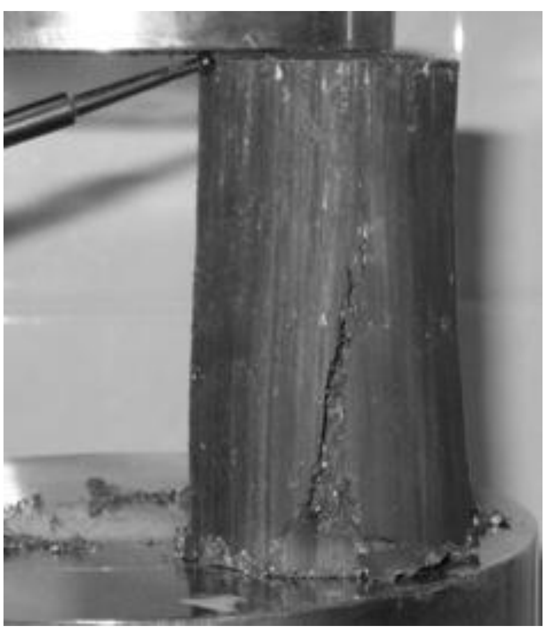


Figure 4.17 50%sludge included mixture

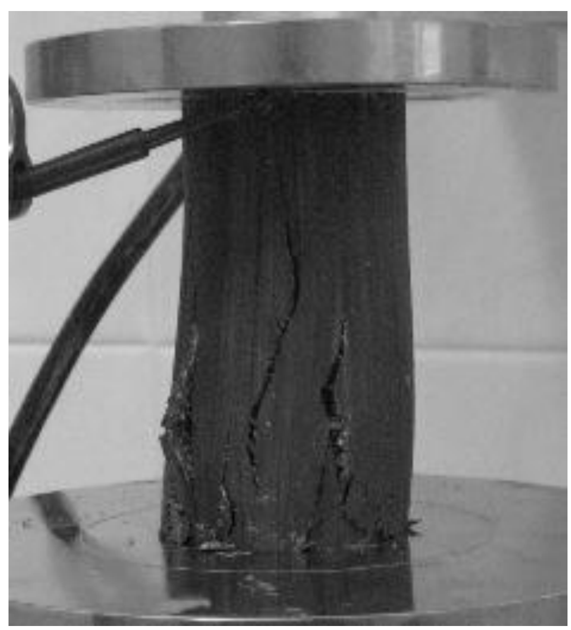


Figure 4.18 60%sludge included mixture

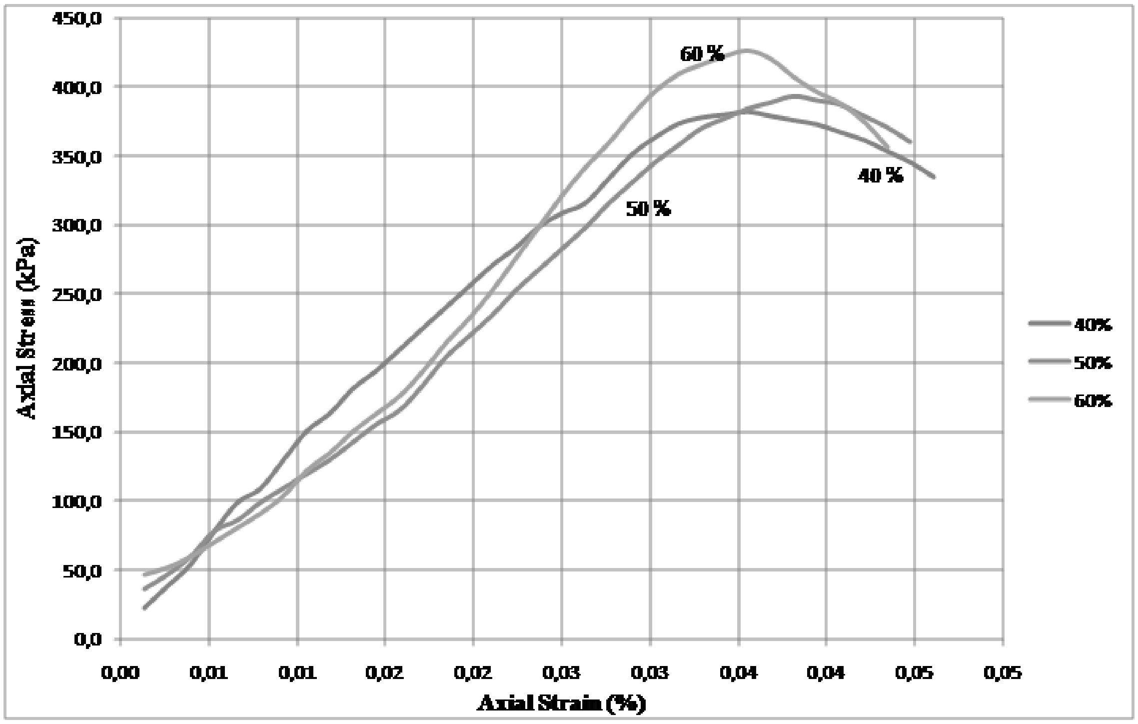


Figure 4.19 Design ratios of composted sludge in Gaziantep clay (%40-50-60)

4.4.3 Third Group Mixtures : 70% - 80%

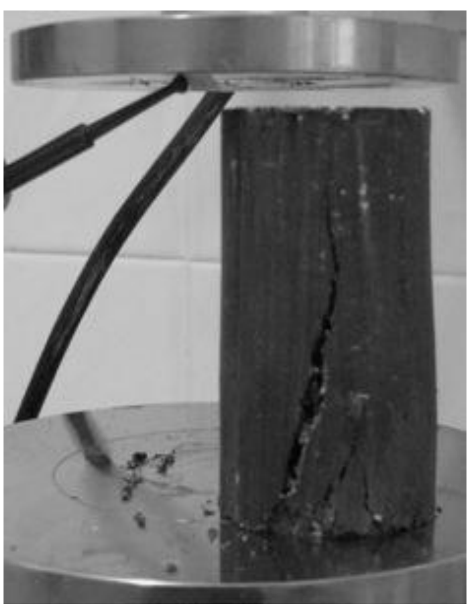


Figure 4.20 70%sludge included mixture

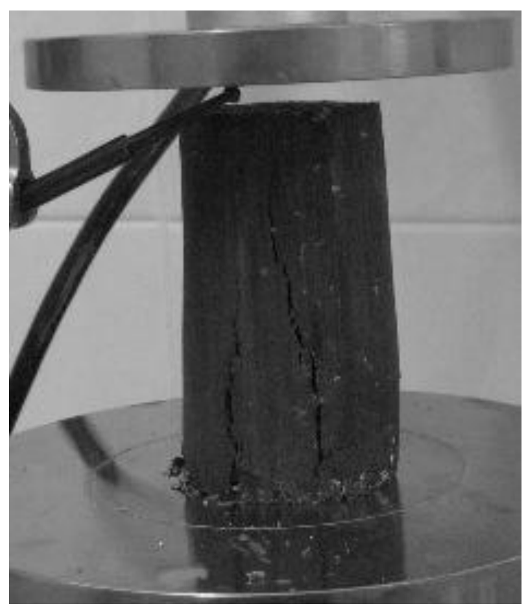
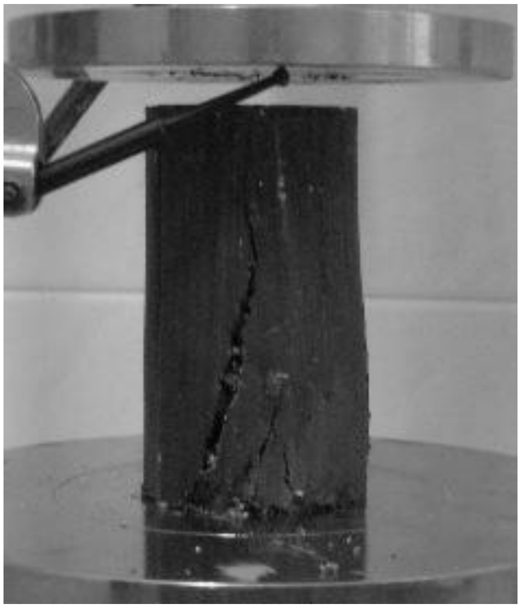


Figure 4.21 70%sludge included mixture



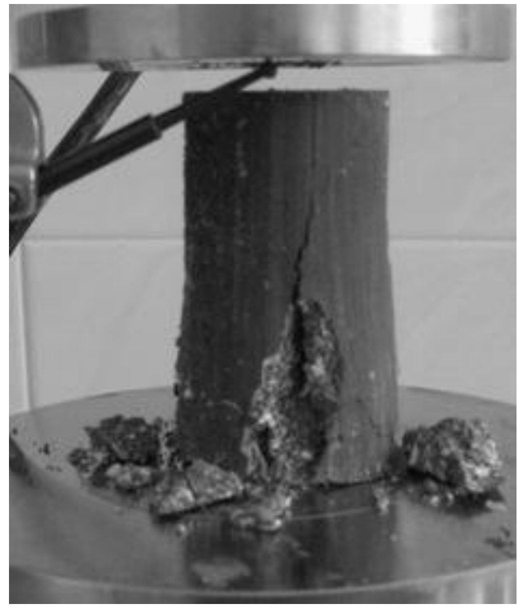


Figure 4.22 80%sludge included mixture **Figure 4.23** 80%sludge included mixture

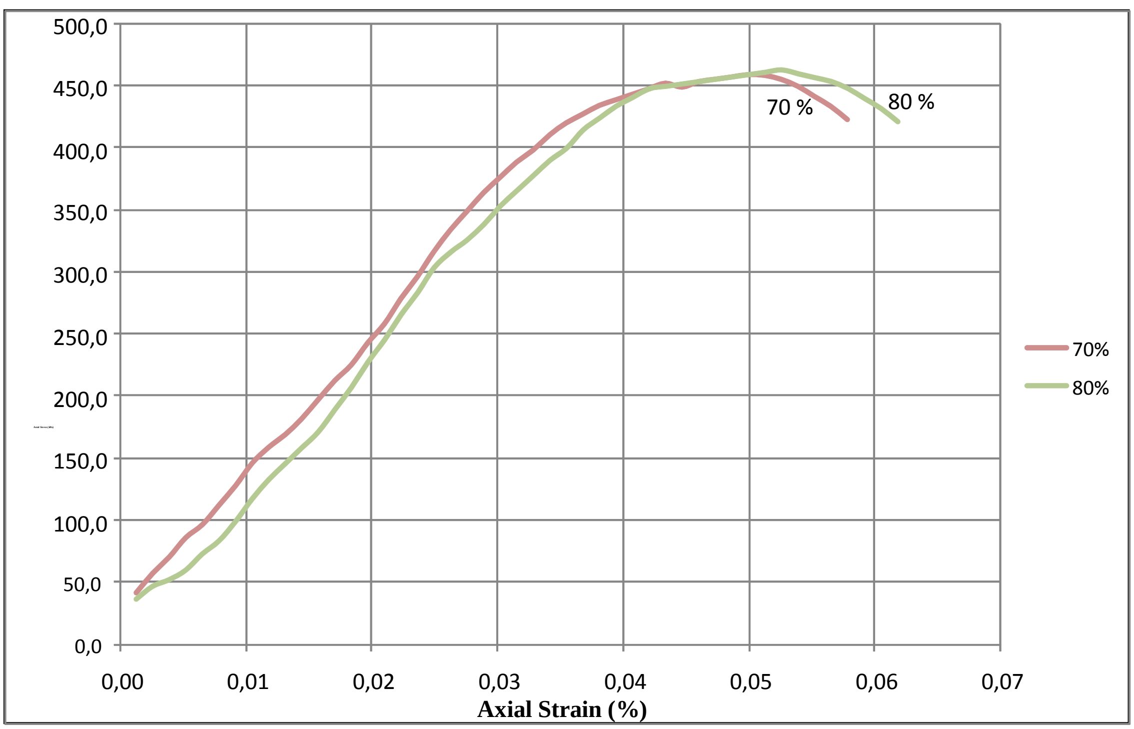


Figure 4.24 Design ratios of composted sludge in Gaziantep clay (%70-80)

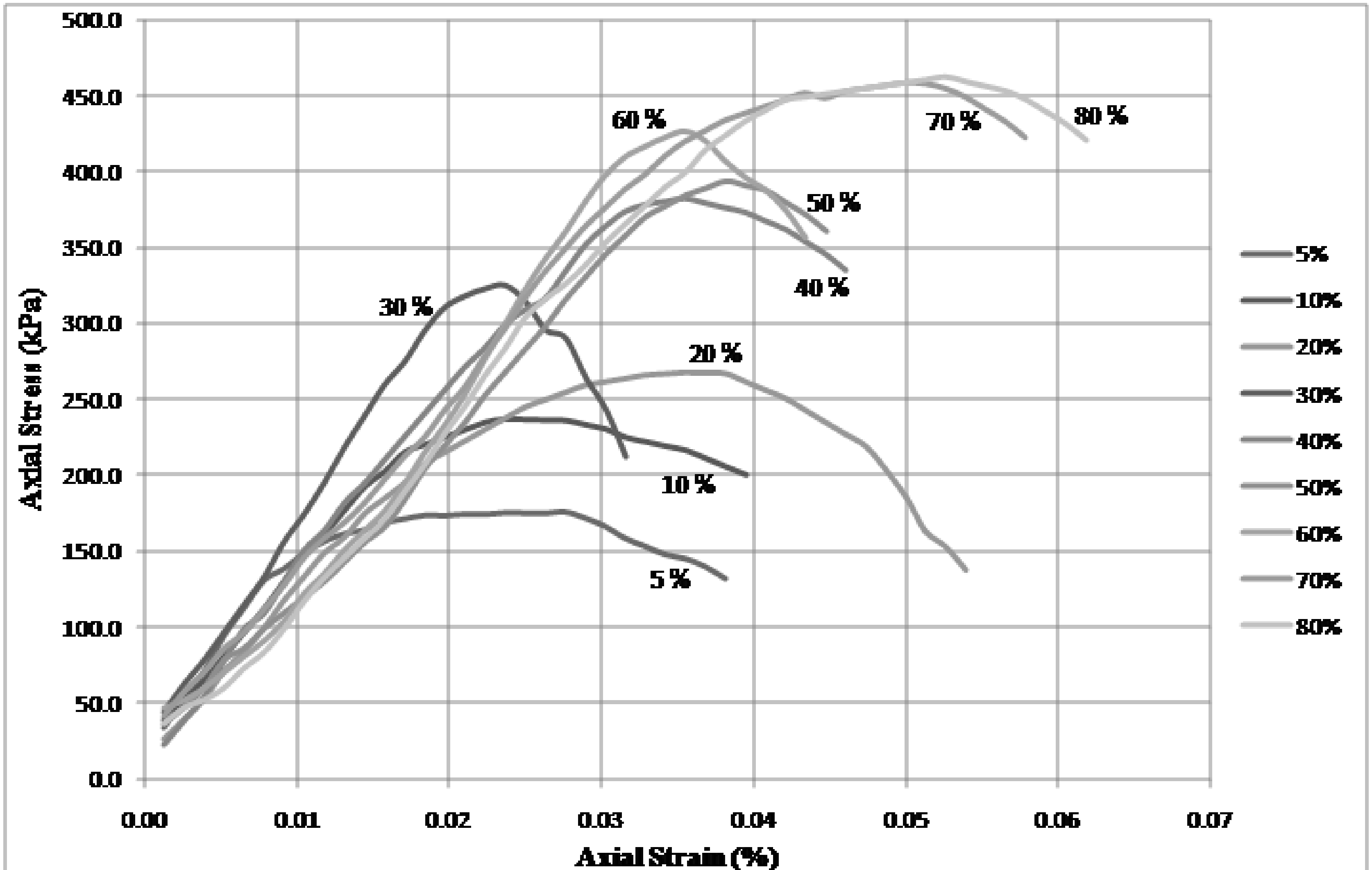


Figure 4.25 All design ratios of composted sludge in Gaziantep clay

Table 4.4 Shear Stresses (c_u) and Normal stresses ($\sigma - q_u$) included according to composted sludge design proportion in Gaziantep clay

	5 %	**10 %**	**20 %**	**30 %**	**40 %**	**50 %**	**60 %**	**70 %**	**80 %**
q_u (kPa)	17.50	22.80	26.50	32.10	38.50	39.60	42.00	45.40	46.20
c_u (kPa)	8.75	11.40	13.25	16.05	19.25	19.80	21.00	22.70	23.10

4.5 Direct Shear Test

This experiment is especially focused different ratios of composted sludge as an additive to the mixture, the re-generated new soil. In order to be realistic this is more probable to meet such constructional problem of soil than other material mixtures in nature as pollutant.

The graphs will be shown according to their mix designs, begins from 5% ,10%, 20%, 30%, 40%, %50 to 60% composted sludge.

Figure 4.26 10% mixture added

Figure 4.27 20% mixture added

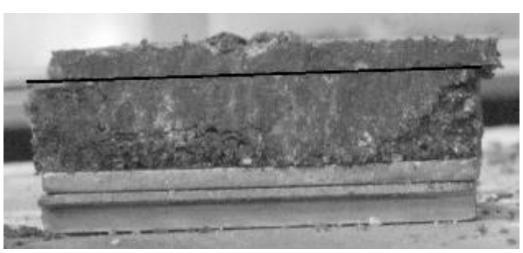


Figure 4.28 20% mixture added

Figure 4.29 30% mixture added

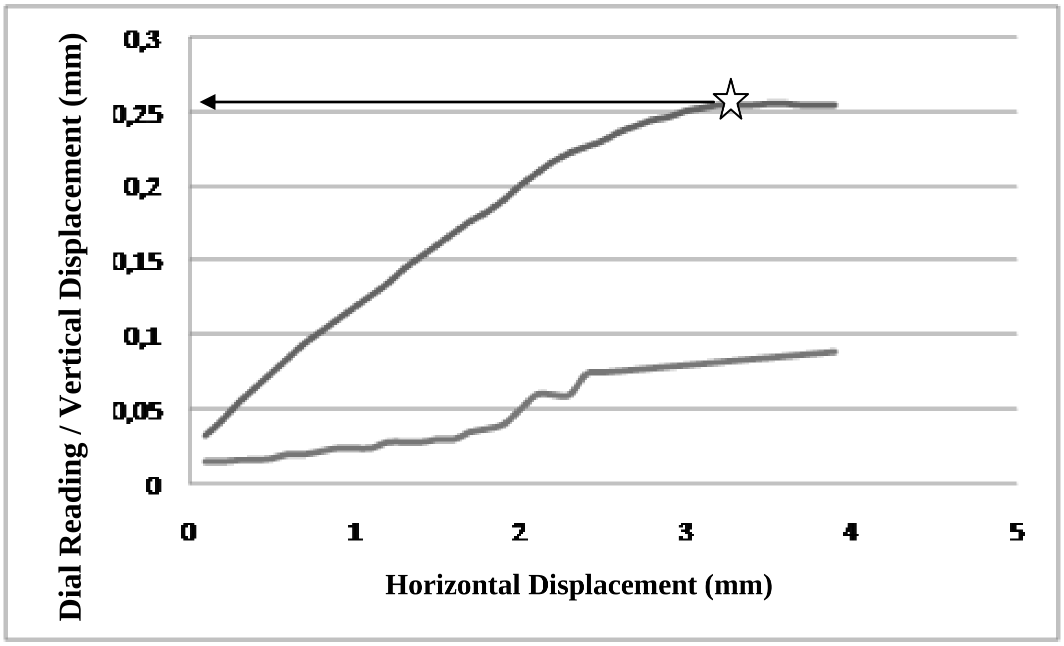


Figure 4.30 5% Sludge included mixture under 50kpa

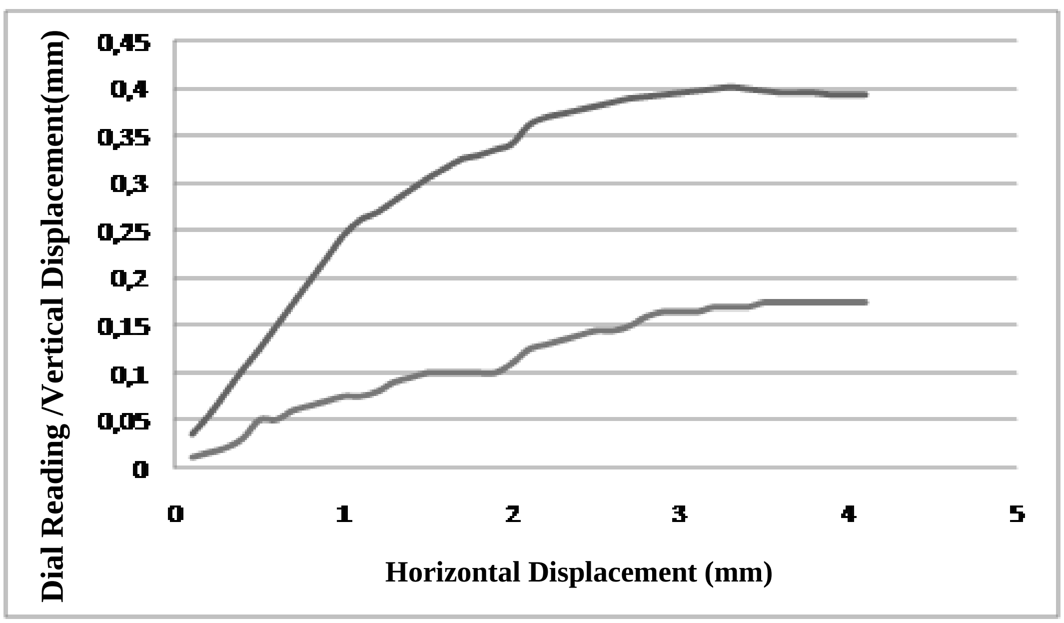


Figure 4.31 5% Sludge included mixture under 100kpa

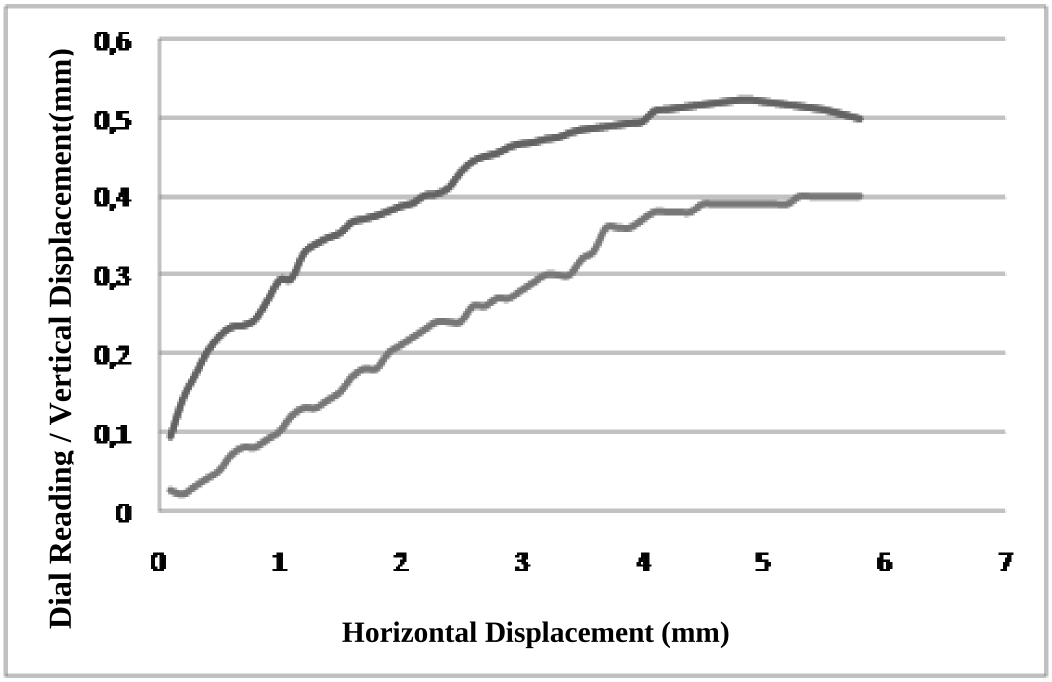


Figure 4.32 5% Sludge included mixture under 150kpa

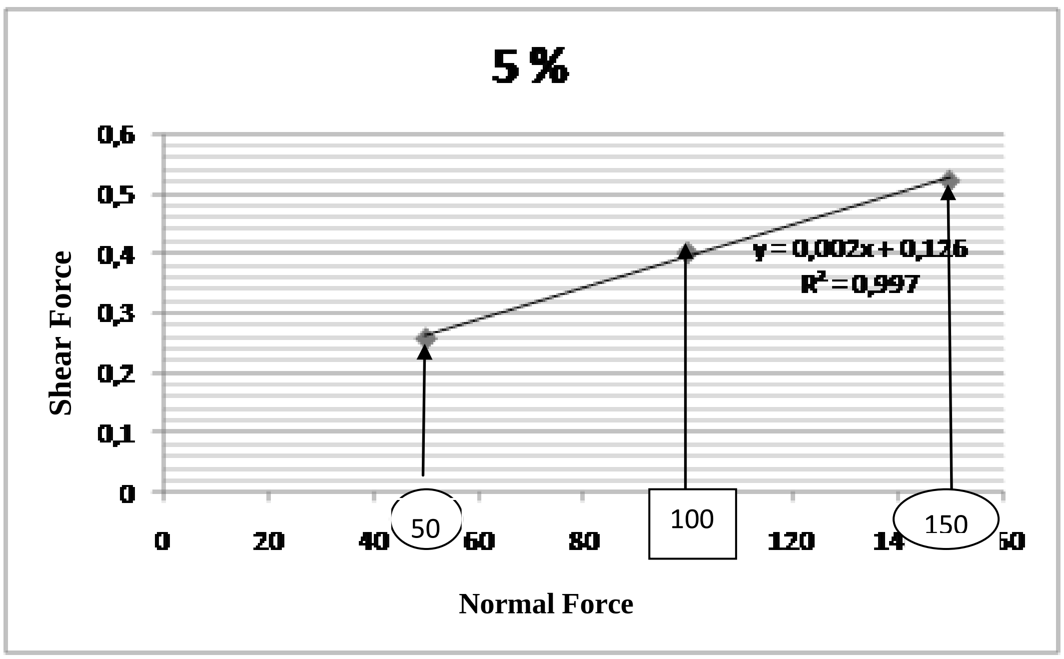


Figure 4.33 5% Sludge included mixture

c= 0,126 Φ= 63 for 5% of composted sludge included in new soil model.

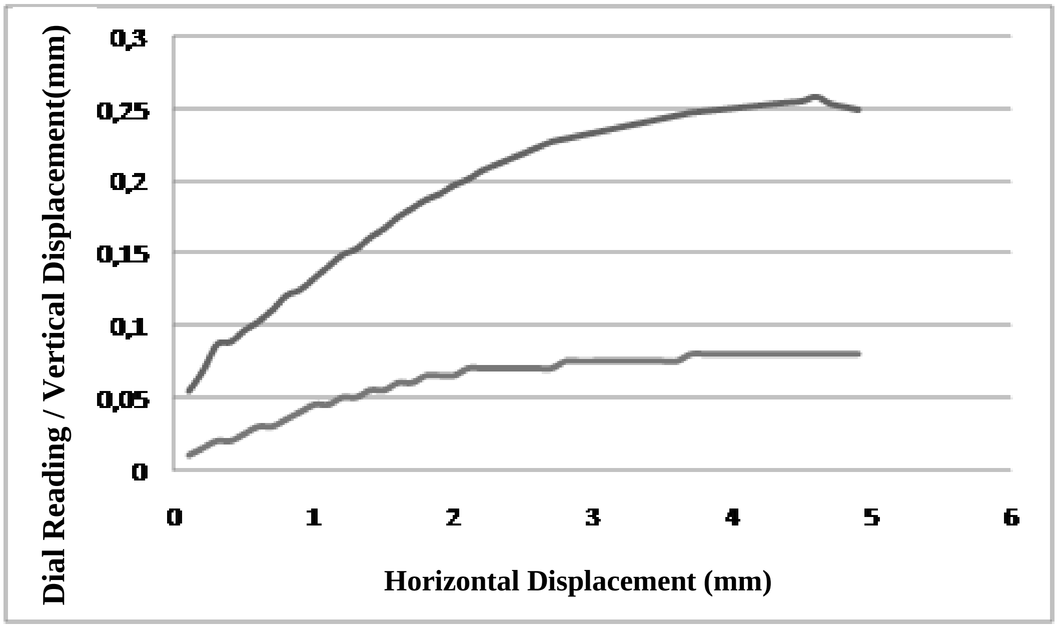


Figure 4.34 10% Sludge included mixture under 50kpa

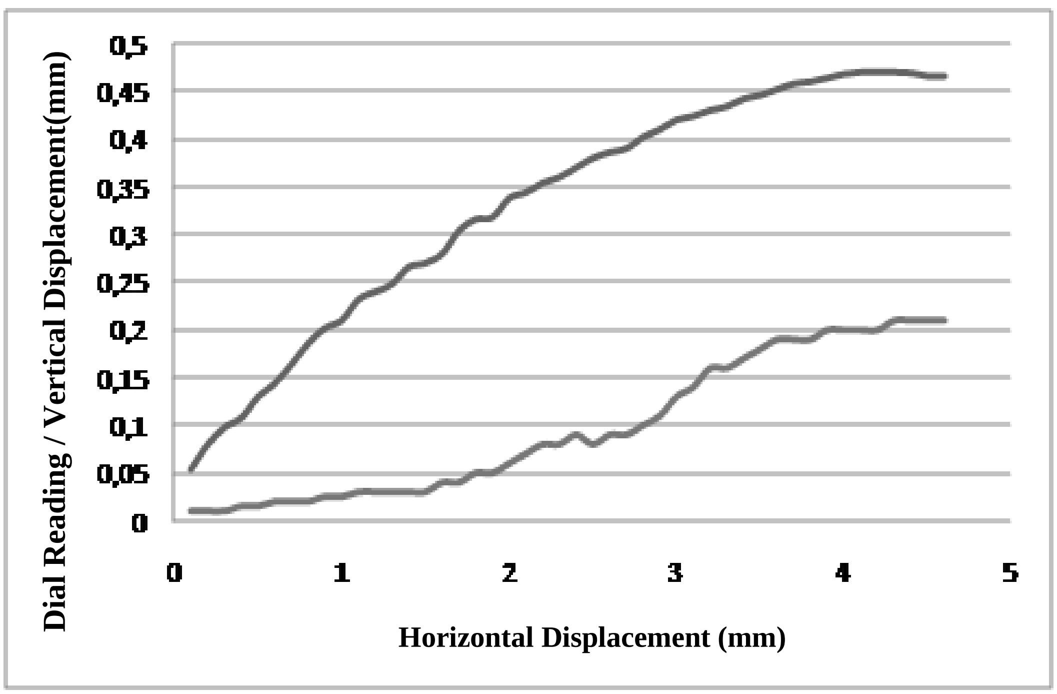


Figure 4.35 10% Sludge included mixture under 100kpa

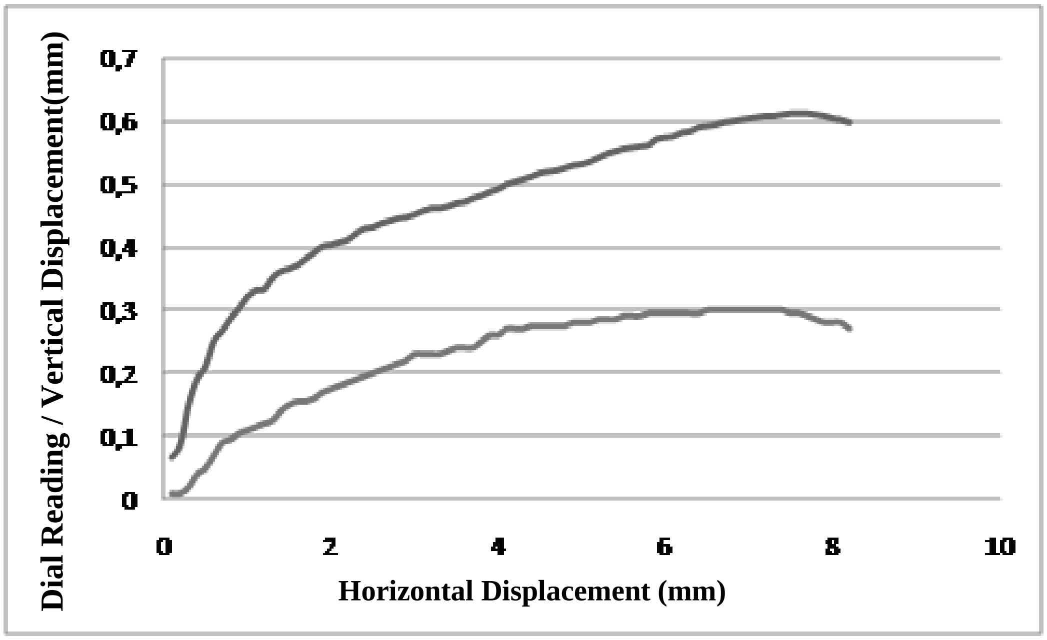


Figure 4.36 10% Sludge included mixture under 150kpa

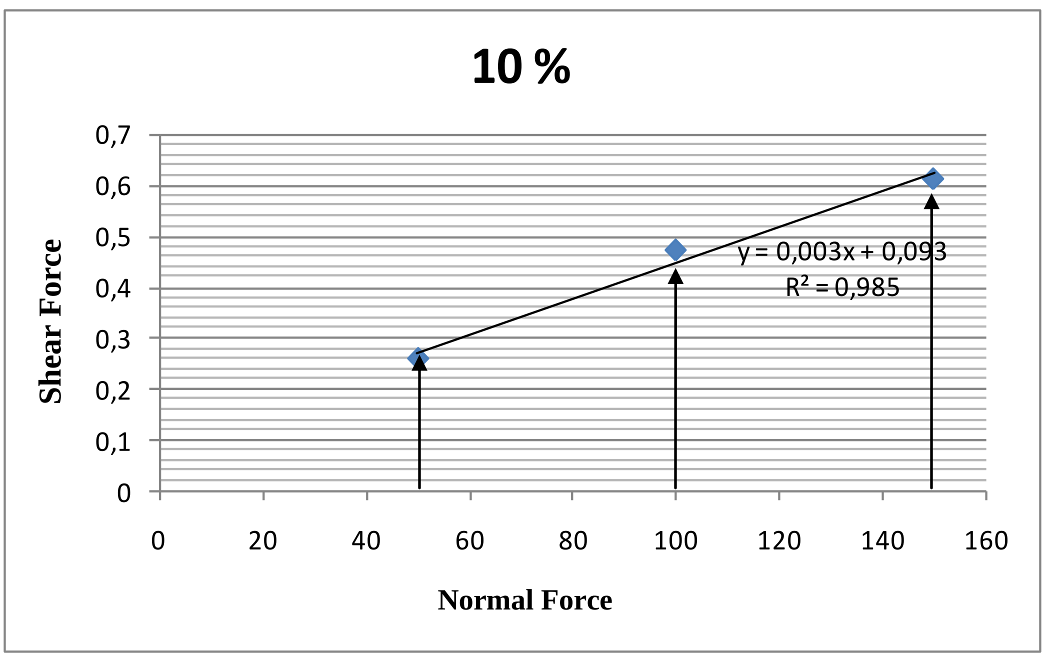


Figure 4.37 10% Sludge included mixture

c= 0,093 Φ= 31 for 10% of composted sludge included in new soil model.

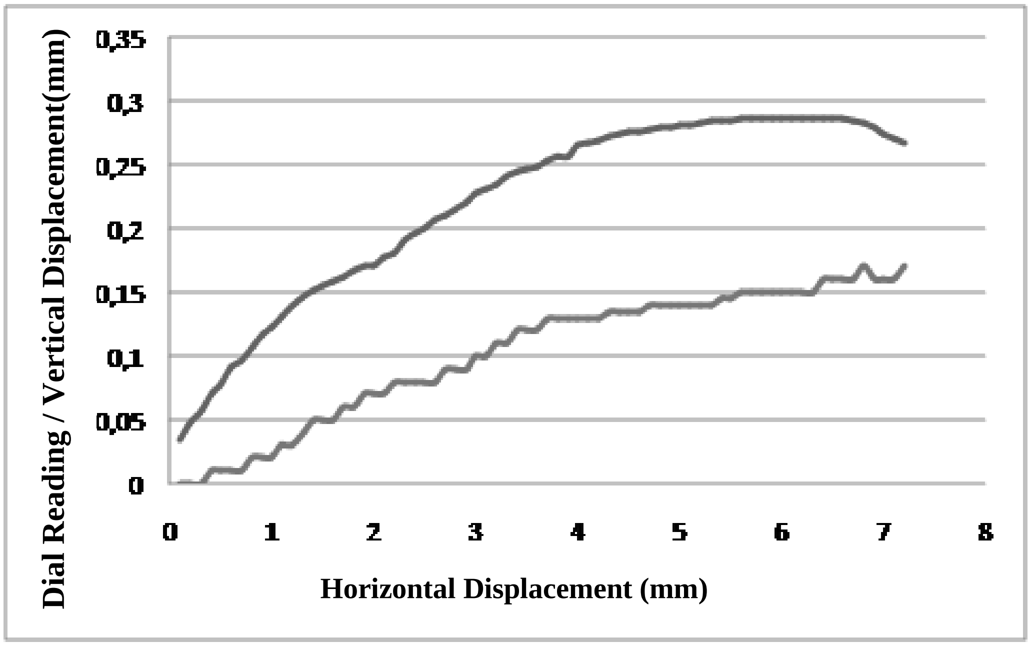


Figure 4.38 20% Sludge included mixture under 50kPa

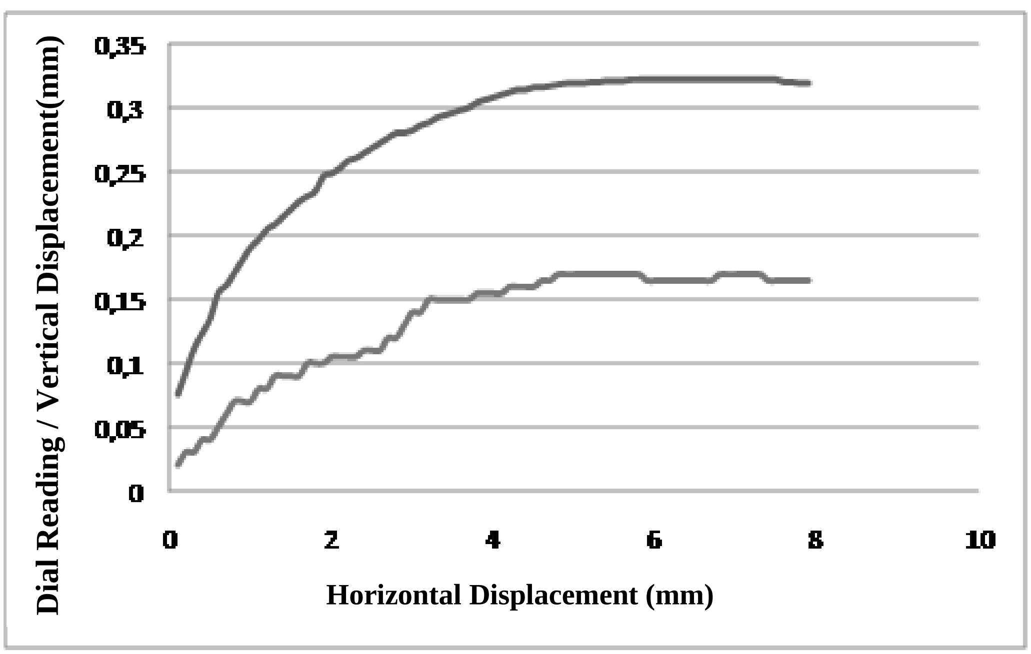


Figure 4.39 20% Sludge included mixture under 100kPa

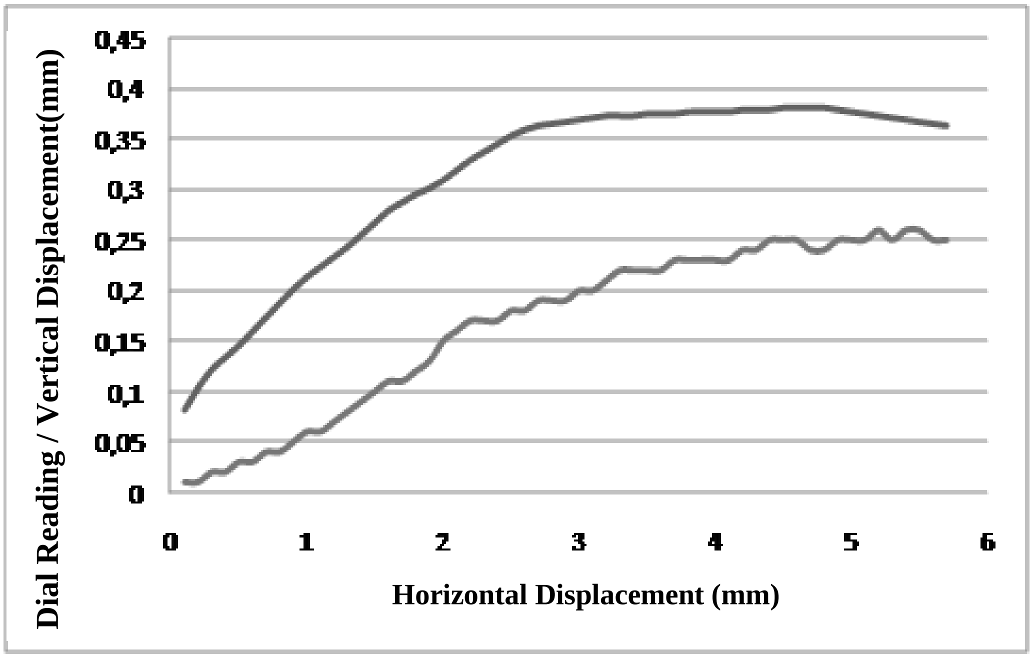


Figure 4.40 20% Sludge included mixture under 150kPa

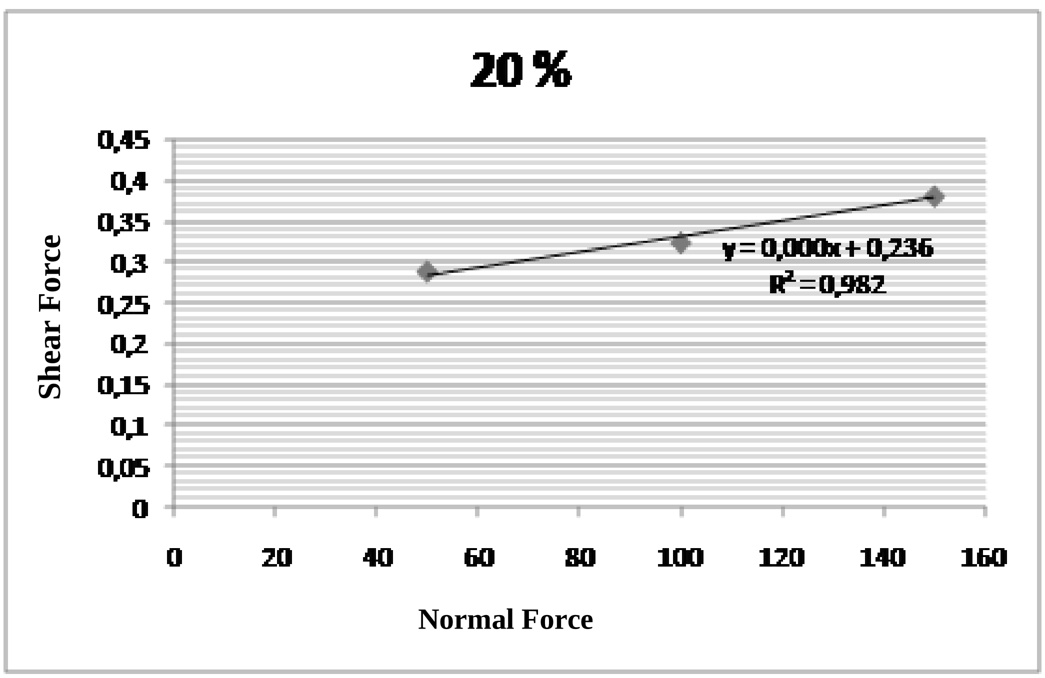


Figure 4.41 20% Sludge included mixture

c= 0,236 Φ= 236 for 20% of composted sludge included in new soil model.

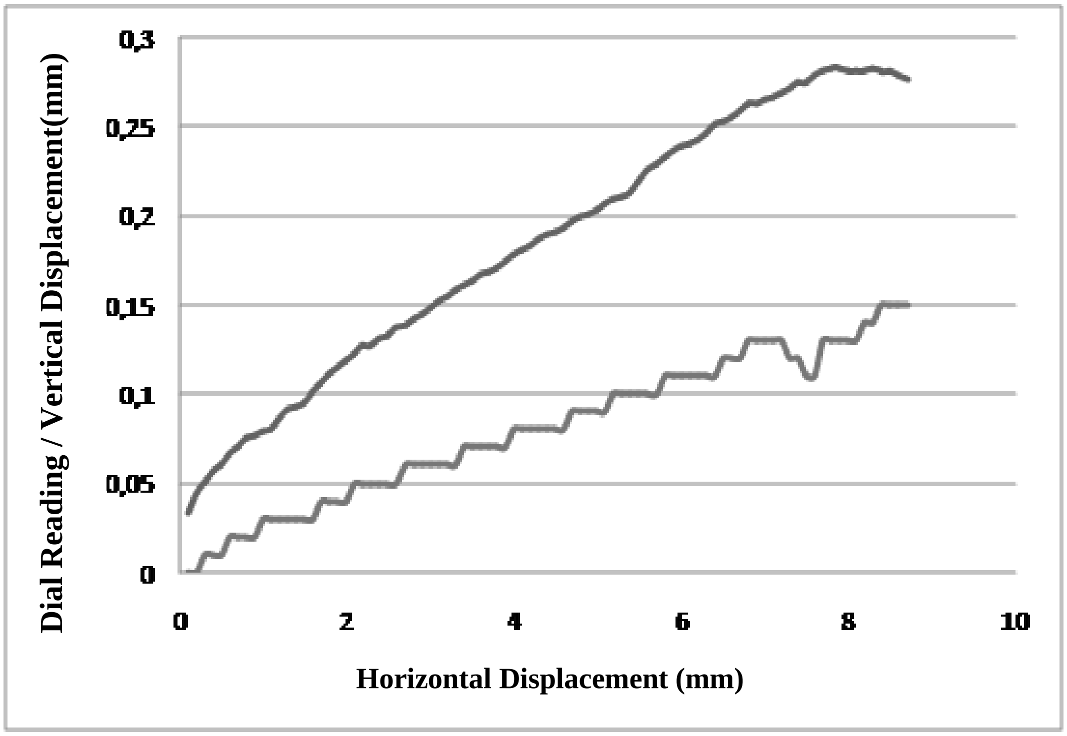


Figure 4.42 30% Sludge included mixture under 50kPa

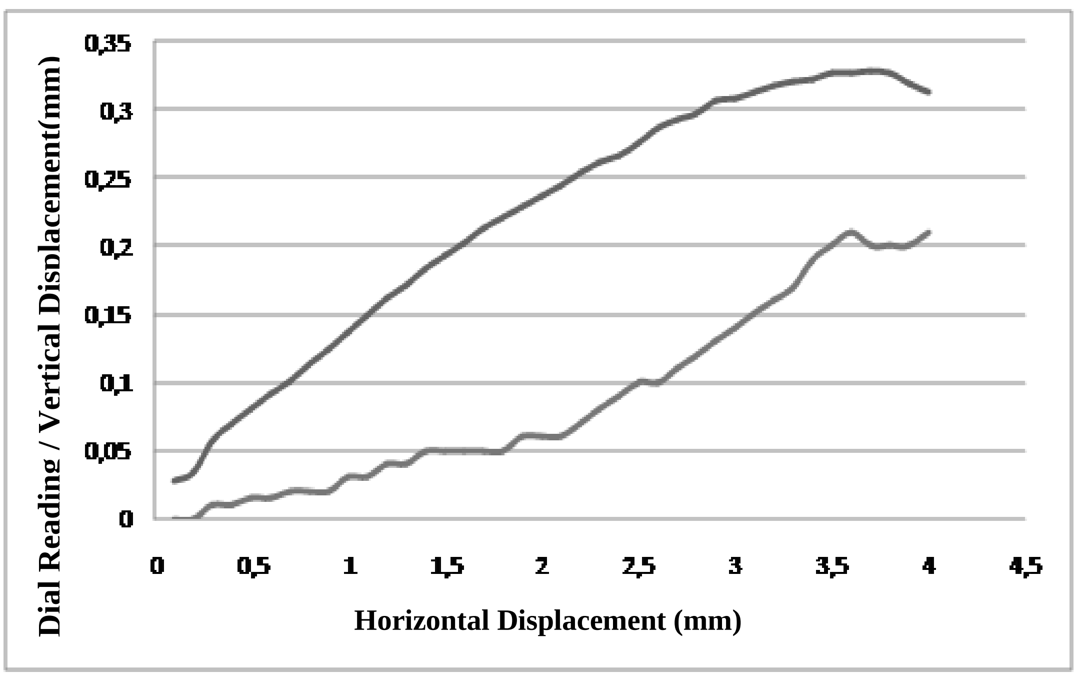


Figure 4.43 30% Sludge included mixture under 100kPa

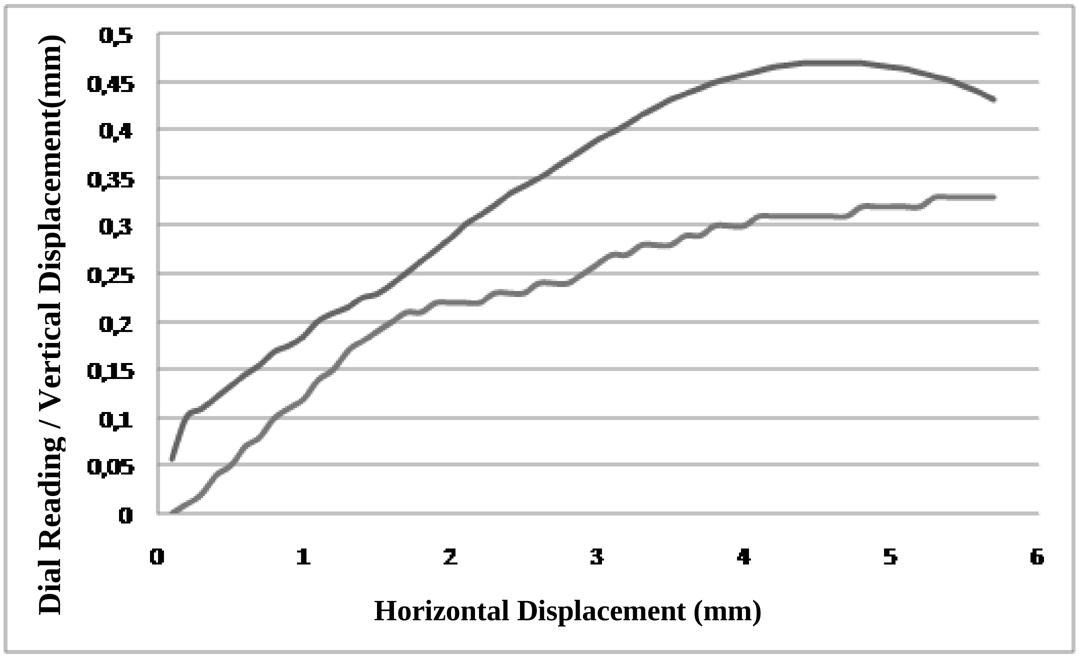


Figure 4.44 30% Sludge included mixture under 150kPa

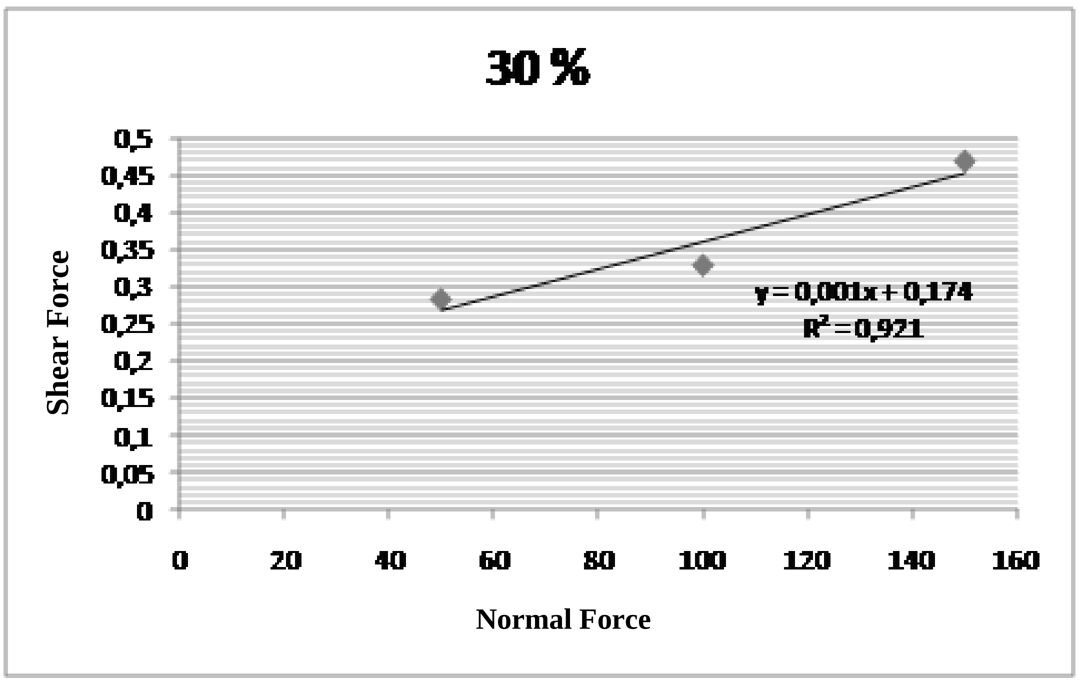


Figure 4.45 30% Sludge included mixture

c= 0,174   Φ= 174 for 30% of composted sludge included in new soil model.

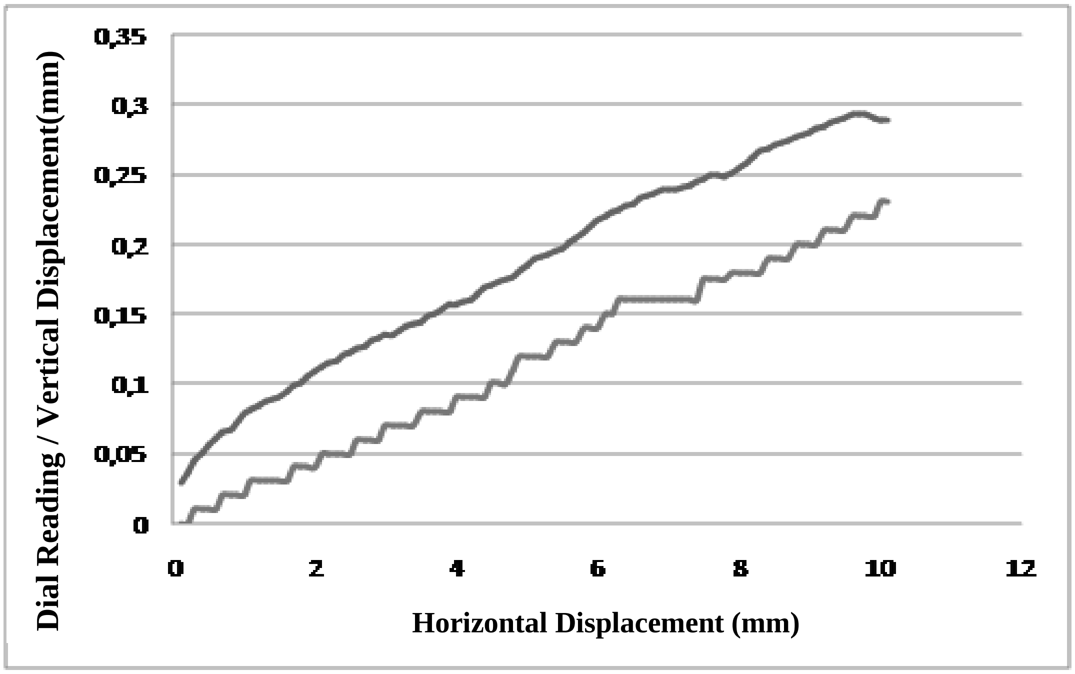


Figure 4.46 40% Sludge included mixture under 50kPa

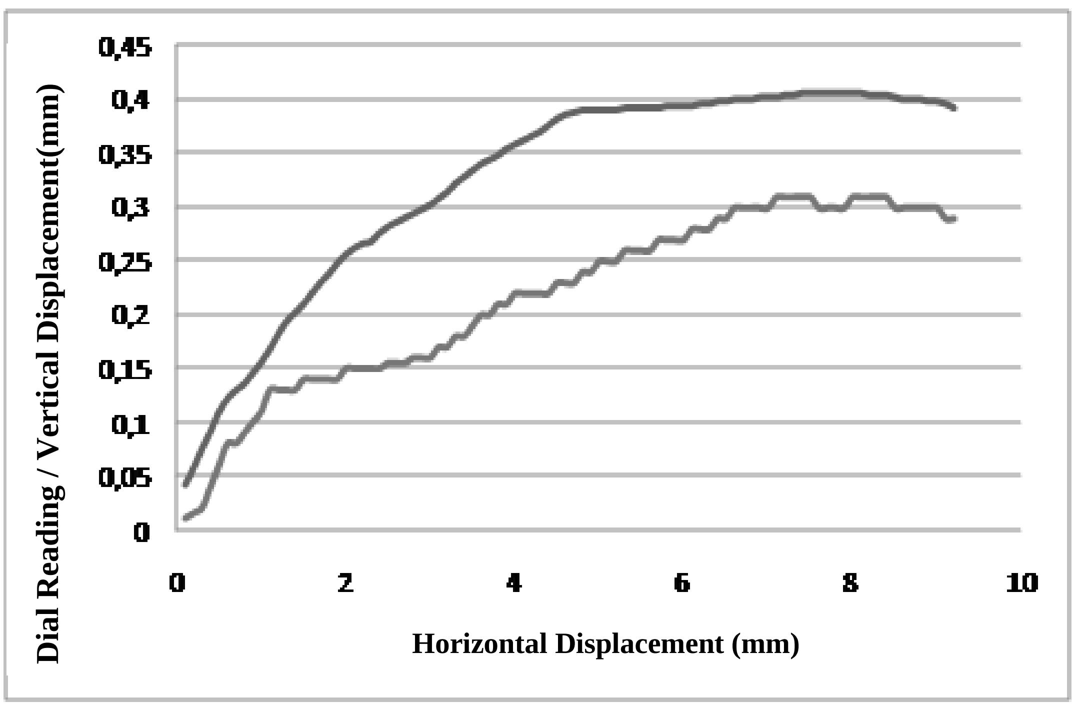


Figure 4.47 40% Sludge included mixture under 100kPa

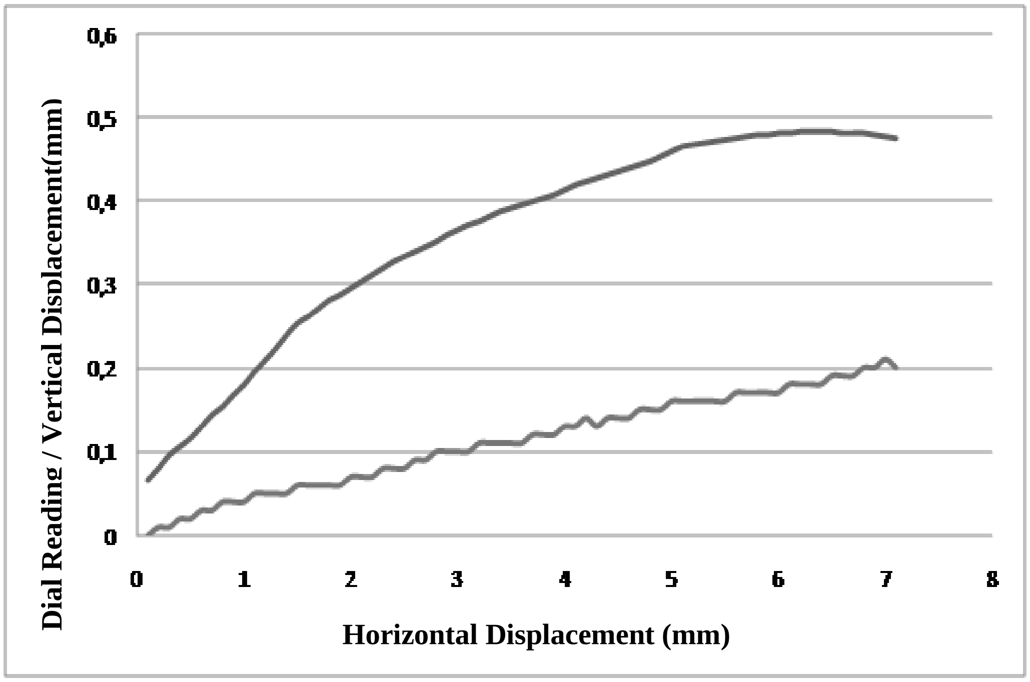


Figure 4.48 40% Sludge included mixture under 150kPa

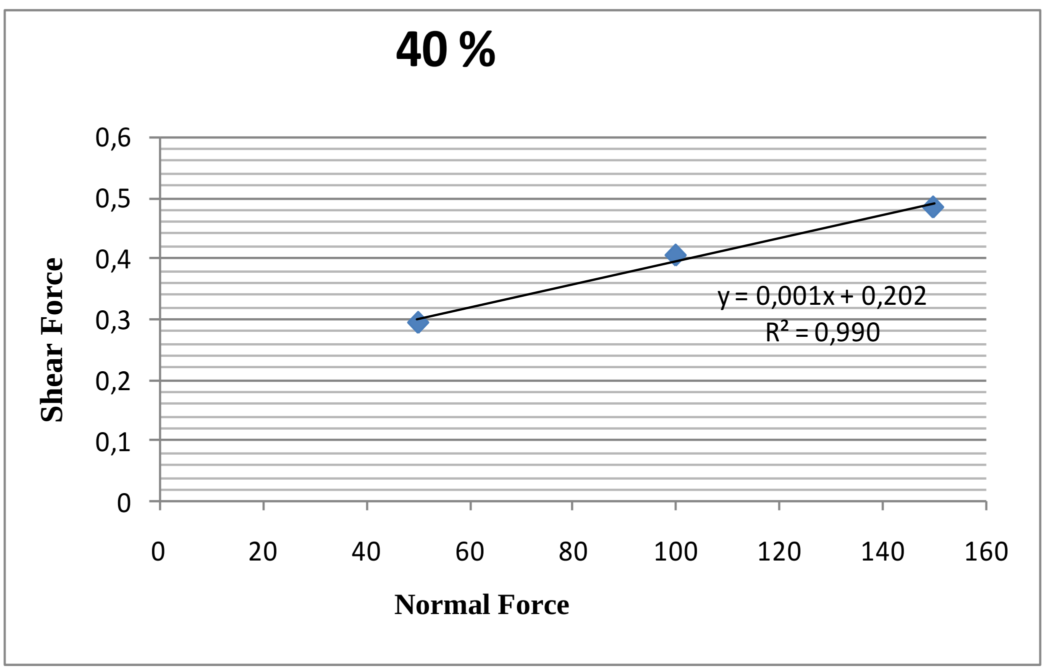


Figure 4.49 40% Sludge included mixture

c= 0,202 Φ= 202 for 40% of composted sludge included in new soil model.

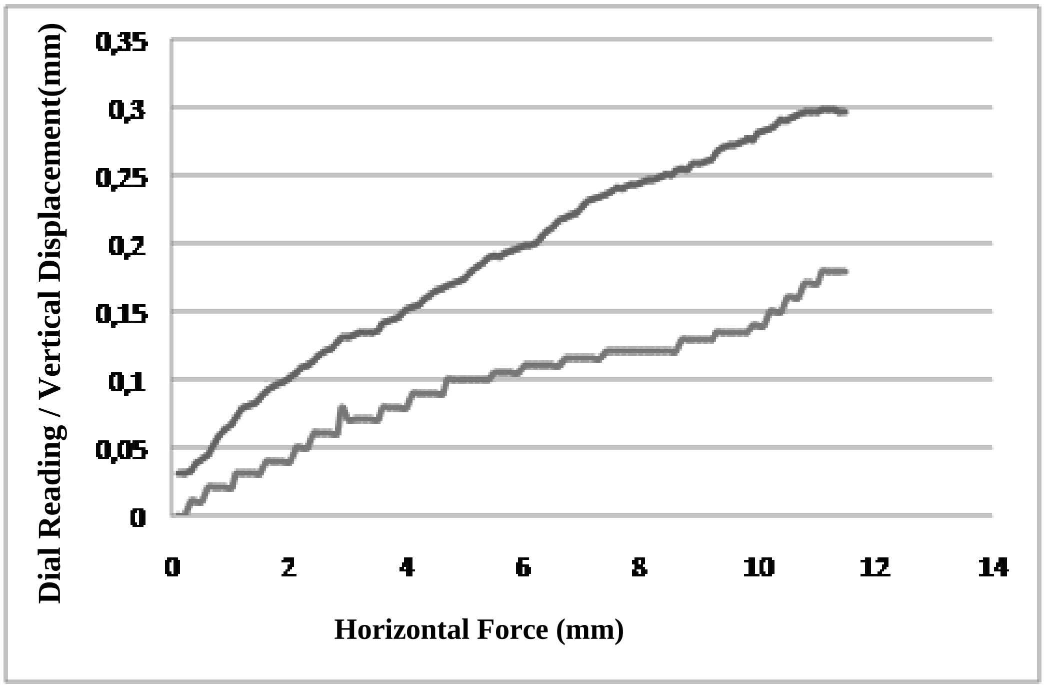


Figure 4.50 50% Sludge included mixture under 50kPa

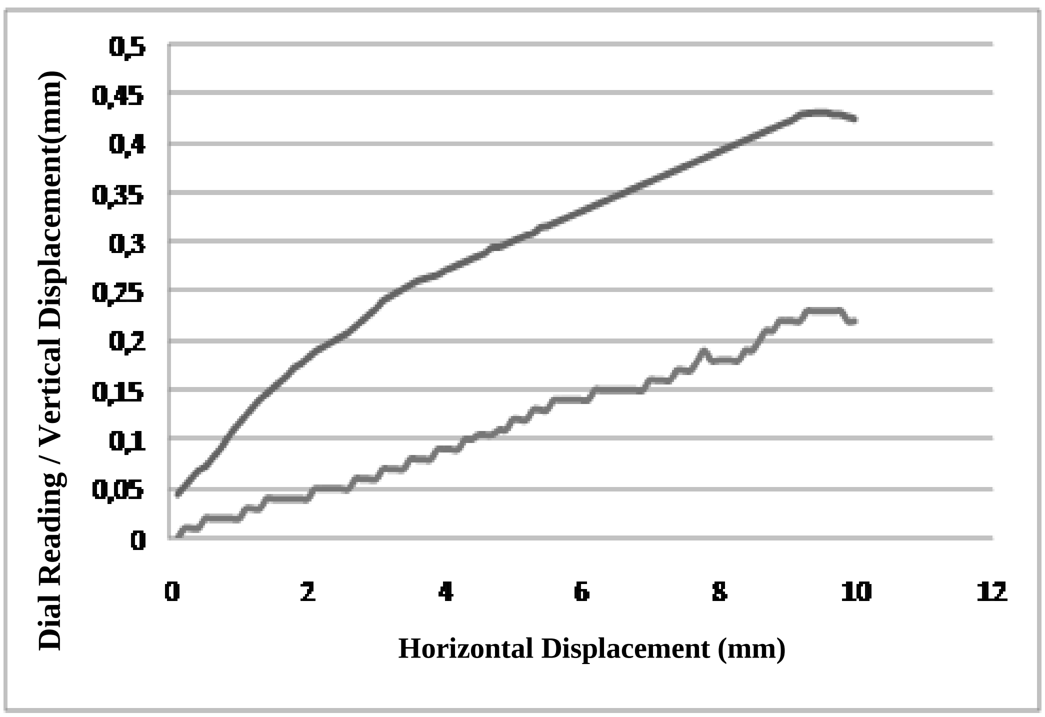


Figure 4.51 50% Sludge included mixture under 100kPa

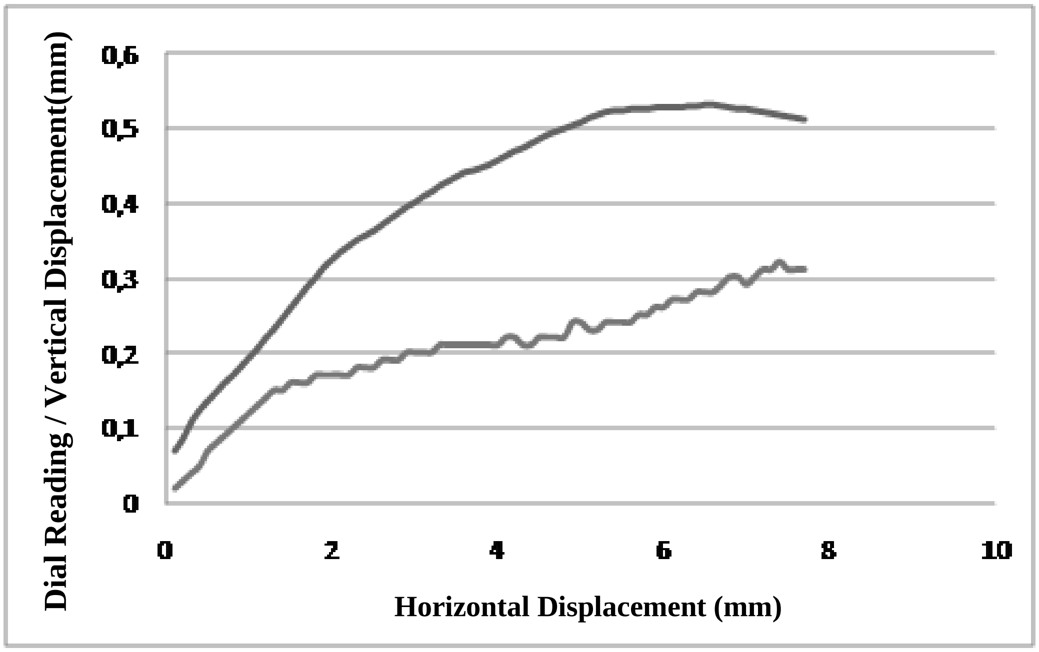


Figure 4.52 50% Sludge included mixture under 150kPa

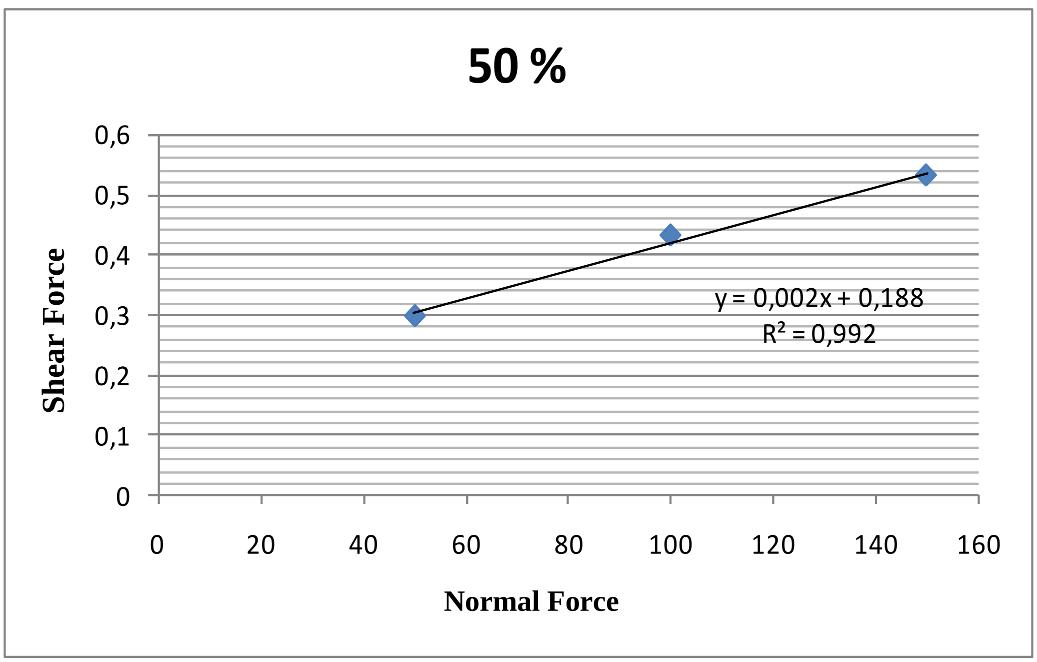


Figure 4.53 50% Sludge included mixture

c= 0,188 Φ= 94 for 50% of composted sludge included in new soil model.

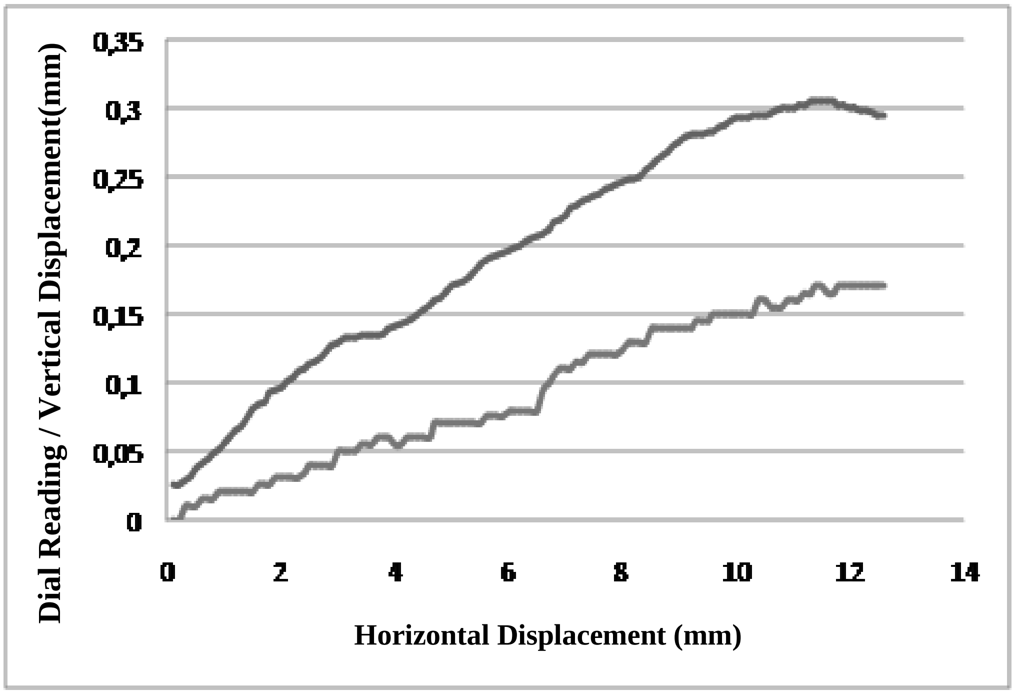


Figure 4.54 50% Sludge included mixture under 50kPa

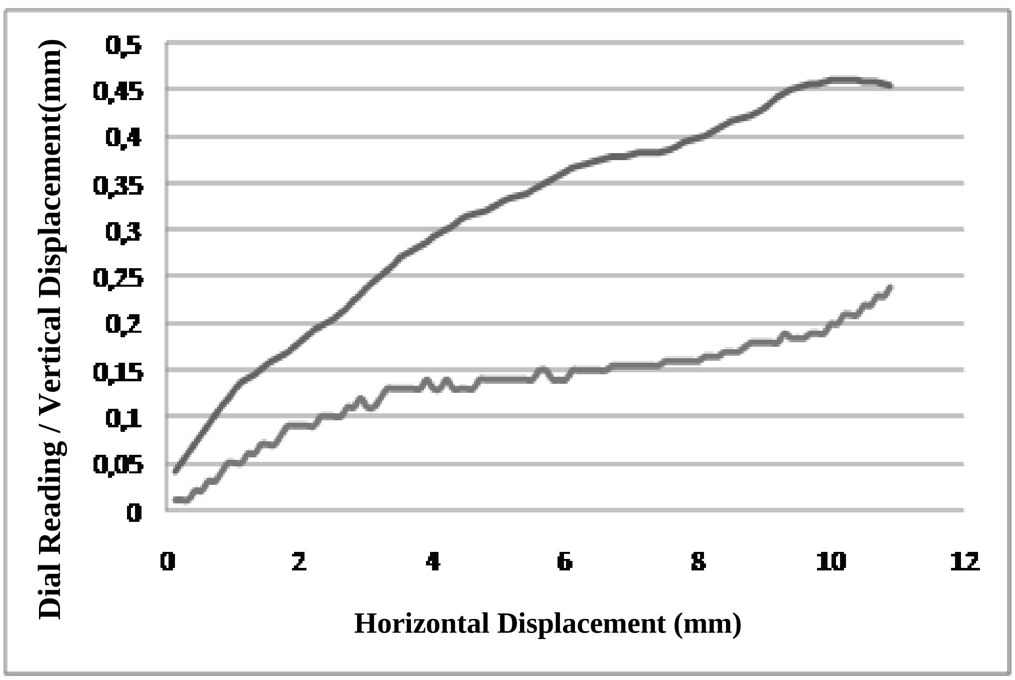


Figure 4.55 60% Sludge included mixture under 100kPa

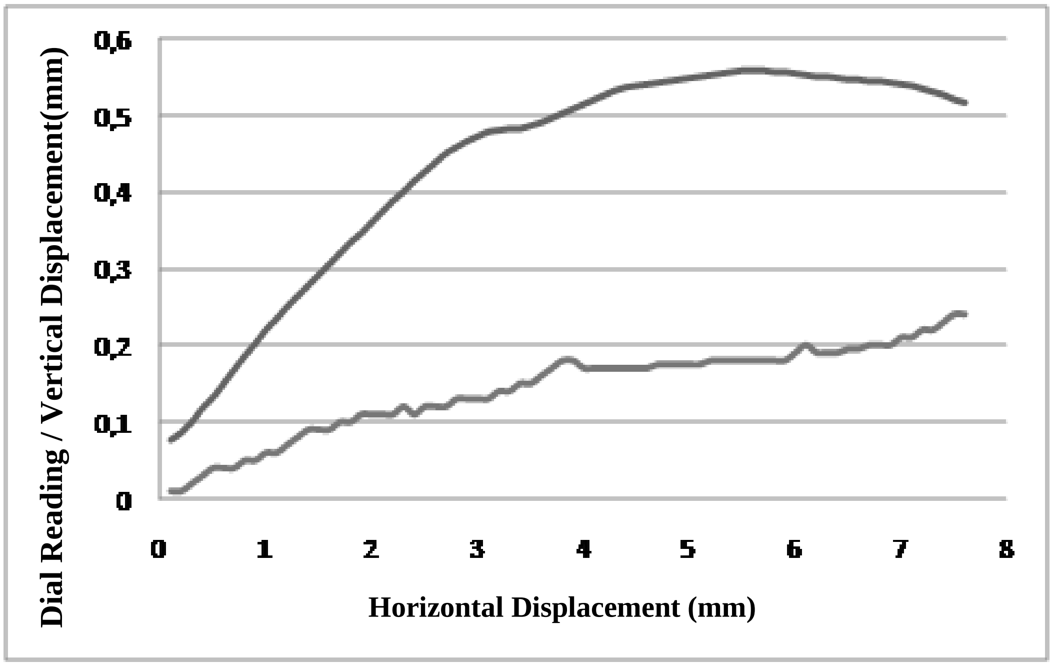


Figure 4.56 60% Sludge included mixture under 150kPa

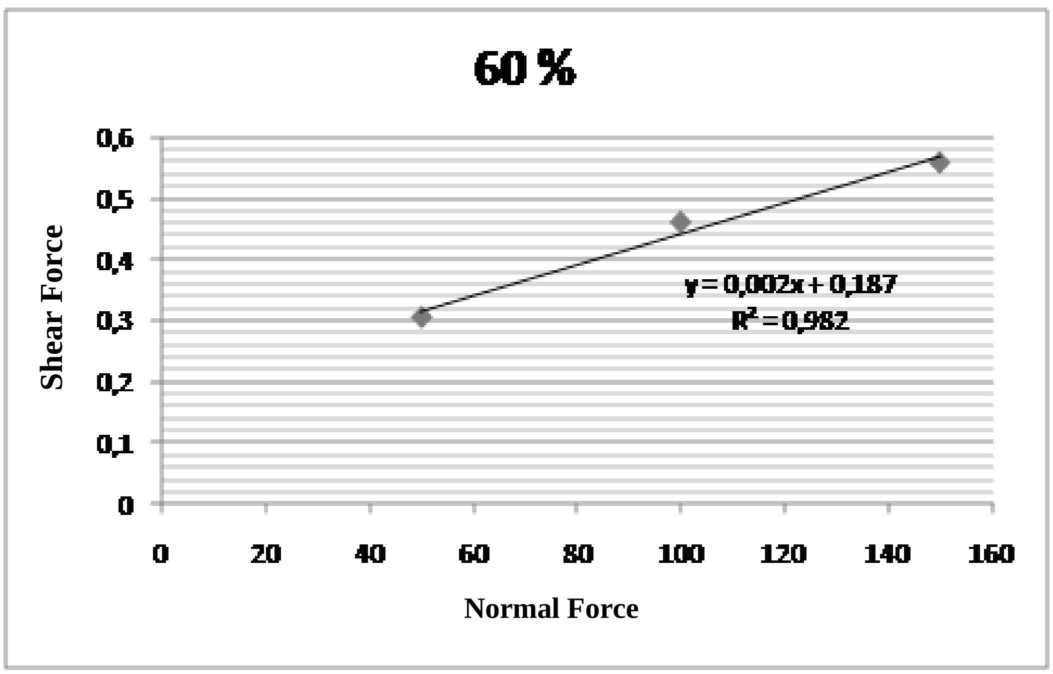


Figure 4.57 60% Sludge included mixture

c= 0,187 Φ= 93,5 for 60% of composted sludge included in new soil model.

Table 4.5 Cohesion (c) and Internal friction angle (Φ)

	5 %	10 %	20 %	30 %	40 %	50 %	60 %
c	0.126	0.093	0.236	0.174	0.202	0.188	0.187
Φ	63	31	236	174	202	94	93,5

5.6 Discussion

In this thesis, the effect of waste water treatment plant composted final product,it is called as composted sludge or sludge, used as main additive. It is tried in case of a construction site building around these places, or on this storage areas. So widely consisting ordinary clay is taken as major material, and it is mixed in different ratios with Gaziantep clay. Parameters are detailed explained in result pages.

It is observed that, composted waste material swells more than its own volume. In addition one other fact is accidently found that it resists against fire. It is neither plastic nor liquid material. Another important thing is, because of its granular structure, when composted industrial waste lose all water in molecular bonds, when it becomes completely dry, it could fly in air freely. Specific gravity of this material is about half of clay, close to density of water. From this view, it may damage lungs esp. in closed door rooms.

Some other thesis, also researched this material from chemical wise and it shows that road embankments may covered and so green view can managed with composted waste. This would also imply more durable roads with higher landscape value and less soil loss.

The more composted sludge added to soil, makes it little bit the more adhesive against forces as is. Same time, bearing capacity increases in similar way. Also, while optimum water content falls, dry unit weight of soil goes up if more sludge is added rationally. Another important information is friction angle and cohesion values, they are too low once it is added to the soil structure.

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